Development and Applications of Special Concretes
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Lecture 15
Anti-washout Underwater Concrete

Namaskar and welcome back to another lecture in our series on development and applications of special concrete. We will start today our discussion on Anti-washout Underwater Concrete. It is a short discussion with basically photographs and a very broad outline of what this method and this concrete is all about.

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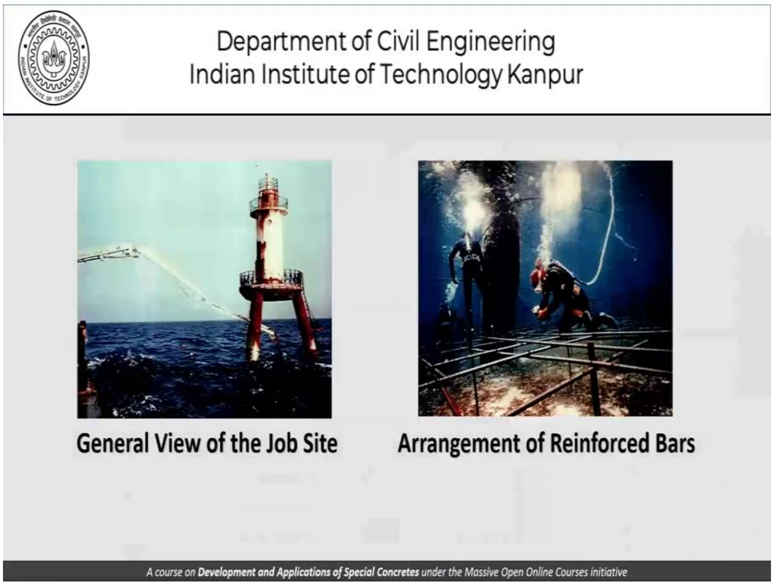

So, getting started this picture here shows a general view of the job site as you would see it in a large scale underwater concreting operation. This picture here on the other hand shows the details that is divers working with let us say the reinforcement work. Now these divers working with the reinforcement work brings to four a very important issue relating to quality control. We have to rely the reliance on the last worker on the line the divers in this case to ensure a proper quality control to make sure that the kind of reinforcement time that should be done has actually been done becomes a lot more important in the case of such special constructions.

Because multiple layers of inspections and re-inspections which is possibly easier in a normal environment is not possible when we are trying to do construction underwater. Keep that in mind when we are working with specifications trying to do the construction work and drew quality control as far as such constructions are concerned.

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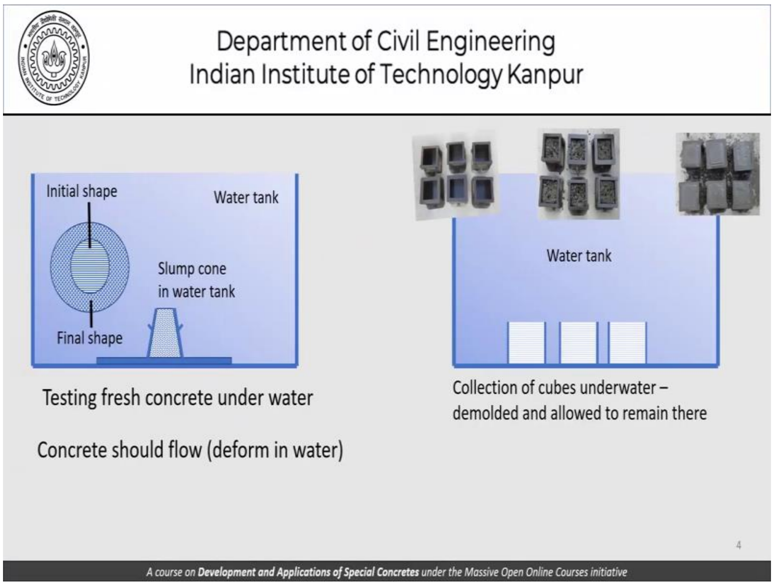

Moving forward this picture in fact the last picture probably puts in better perspective what we were trying to do the last time when we looked at this picture. What we said here was that the testing for fresh concrete and the collection of cubes as far as strength is concerned for such concrete underwater concrete should be carried out under water itself. That is the concrete should be allowed to deform under water and the cube should be demolded and allowed to remain there because that is what is expected of that concrete.

As far as the water tank is concerned yes there are other specifications which need to be worked out what should be the height of this water tank. Whether the water that we use here can be normal water or it should be sea water or it can be let us say artificial sea water. There is a specification which tells us how to make artificial sea water what is the chemical composition that you should use if you want to make artificial sea water.

Try to understand, that try to look for literature and identify the specification and the composition and of course you can compare it with the natural sea water. So, these are things which are left out from the scope of this discussion where we are saying that okay so long as we understand the principle that the test should be carried out under water. The detail part of it whether it should be salt water or it should be normal water that can be worked out as far as individual specifications are concerned.

All the test methods are concerned so, I would encourage you to read some of the test methods relating to underwater concrete and find out what they have to say about the nature of water to be used in this water tank.

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Moving forward this is another picture where concrete is almost being placed and we can see that placement of high-quality underwater concrete leaves the marine life largely undisturbed and you can see fish freely moving around this construction site. And you can see a diver trying to do certain operations.

