Concrete Engineering and Technology
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Lecture - 23
Shotcrete and underwater concrete

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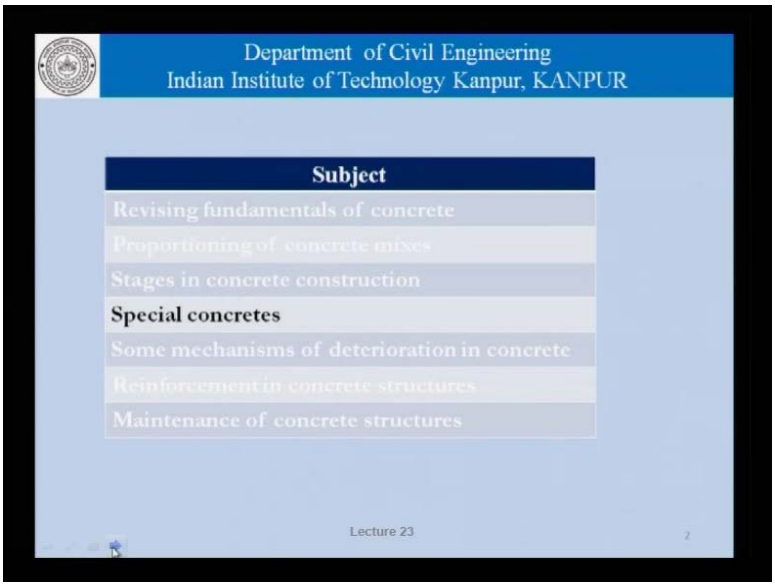

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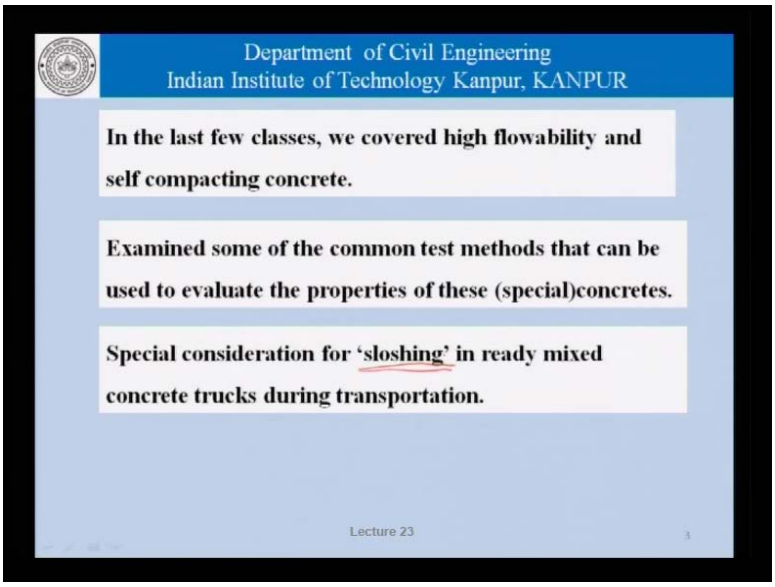

And welcome back to another lecture in this series on concrete engineering and technology. We will continue our discussion on special concretes. In the last few classes we had covered high flowability and self-compacting concretes and we are talked about how the properties of the paste space or the mortar space need to be engineered, in terms of viscosity and so on. So, that the concrete has adequate flow ability as well as segregation resistance.

Then we had examined some of the common test methods that can be used to evaluate the properties of these special concretes, in terms of their flowability, passability, self compactability and so on. These test were over and above the normal test that we use in fact the rider was that in special concretes, we basically need special tests in order to evaluate them and determine their suitability in terms of use and at the same time these special test should be really a part of the quality control regime, that we make when we are using these special concretes.

Now, one of the considerations in that discussion that we did not mention specifically was sloshing. Now, this is the phenomenon, which occurs when fluids are being transported in crux. Now, in the case of high flowability concretes, the concrete is more or less a fluid and while its being transported in agitator crux. We have to be careful that the concrete does not slosh, and if it is sloshes what are the implications of that? So, the driver whose transporting these concretes in his crux needs to be aware that the concrete is transporting or she is transporting is not really normal concrete and has a tendency to slosh. Now, that really shows that once we has been using special concretes, there is a need to not only do quality control and so on as far as the material is concerned, but also adequately train the personal who handle these concretes.

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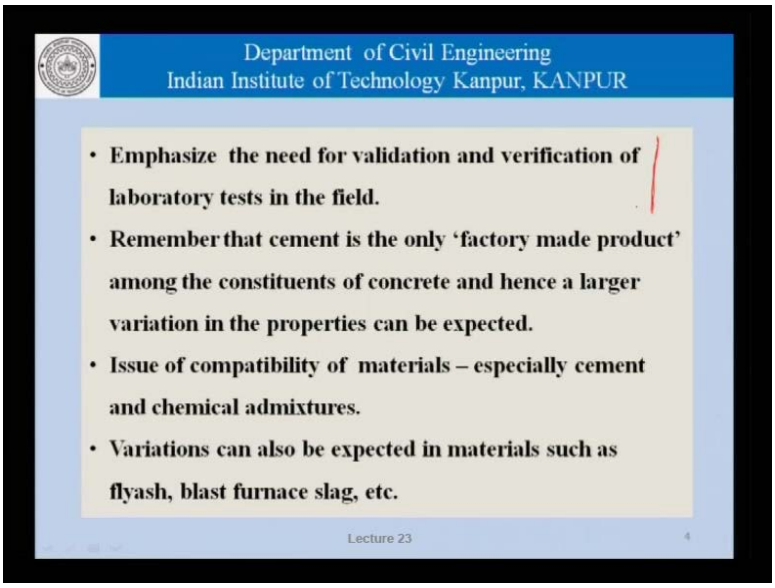