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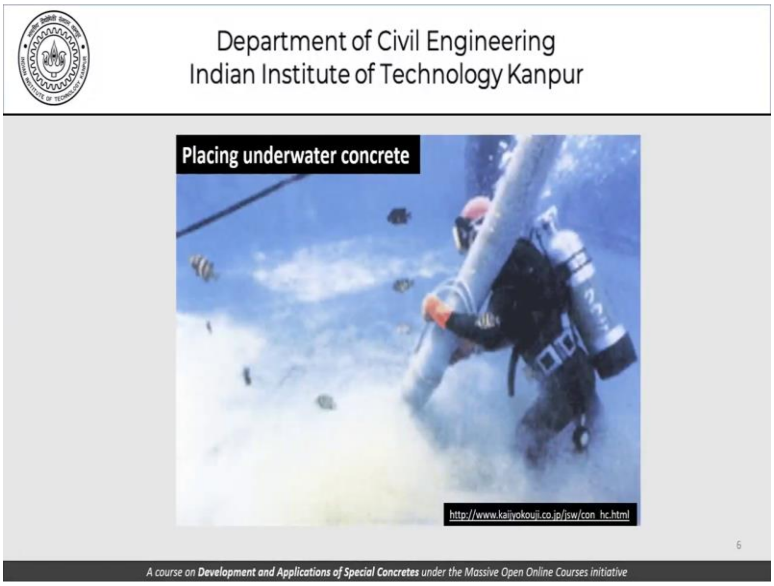

And this picture brings it out even more clearly for the diver is holding a concrete pipe and placing the concrete. So, we can see that the amount of wash out as far as cement is concerned is much less than you would expect and we can still see a lot of fish in the region.

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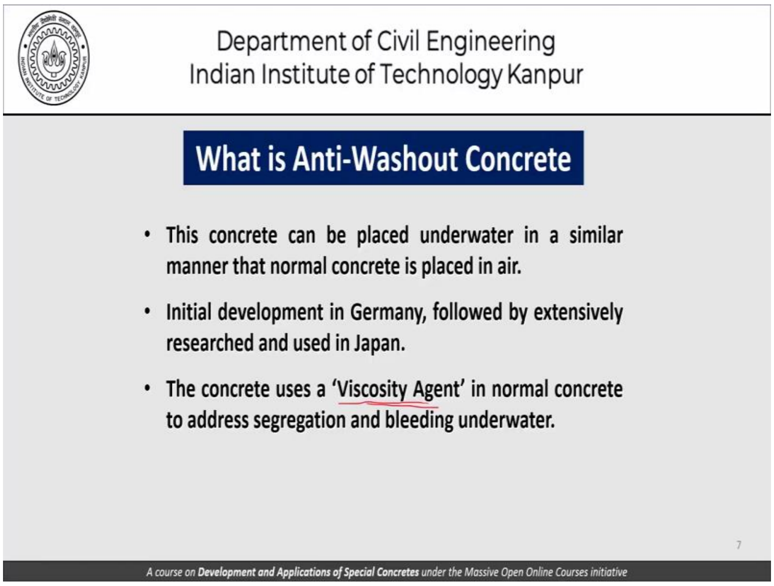

Now what is the formal definition of anti-washout concrete. This concrete can be placed under water in a similar manner that normal concrete is placed in air. Initial development of this concrete took place in Germany followed by extensive research and used in Japan. And this concrete uses a viscosity agent in a normal concrete. We will show, how the concrete that we use in anti-washer concrete. We will see in a few slides the concrete that we use for anti washout concrete is more or less normal concrete except for the fact that a certain amount of viscosity agent has been added to impart viscosity to address segregation and bleeding that may occur in a normal concrete under water.

Now these has other implications as well as we shall see in this lecture a little bit and more so in the next lecture.

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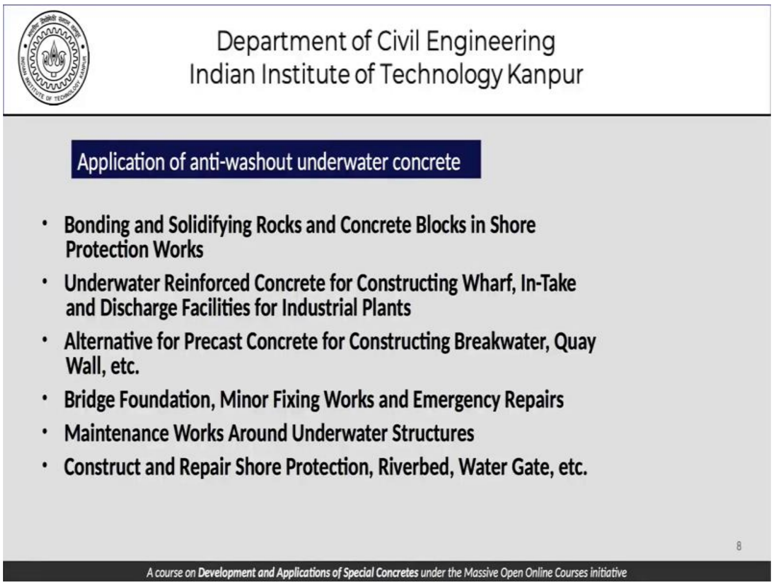

Applications of such concretes include bonding and solid fine rocks and concrete blocks in shore protection works, underwater reinforced concrete for construction of wafts. Intake and discharge facilities for industrial plants. Alternative for precast concrete for constructing break water quay walls and so on. Bridge foundations minor fixing work and emergency repair works maintenance works around underwater structures construction and repair of shore protection riverbed, Watergate and so on.

So anywhere we are trying to place concrete underwater. What we are not talking about here is whether the water is moving or not that is a separate discussion it is an important discussion but we are leaving it out from our discussion for the time being. Anyway, the concrete is being placed under water we can use anti-washout underwater concrete.