Continuing from that discussion, I would like to also emphasize the need for validation and verification of laboratory tests in the field, when we are talking of special concretes. We may carry out certain test in the laboratory, but it is important that all those tests are verified and the results seen to be matching in the field because there can be all kinds of reasons. Why the mixing conditions, the batching conditions and so on may be different in the field than those that were available or that were practiced in the lab?

So, there is a reason why we must ensure or insist that the properties of the concrete achieved in the lab are duplicate or they are verified in the field test. We should remember that cement is the only factory made product that we use as far as the constituent of concrete is concerned. As a result of that, we can expect and indeed we get a lot of variation in the properties of the ingredients. Therefore, the properties of the concrete we had elude it to this when we are talking of high flow ability concretes, in terms of the properties of the coarse aggregate their size the particle size distribution, the surface characteristics and so on.

All that changes from lotto lot from quarry to quarry and therefore, we need to have methods which are robust enough to take care of these variations. So, concrete even though ready mix concrete even though it is a factor made product, it is susceptible to a much larger variation than that we can expect from another factory made product. That is

something which we need to be very, very careful about when we are talking of special concretes.

We have the issue of compatibility of materials especially in terms of cement and chemical admixtures. The cement even though they are factory made its always likely it is always possible that there may be a slight variation in the quality in terms of the chemical composition and so on. So, from the normal test that were carried out which were very, very super special in a manner of speaking those differences would not even come out. In fact, in sites we hardly ever carry out a chemical analysis.

For example, of cement what we do is fineness initial setting time final setting time strength development and so on. When we are talking special concretes and we are using chemical admixtures, which have dependency or which can call changes in the properties of concrete in minute doses. Then these tests need to be verified, we have to be very careful to ensure that the mix that we use is robust the properties, that we get are within an acceptable range.

Continuing with the discussion on variation mineral admixtures like fly ash or blast furnace slag, could also vary in property. For example, fly ash the properties would vary depending on the kind of coal that is used in the herbal flower plant. It would vary depending on the temperature, that we furnace used to power the coal the method of collection of the fly ash and so on and so forth. So, in a nut shell concrete is not a material which can be easily duplicated that gives us a sense of uniqueness of each concrete mix and that uniqueness is something, which we must understand. No matter how much experience we get, we must always ensure and insist that the properties that we obtain in the lab are replicated at site using the site conditions.

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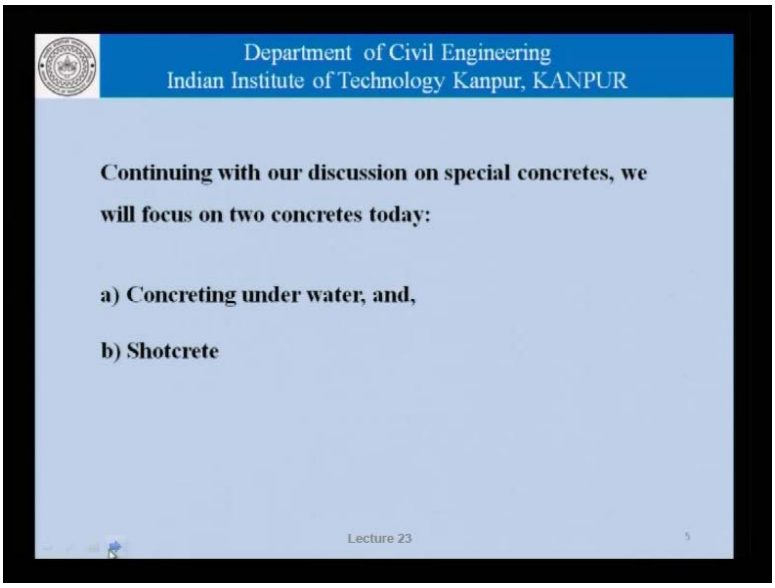

Now, this was general discussion a few general remarks on handling of special concretes and continuing our discussion as far as special concrete is concerned. We will concentrate a focus on two aspects today; one is concreting under water. Very often we need to place concrete under water it just not possible to remove all the water and then try to create a dry environment for concrete. We sometimes need to place concrete under water or in water and there we need a special considerations. We have to be especially careful and that is what we will talk about today. We will talk about concrete this is another special method of concrete construction.