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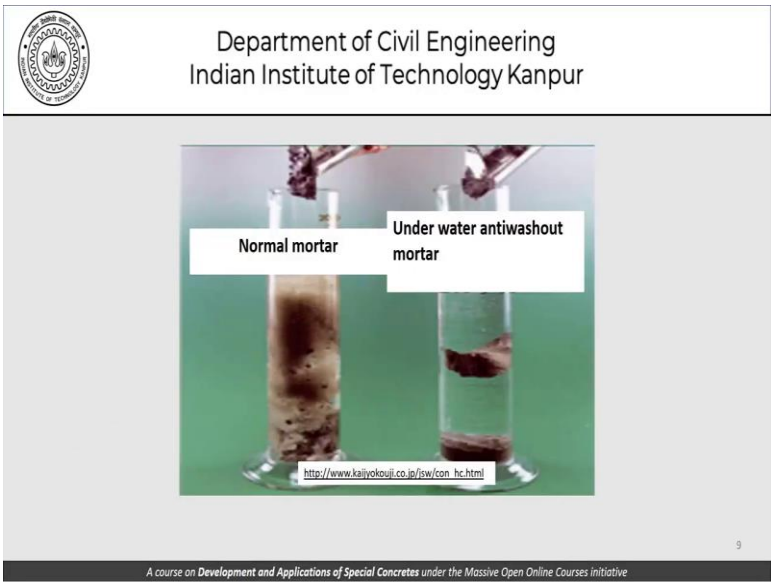

Now this picture showing normal mortar and underwater anti-washout mortar being placed in a measuring cylinder of water shows the picture as to how the underwater concrete or the anti-washout underwater concrete is so different from normal concrete. Normal concrete would involve this kind of segregation or a washout of cement particles or even fine sand particles from the mortar once it is dropped in water.

This is not happening at all as far as this particular case is concerned because this mortar has that viscosity agent that we talked about. So, this viscosity agent imparts a certain amount of viscosity to the paste phase and therefore to the mortar phase and therefore to the concrete phase which makes segregation extremely difficult. So, since the segregation is difficult certain other things follow but that is what we are going to talk about. Momentarily, and stick to that discussion even in the next class.

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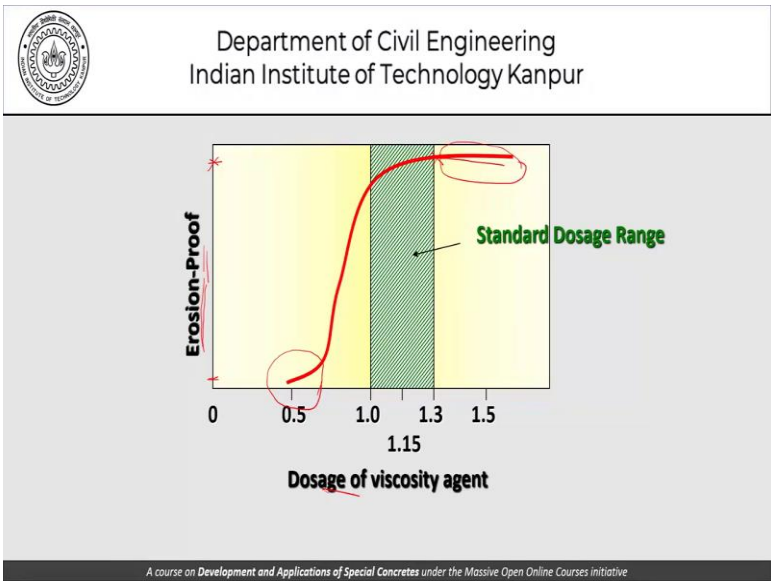

Now here is the variation of the erosion proofness whatever you call it. So, since its erosion proofness a high value means high amount of erosion resistance. Here we are talking of low erosion resistance. So, if we use very little viscosity agent, we obviously do not have any erosion resistance the erosion proofness is zero. And if we increase it beyond this point let us say there is virtually no difference, because we have already achieved a value close to 100% there cannot be any more improvement.

Now therefore as far as an engineering judgment is concerned, we are probably better off trying to use the dosage of the viscosity agent in the range of one to one and a 0.5%, 1.3% and so on. So, this becomes our standard dosage. Even though it is standard dosage like any such discussion this is highly dependent on the cement being used the sand being used their characteristics in terms of fineness chemical composition and so on.

And therefore, we always need to do laboratory tests to determine what would be an efficient dosage that we use as far as the viscosity agent is concerned to achieve the right amount or the desired amount of erosion proofness or segregation resistance.

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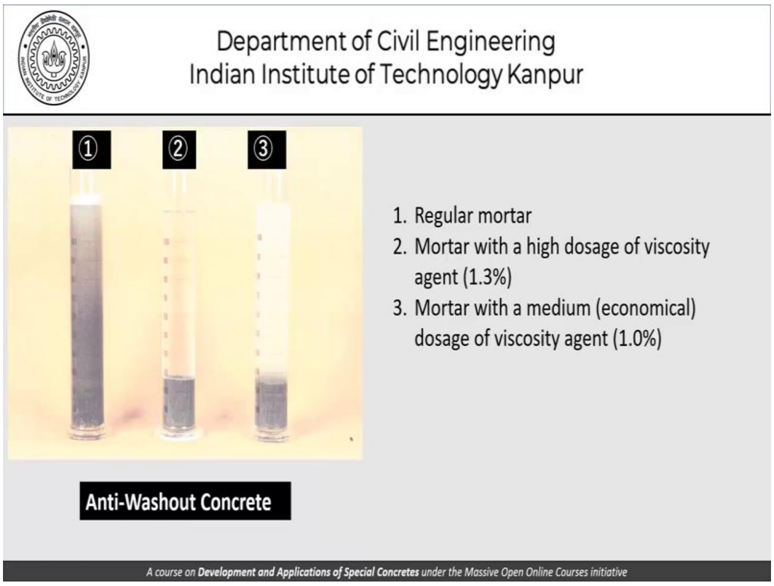

Here is another picture showing more or less the same thing this is regular mortar and two is a motor with a high dosage of the viscosity agent this is 1.3% and this is let us say an economical dosage where it is 1%. So, you can see certain amount of turbidity that is lesser here but if you are willing to live with this yes you can make do with 1% of the viscosity agent instead of going to 1.3.