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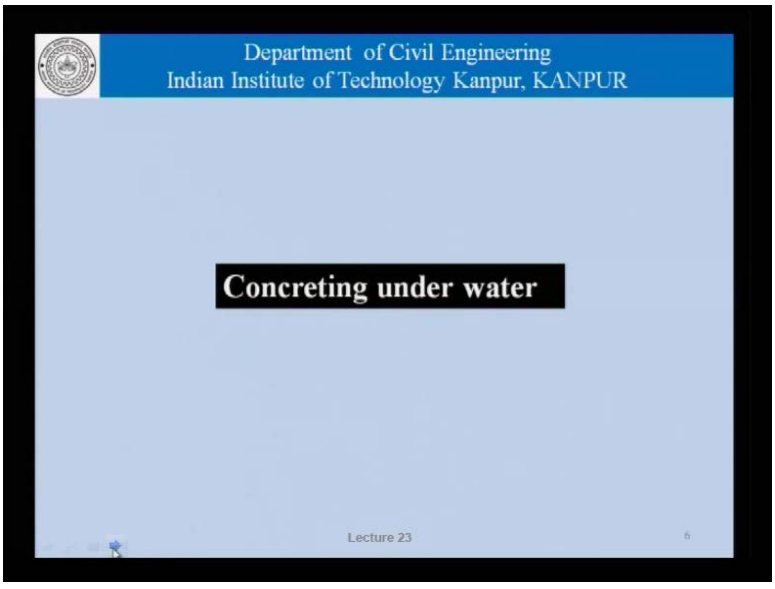

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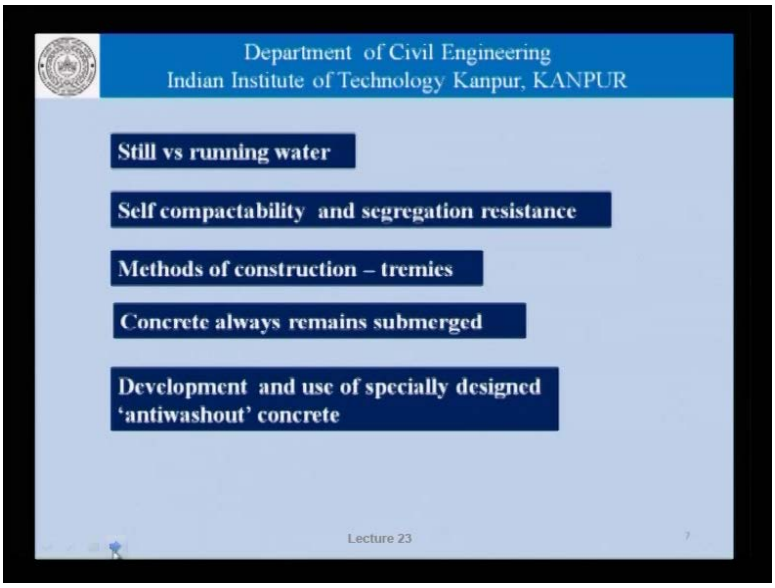

So, under water concreting and shotcrete is what is the topic of today continuing with our discussion under water concreting there are certain key words that we need to keep in mind one is still versus running water. So one situation can be when a concrete is being placed in still water; that is the water is not running there is no movement in the water and concrete is being placed there. So, all that concrete has to do really is to displace the water and be there. Whereas, in running water the concrete can be swapped away, it can segregate a lot more easily.

Of course, even in still water the tendency to segregate will still be there, but in running water it becomes even more, which means that when we are talking of concreting under water or placing concrete under water one has to understand the implications of still versus running water and lay down a specification. That if the speed of water the velocity of water is more than a certain number, then certain other provisions will apply certain other specifications will apply.

The same concrete which can be placed in still water may not need the requirements when it comes to running water and so on. So, once the engineer is aware of the fact, then he looking for the right kind of specification as to what is the kind of concrete that is going to be used under those conditions. Another key word that comes to our mind, when you are placing concrete in water is self compactability and segregation resistance. Concrete falling through water has a much larger tendency to segregate it should also be

such that it should be self-compactable. We do not want to vibrate concrete on the water, we would like to just place it.

Let the concrete take the shape of the fond, which has been set in place and hardened. So, we would like the concrete to have self compactability, it should be able to move through the reinforcement because of course, as far as the underwater concreting is concerned, it is not really plain concrete all the time. There can be reasonable amount of reinforcement in those structures and the concrete can be reinforced concrete. Therefore, the concrete should be able to negotiate the spaces between the reinforcement and should have adequate segregation resistance.

As far as the methods of construction is concerned, one of the methods that is commonly used is tremies or rockets and so on. So, in any case the concrete is simply taken under water and dropped we will talk about tremie construction a little bit later. We have to be careful, whether the concrete remains always submerged? Now, if it remains always submerged, the kind of demand on the concrete is different compare to a situation where the concrete may be placed under water. But over a period of time during its service life it is exposed to air at times.

For example, if it remains under water all the time, then considerations like drying shrinkage simply do not apply. Whereas, if it is exposed to the atmosphere or the air during certain periods of its service life, then we have to be careful in terms of drying shrinkage and the related issues in concrete. We can talk in terms of underwater concreting in two ways. One is that we have a special method of construction, which enables us to do the construction under water, but the concrete that we use is normal concrete or slightly modified concrete that is sometimes it is stated in codes and procedures.

That if the concrete is being placed under water a certain amount of extra cement may be used or should be used, that comes from the fact that the code writer believes that when the concrete is being placed in water a certain amount of cement may be washed away. Therefore, as long as we are putting an extra amount of cement in the system strength developments and so on will not be adversely effected. The second approach is to say that well we design a special anti washout concrete, which does not segregate when placed in water and this is something which we will see in a couple of slides later on.