This obviously has not only implications in terms of segregation resistance but also setting time and so on. So, one must try to understand all the implications in designing that concrete mix which includes the determination of the right dosage of the viscosity agent.

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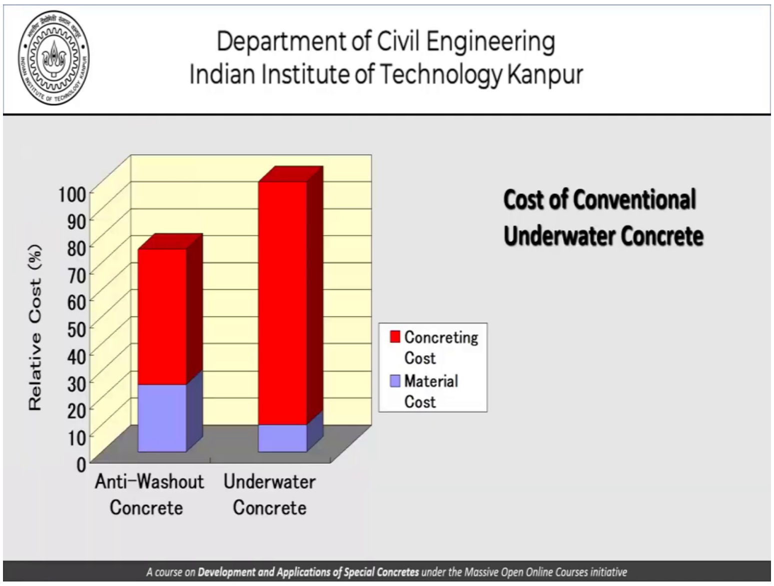

As far as using underwater concrete is concerned or the anti-washout concrete is concerned the anti-washout concrete is more expensive as far as the material cost is concerned. There are reasons for it, more cement is used than in conventional concrete. The amount of coarse aggregate which is the cheapest of the raw materials goes down therefore the material cost indeed increases.

Having said that the construction cost or the concreting cost which is the other part of construction goes down drastically and therefore the total cost of construction is still maybe 70% or 75% of the conventional construction costs. So that is how we can try to understand or get a better view of changes in the material cost and change in the construction cost in making a final decision whether or not we should use the anti-washout concrete or go for conventional concrete.

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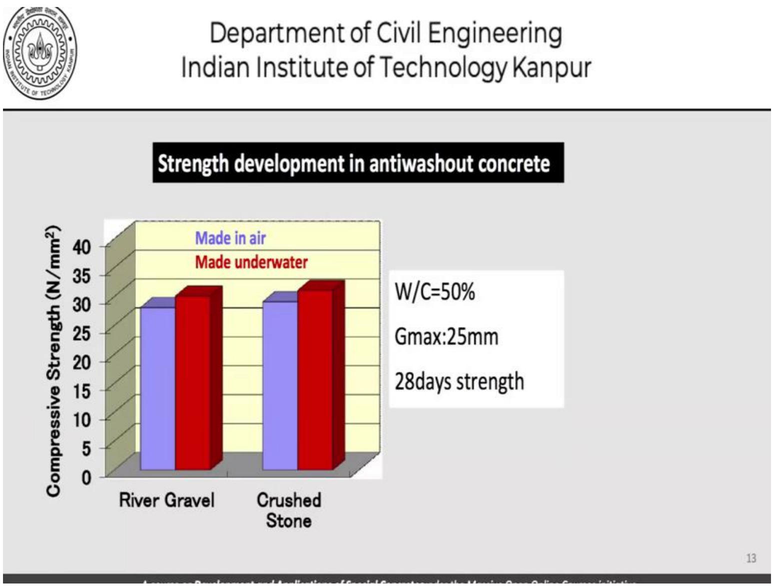

This here is a representation of the strength development in anti-washout concrete and you can see here that the concrete is very much a normal concrete water cement ratio 50%, 25 mm of maximum size aggregate and we are talking of 28 days strength as usual. If you are using river gravel or crust stone made in air or made in water or made under water the strengths are not drastically different, they are just marginally different.

And we can say that even if concrete specimens are collected under water or and in the air the strength values will not be so drastically different. So, we need to have this kind of backup data which has been collected for a particular site using a particular material by a particular contractor. So that the engineers have more confidence in going ahead and using a particular material. As I keep emphasizing use of special concretes use of special mixes places a lot more responsibility on the contractors and the builders.

And even of course the clients who permit that use in terms of quality control in terms of developing the right specifications.

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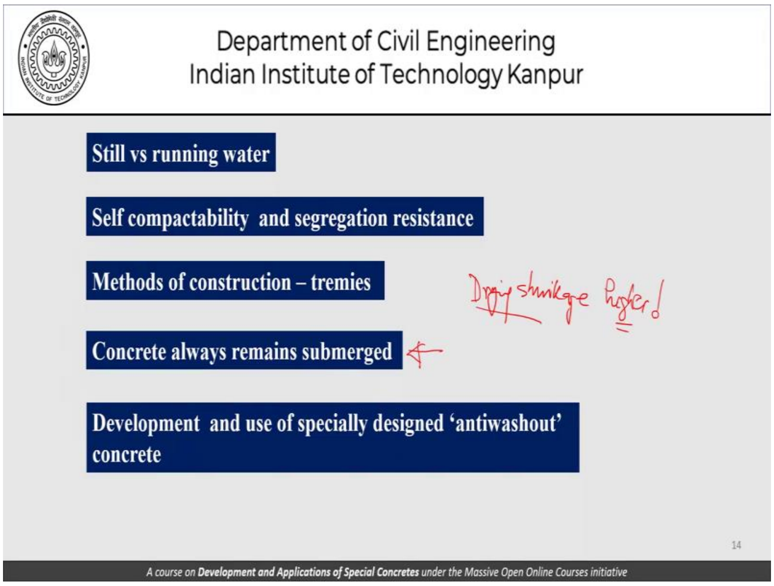

Now this slide here draws our attention to some of the other things that we have left untouched as far as this discussion is concerned. One is that of still versus running water, self-compactability versus segregation resistance, methods of construction for example tremies or buckets, concrete always remains submerged. Now this condition must be specifically borne in mind because at certain times it has been reported that the drying shrinkage of underwater concrete or the anti-washout concrete is higher than normal concrete that does not bother us so much.