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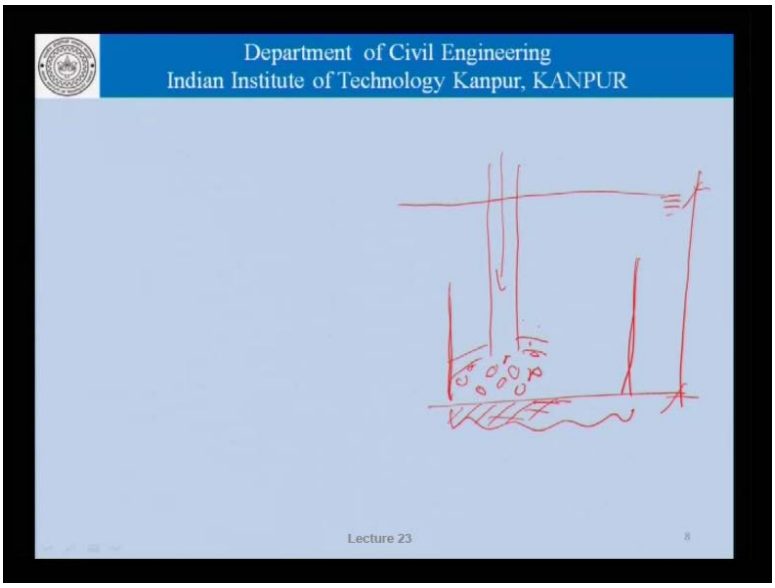

Let me just spend a minute on tremie construction or the construction using buckets what is really done is that, if we have this as the… Let me spend a minute on how construction under water is effectively done? We have water from here to let us say this point. So, this is all water this is the formwork that we are put in place and we want the concrete to be placed within the formwork, without having to remove or without being able to remove the water.

So, what we do is lower at pipe which is called the tremie pipe, we put concrete into this and as the concrete emerges here. We gradually rise this pipe keeping on oaring more and more concrete into it, making sure that the fresh concrete that emerges here is not in contact with the water and only the initial concrete, which came out or emerge from the tremie pipe is in contact with water. As the tremie pipes moves up more and more concrete gets poured all over the place and we are able to get a construction underwater.

Depending on the size of this member, that we are trying to cast two pipes or more than two pipes can also be lowered and it should be ensured that the concrete has been placed in a manner that there no coal joints and so on and so forth. So, as far as tremie construction is concerned, one of the important precautions that one must maintain is that the end of that tremie pipe is always submerged or always buried in the concrete. It is not exposed to water or we do not want as far as tremie construction is concerned is that the tremie pipe allows the concrete to fall under water.

This concrete is always fresh concrete is always in contact with water. So, if the concrete is allowed to fall freely in water that is something, which is not acceptable as far as most tremie construction is concerned. We try to avoid free fall in air more showing water. So, as far as water is concerned we must insist that the tremie pipe is always buried in concrete being placed.

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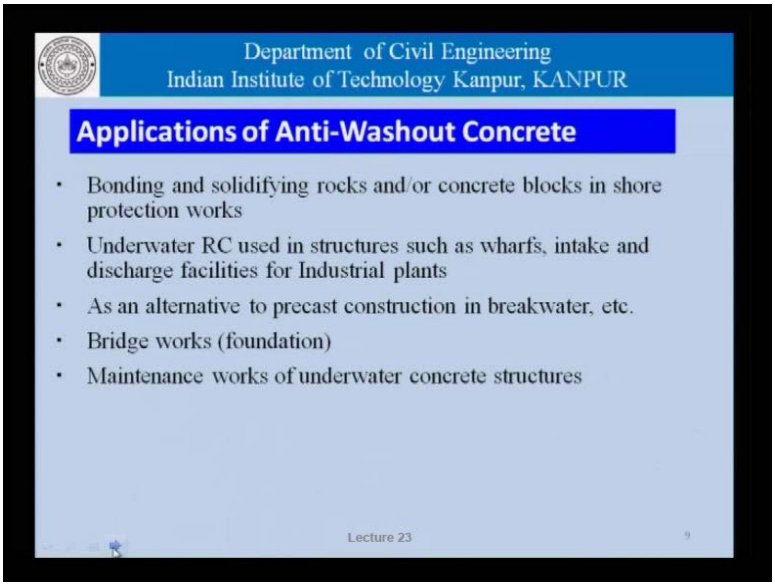

Now, coming to areas in which we are looking for such concretes it could be in terms of bonding and solidifying rocks and a concrete blocks in shore protection works and marine structures or it could be in under water reinforced concrete used in structures. Such as wharfs intake and discharge facilities for industrial plants. So, it is not all the time that we are talking in terms of marine structures, it could be industrial plants it could be rivers anywhere it could be an alternative to precast construction in breakwaters. It could be foundation work in any bridge, it could be in terms of maintenance work of any of these underwater structures.