Simply because the concrete always remains submerged in water and the drying shrinkage does not come into play. So again, important to note that we must understand the environment in which the concrete is going to be when studying its properties or making an evaluation of those properties there is nothing wrong in studying the property. There is nothing wrong in evaluating it but keep that evaluation in the framework of the actual environment.

Development and use of specially designed anti-washout concrete that is something which we will see in a greater detail possibly the next lecture. This is just one example of the use of the anti-washout concrete.

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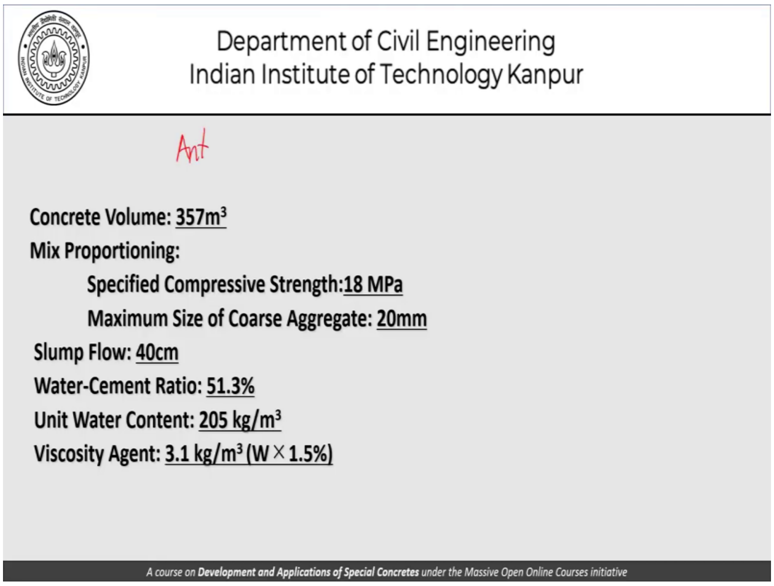

Now what we see here is concrete being used for a volume of 357, 360 cubic meters with a required compressive strength of 18 MPa using 20 mm aggregate slum flow 40 centimetres water cement ratio of 51.3 and a unit water content of 205 with the viscosity agent given in terms of water percentage being 3.1 kgs per cubic meter. Now what it shows is that as far as the concrete is concerned it is a very, very normal concrete from all points of view.

The compressive strength the water cement ratio the maximum size of aggregate only thing is that the water content is slightly larger than normal concrete that we would expect in this day and age. Not only that this is the water content after a certain amount of super plasticizer has been used. So, this water content with the super plasticizer usage is what is the crux of the anti-wash out under water concrete.

I am leaving it to you to do as an assignment a study of the different proportions that are available. I am going to show you one or two of them just now but it is left to you to study some cases where this anti washout underwater concrete has been used.

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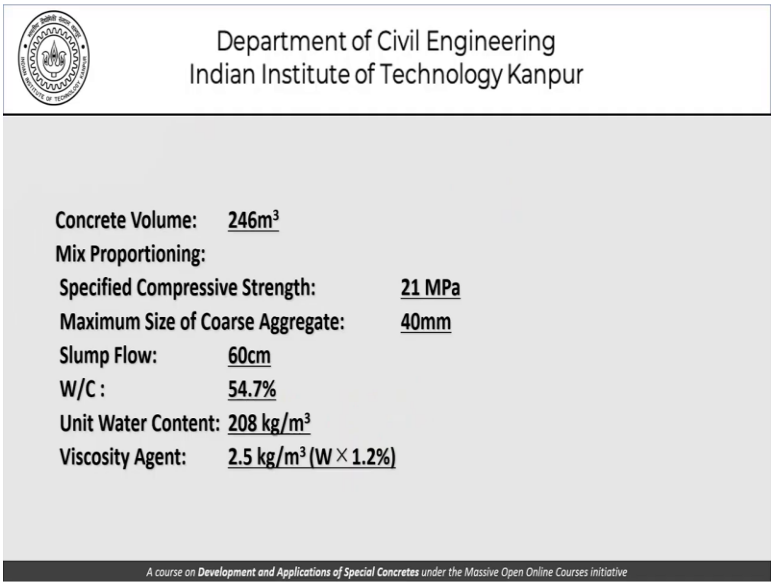

This is yet another example that 146 cubic meters of concrete has been used with 21 MPa the required strength 40 mm aggregate 60 centimetres slump flow 54.7% of water cement ratio and the water content being 208 and here we are talking of a viscosity agent at 1.2% of water which turns out to be about 2.5 kgs per cubic meter. So, the amount of viscosity agent is very small but its effect is very, very significant. As far as the properties concrete are concerned.

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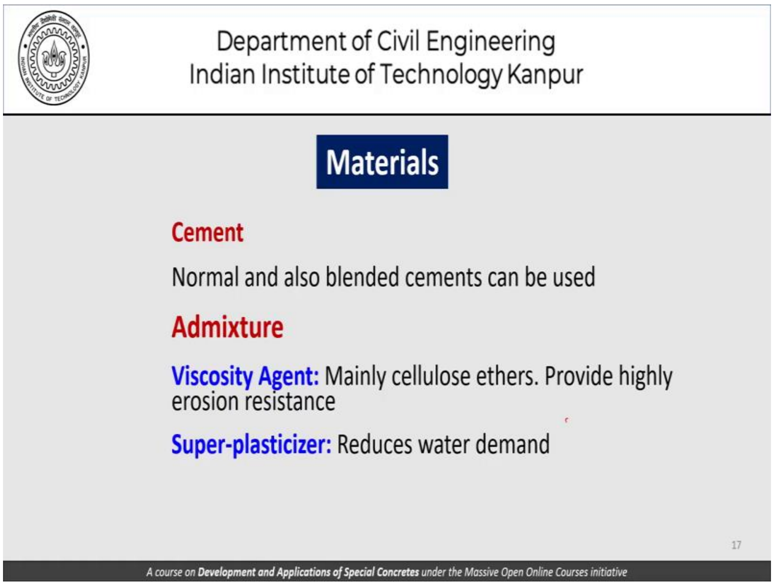

Now coming to the materials that are used in these concrete normal blended cements whatever you have there is nothing special required for cement. As far as using the anti-washout underwater concrete is concerned. As far as Admixtures are concerned, the viscosity agent of course is a special agent it is mainly cellulose ethers provide high amount of erosion resistance and of course you use super plasticizers to reduce the water demand.

And that is what I said that when we are talking of 205 kgs of water that is after we have used a certain amount, of super plasticizers then we need this much water. So, you can imagine how much is the kind of cement content that is really going into this system.

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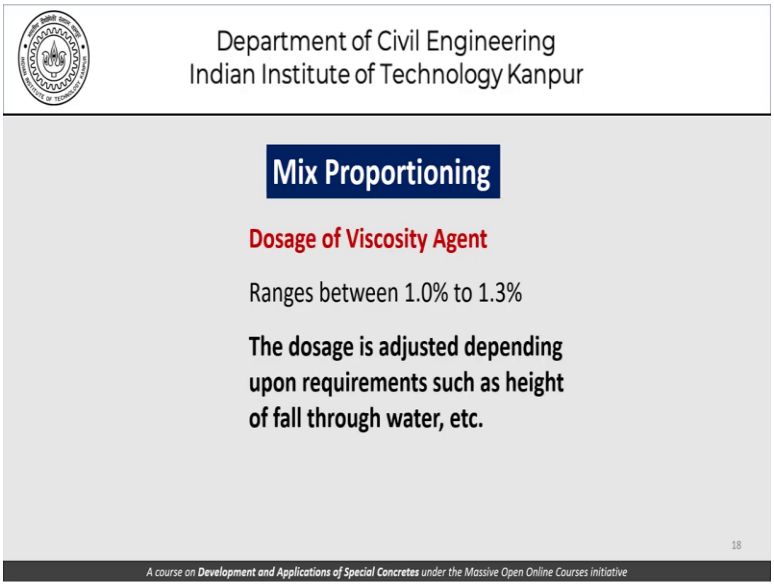

As far as proportioning is concerned the dosage, we already discussed viscosity agent ranges from about 1 to 1.3% and the dosage is adjusted according to the requirements such as height of fall through water and the kind of characteristics of materials that we have.

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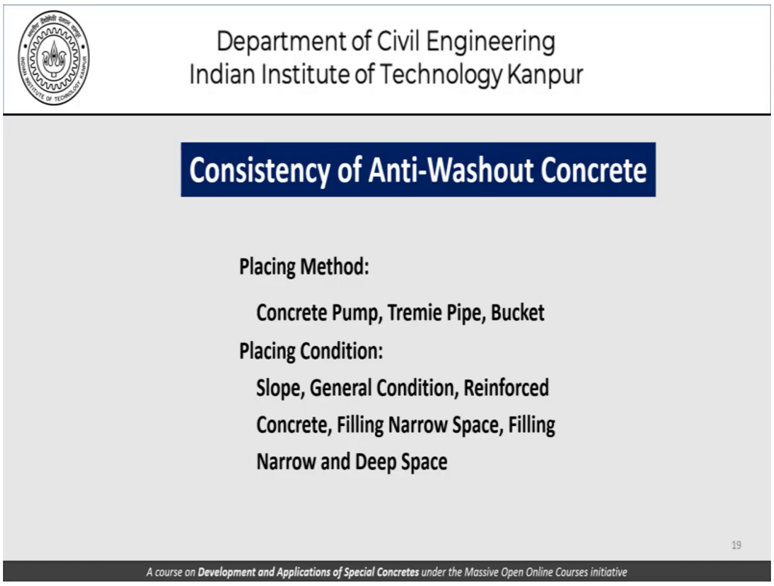

And as far as the consistency is concerned in terms of the slum flow required it could depend on the placing method which could be pump, tremie, tremor bucket. The placing condition of the concrete whether it is slope general condition of this layout there, reinforced or not reinforced, filling narrow spaces that is not involved, deep spaces and so on. So, the placing condition and the placing method together as usual gives us the required kind of consistency which we want from the anti-washout concrete used.

Recall that in the first case that we saw we had a slump flow of only 40 centimetres but in the second case the requirement was 60 centimetres. So, the consistency in terms of slump flow could be quite different depending on the different conditions depending on the different methods. This is the recommended consistency for anti-washout concrete under different conditions.