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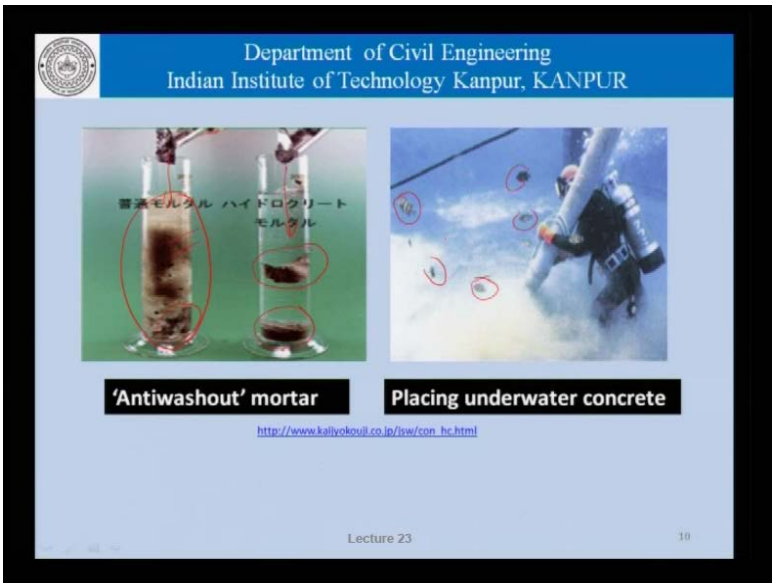

Now, if we look at anti washout concrete that is the special concrete or a special concrete, which has properties that enable it to be especially useful underwater. This picture here shows and anti washout mortar, that is we do not have aggregate in it, but if we look at a normal mortar which has been placed or which has been dropped in still water, then we see so much of muddy of the water. That is really the washout that is occurring as far as the cement and the fines are concerned.

It is not only the cement, which is being washed out it is also the fine cement in the mortar that are washed out and the water becomes muddy, but it of course, particles being heavier than water. There is a certain amount of settlement that occurs as well. Now, if we are able to have a concrete or a mortar which is something like this, that it can be dropped through the water without muddying it, then we have the basis of an anti washout concrete or an anti washout mortar, that is we have imparted to the mortar sufficient amount of cohesiveness that the washout or techniques tendency to washout is over powered by the cohesion.

Now, the point really is, how do we impart this cohesiveness and that is what is the crux of the problem as far as design of anti washout concrete is concerned? Another things that needs to be reiterated here is the fact that, so long as we have a mortar which is anti washout getting the concrete which is anti washout is not all that difficult because at the end of it aggregate suspended in mortar is the concrete. So, long as the mortar does not

have a tendency to segregate, it will keep the aggregate with it and therefore, we will get an anti washout concrete, another picture here shows that of placing underwater concrete using a diver.

So, here we are not really using a tremie kind of construction, here the diver is simply placing the concrete just as a normal material being placed underwater. So, one of the things that is notable about that picture is the fact, but you can see fresh around here which shows that the concrete is not segregating or there is very little washout that is occurring in the concrete, that is there is no muddying or sullying of the water around the place where its being placed. So, this is the kind of construction that we are really talking about this one of the very famous photographs of underwater concreting. I would encourage you to take a look at it sometimes and try to study about it little more.

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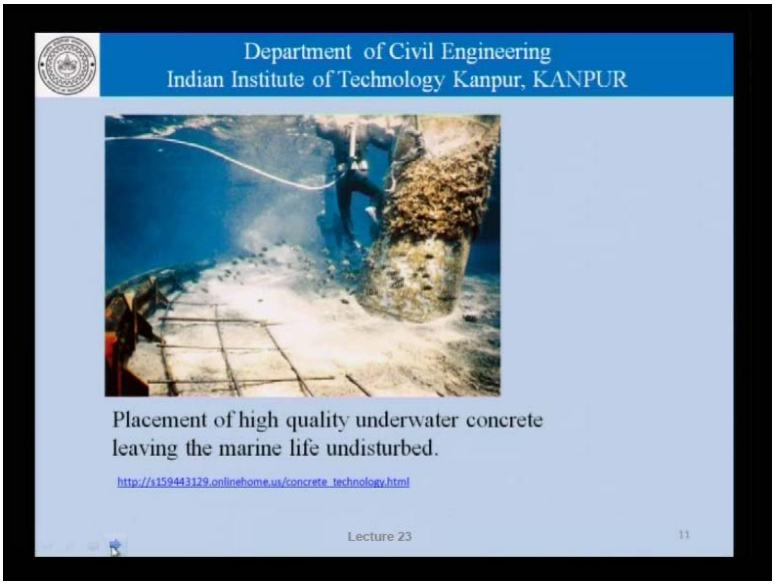

This again is another picture of rehabilitation kind of work, where a diver is trying to place high quality underwater concrete without disturbing the marine life. Anti washout concrete something which can be placed under water in a manner, which is as easy and similar to that of normal concrete being placed in air when we placing concrete in air, we do not think twice. Similarly, when we are placing anti washout, similarly when we are trying to place anti washout concrete in water, we do not have to think twice about it segregation and so on.

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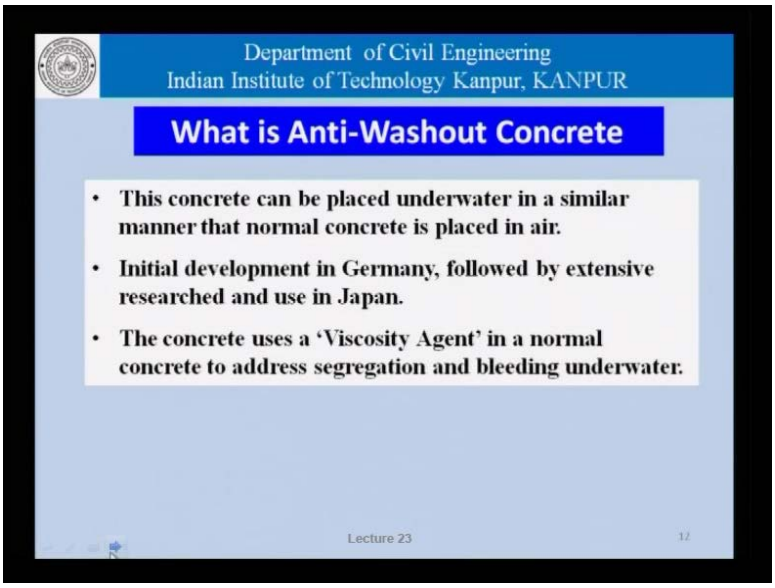

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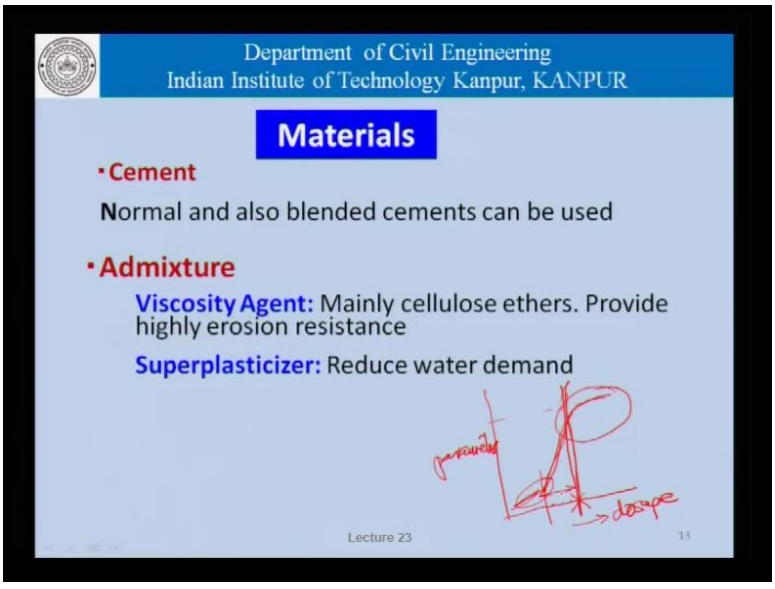

Initial development as far as anti washout concrete is concerned, to place in Germany and it was followed by extensive research and applications in Japan. The concrete uses obviously viscosity agent as a negative to normal concrete to address the problem of segregation and bleeding underwater. So, this is what is the crux of anti washout concretes as far as the materials are concerned. Normal blended cements can be used as far as admixtures are concerned one has to be careful, its primarily that trick involves the use of cellulose ether based viscosity agents, which provide the erosion resistance to the concrete.

Of course, we need to have super plasticizers to reduce the water demand as far as the dosage of these admixtures is concerned. Some experiments have to be carried out to determine the right kind of dosage. Normally speaking, as the dosage of a chemical admixture is increased its effectiveness increases, but at the end of it there is a limit beyond, which further addition of the admixture does not lead to any improvement at a desired property.

So, what we are looking at is a curve which is something like this that is at this point if the dosage is very low the effectiveness is pretty low, but within this range as we increase the dosage. If this is the does, the dosage and this is the parameter that we are trying to monitor, then in this range it makes a lot of difference as to what is the kind of dosage, which is being used. But beyond this point there is no real point in increase in the dosage of the chemical admixture. Obviously has the implications in terms of the money that is the concrete becomes more expensive.

So, we must know this point because we should understand that beyond that point there is no effect of or no improvement that we get in terms of the property the concrete. So, as far as the viscosity agent is concerned or the super plasticizers concerned, we have to be careful and try to determine these point the effectiveness and that is what varies from one admixture to another one, cement to another and compatibility issues come in. So, that is why we need to have a online kind of a laboratory, which is a very real kind laboratory, which keeps testing the cement that are coming in and being use that sites and also the chemical admixtures when it comes to these special concretes.