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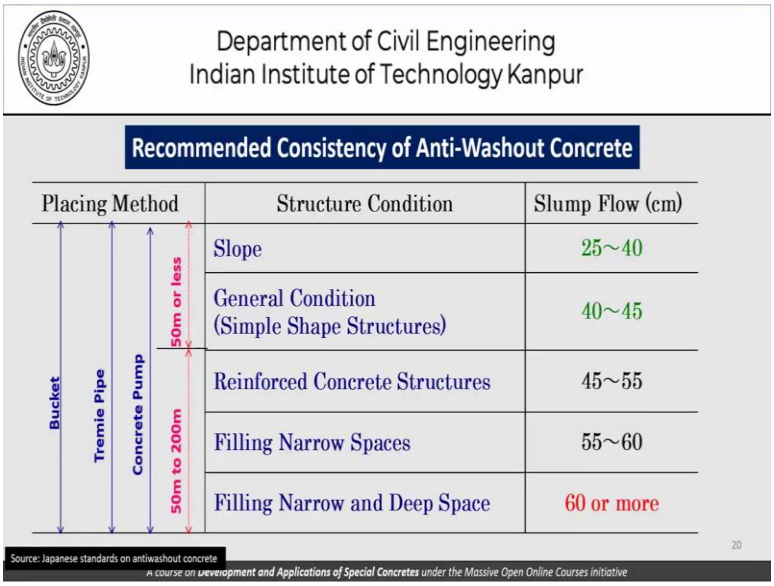

For example, slope simple shaped structures reinforced concrete structures, filling narrow spaces, filling narrow and deep spaces. If you are buckets, tremies or concrete pumps this is the kind of slump flows that you are talking about. It could range from 25 to 60 or more and 25 as a slum flow should be an interesting value for you because the geometry of the slump cone tells us that this diameter at the bottom is only 20 centimetres.

That means, 25 or 30 centimetres kind of a slump flow is hardly any slim flow that means the concrete hardly flows. These low values almost mean that the concrete does not flow. So, it is just extremely viscous of course when it comes to these larger values there are some other issues involved. For example, if you increase the viscosity of the concrete what are the other parameters that will come into play.

Will it deform very quickly after you remove the slump cone, just think about it and I will probably answer that question towards the end of this class if I do not answer it in another slide.

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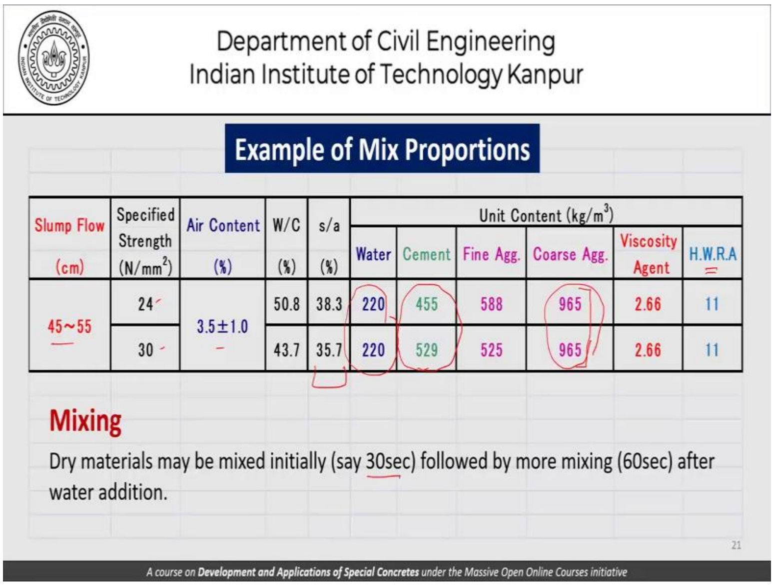

Examples of mixed proportions here are two examples a slump flow 45 to 55 centimetres. If these are the strengths, we are talking about the air content we are talking about water cement ratios. So, this is the typical water content which pushes the cement content to these values and the coarse aggregate content let us say is to these values because, your s/ a is not so very different, s/a governs the coarse aggregate to fine aggregate volumes in the concrete.

So, if the s/a is the same and we have put in a lot of paste in the system. The mortar volume obviously goes up because the total volume of coarse aggregate has gone down that is something which is very, very interesting to observe. And just see the amount of high range water reducers that have been used. So, this exercise is an incomplete exercise I am just giving you the pointer.

And I would like you to actually look up reports which talk about the mix proportions used in some of the concrete projects where the anti-washout concrete has been used. As far as mixing is concerned dry mixing may be initially carried out for about 30 seconds followed by more mixing more vigorous mixing which could be 60 seconds or whatever it is after the water addition.

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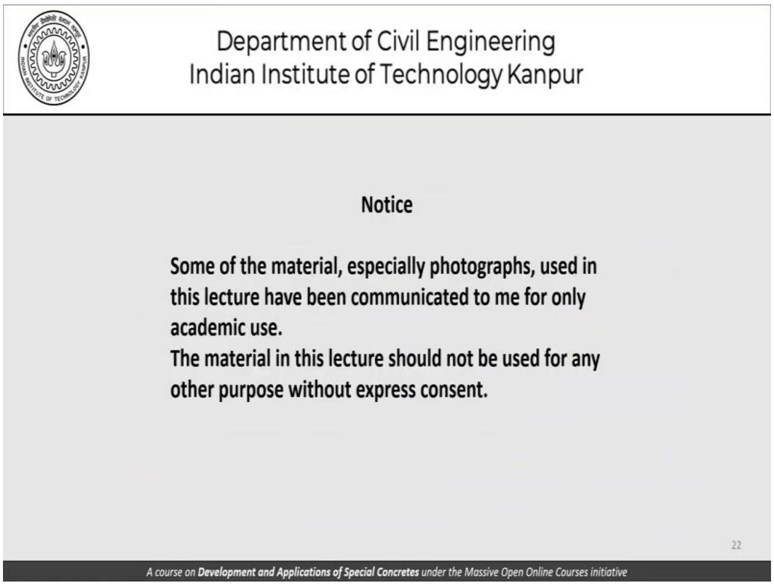

With this I more or less come to an end of the presentation today which I told you will be a brief presentation. And this material a lot of it has been communicated to me personally by my friends and it should be used only for academic purposes and not anywhere else without express consent.