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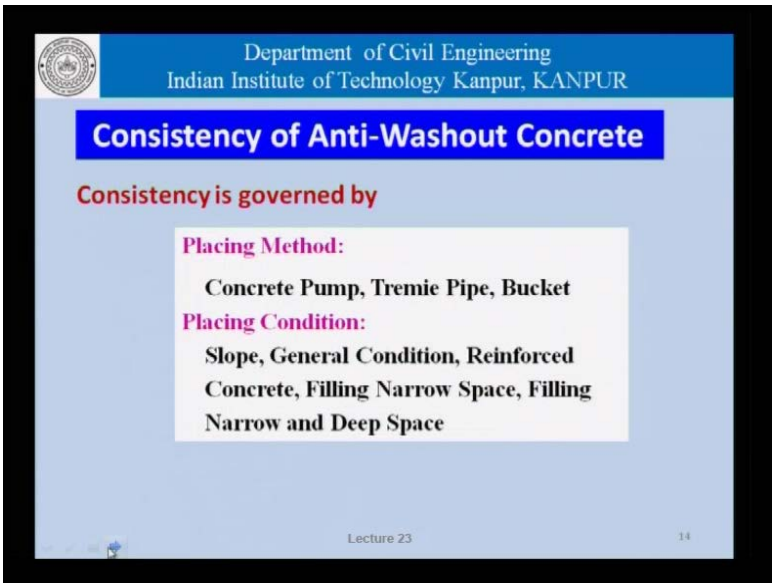

Now, as far as a consistency of anti washout concrete is concerned, its governed by the placing method and the placing condition. So, with this we conclude our discussion on anti washout concretes. So, in a manner of speaking anti washout concrete is basically just another high flow ability concrete, which is specially designed to be placed in water.

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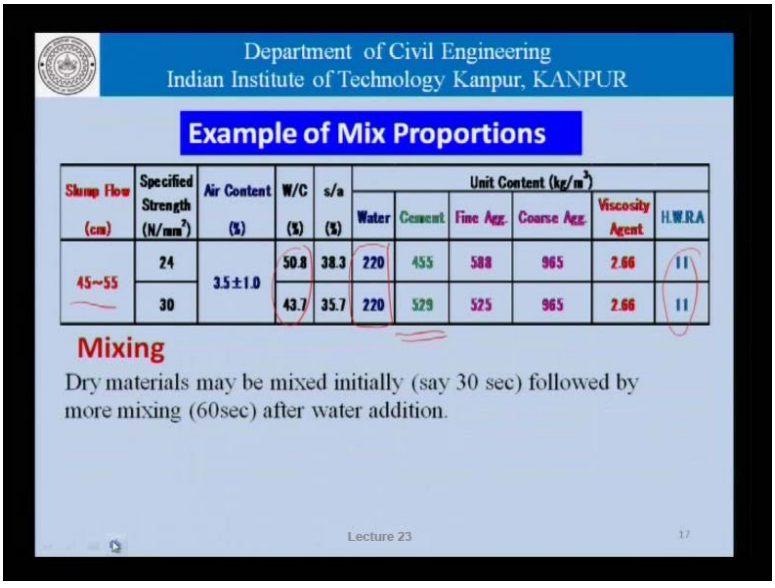

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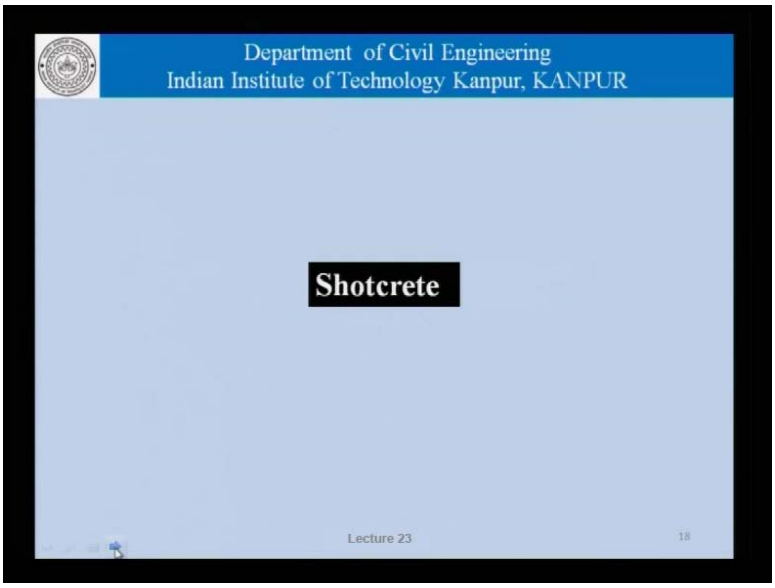

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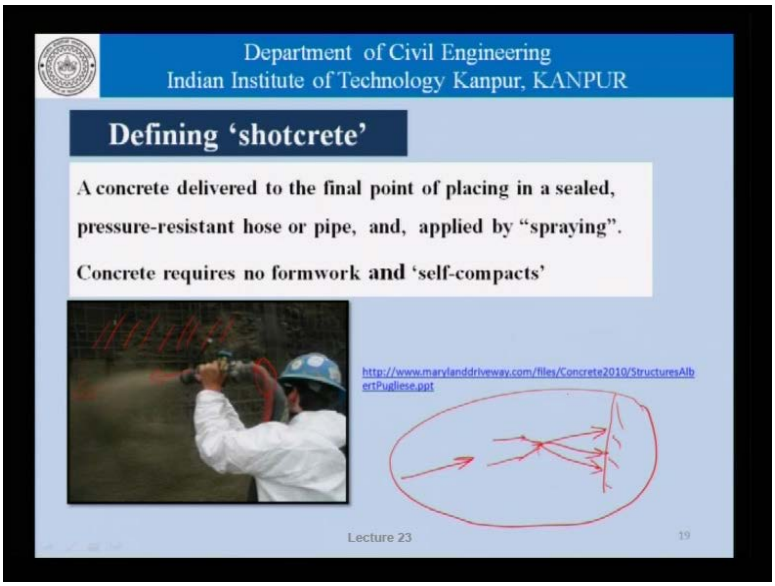

Now, from this regime where we are talking in terms of slump flows and so on. Let us move to another concrete which is shotcrete and this is an entirely different method of concrete construction. As far as definition is concerned, it is a concrete that is delivered to the final point of placing in a sealed pressure resistance hose or pipe and applied by spraying, this concrete requires no formwork and self-compacts. Now, if you look at this picture which shows shotcrete construction in progress, this here is the area or the place where the concretes finally needs to be placed.