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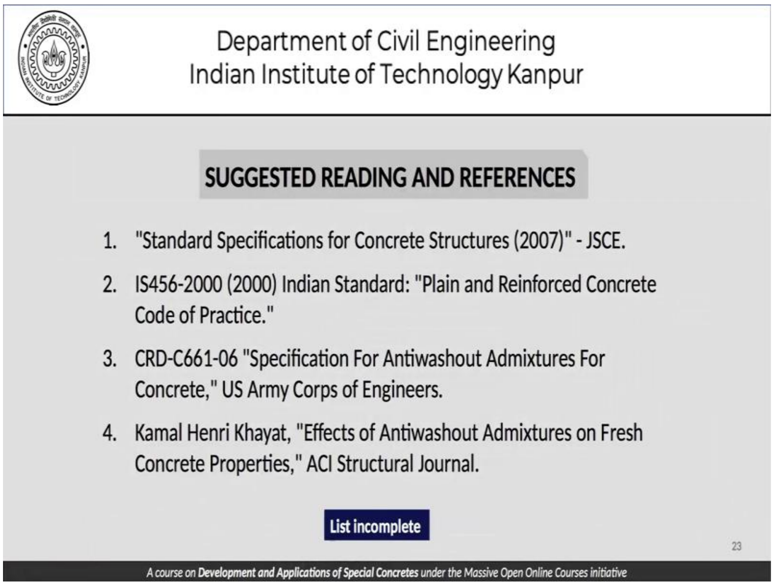

This slide gives the suggested reading and references which you might find useful in following the material which has been presented today. However, this list is by no means exhaustive and in fact it is for that reason that I have written lists incomplete and you are requested and encouraged to look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

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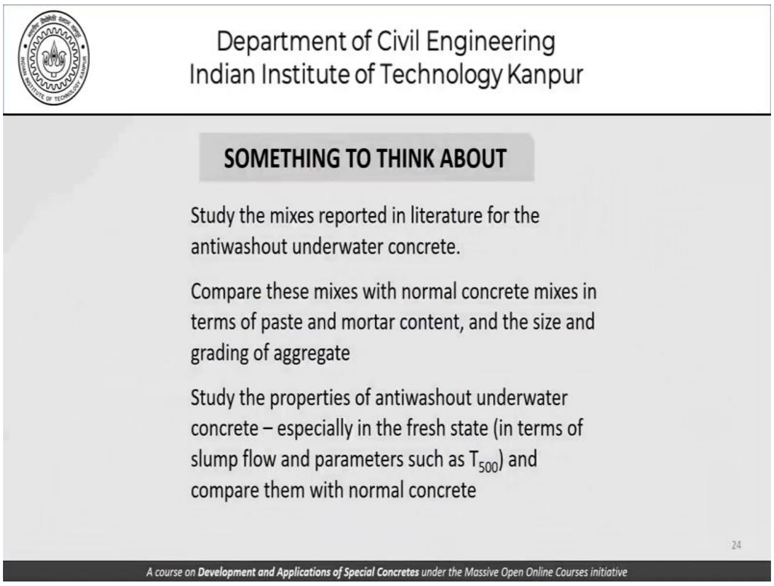

As far as something to think about is concerned I have already mentioned a couple of things to you study the mixes reported in literature for anti-washout underwater concrete. Compare these mixes with normal concrete mixes in terms of the paste and water content and the size and grading of aggregate both fine and coarse. And study the properties of anti-washout underwater concrete especially in the fresh state in terms of slump flow and parameters such as T_{500}.

Now T_{500} is the time that the concrete takes to achieve a diameter of 500 mm in a slump flow test. So now if the viscosity agent is not used what is the kind of time that you would expect the concrete to get to a diameter of 500 mm. Recall that the initial diameter of the bottom of the slump cone is 20 centimetres or 200 mm. Now for that diameter for that concrete to spread to a diameter of 500 mm how much time will it take with and without the viscosity agent? That is something which I am leaving it to you to think about and not only think but also get some actual values from literature.

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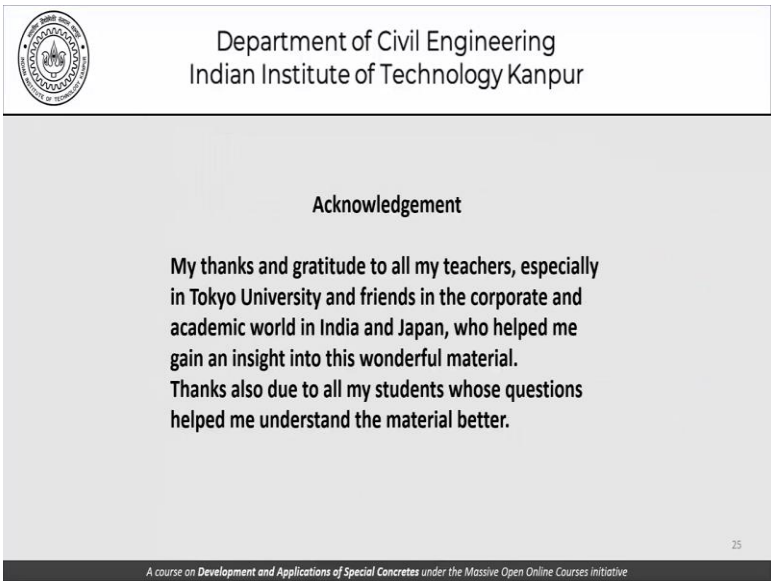

Coming to an end of the discussion today my gratitude once again to my teachers in Tokyo university, my friends in the corporate and academic world in India and Japan who have helped me understand this material. And of course, to my students whose questions have helped me understand the material better. I look forward to seeing you again in another lecture where we will continue our discussion on anti-washout underwater concrete. Thank you once again.