It is being transported through this pipe, which is under pressure and the concrete is being pumped out in the pressure coming out through this nozzle and is getting deposited on the surface which is being concreted. So, in a manner of speaking, if this is the surface on which we want to concrete we take a nozzle here, bring concrete under pressure and this concrete is deposited on this surface. So, this is what is the fundamental shotcrete construction?

Now, in order to have this construction, what are the kind of thing that we need to do as far as the concrete is concerned? This is something which is very different from normal concrete construction, in terms of formworks, in terms of vibration and all that as far as formwork is concerned. Of course, as we see here there is no formwork requirement, the concrete is applied on a surface and simply stays there. In very special cases concrete could be deposited against a formwork, which is then removed, but that often does not happen as far as compaction is concerned. In the case of shotcrete, it is achieved by the high speed of deposition. So, when concrete particles whether it is cement or its coarse aggregate and so on. The fact that they are deposited with certain amount of speed that ensure, so the concretes compact or it compacts the layers of concrete being cast.

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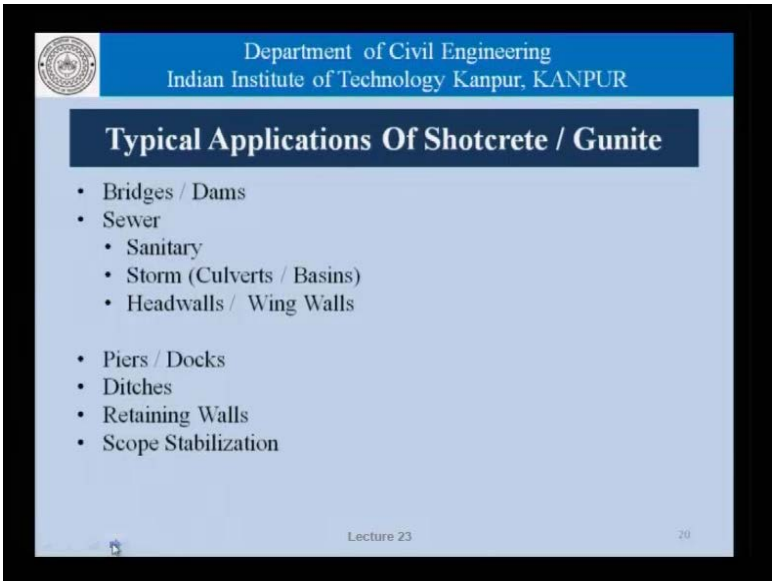

So, if we keep this picture of shotcrete construction in mind, we will understand the kind of discussion that follows the application. As far as shotcreting or sometimes also called guniting could include, construction in bridges repair works in bridges or dams. As far as

sewers are concerned, whether its sanitary or storm or culvert basins headwalls wing walls piers and docks ditches retaining walls slope stabilization and so on. So, there are lots of areas in civil engineering where shotcrete finds in application. It is not only structural engineering in terms of buildings and so on, that it is required. It is also required in terms of stabilizations of soils it required in terms of stabilization in slopes, it is required to repair work of structures and so on.

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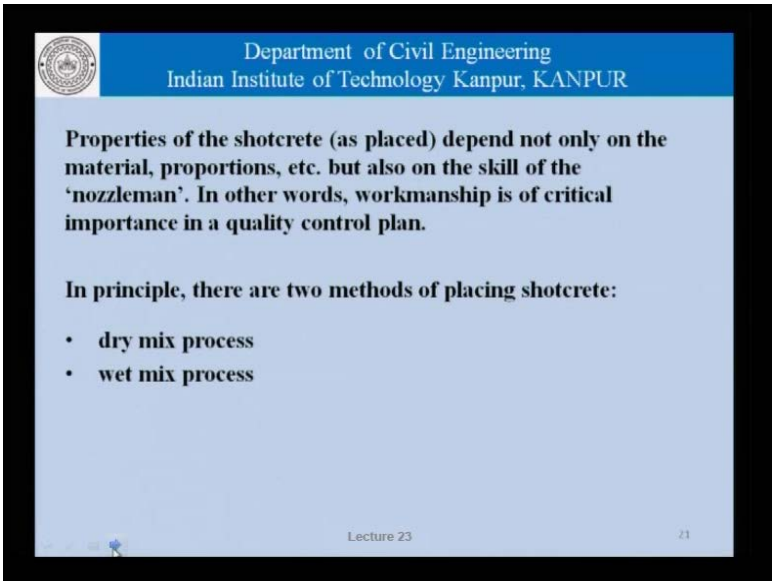

Now, the properties of shotcrete as placed depend not only the material in proportions etcetera, but also the skill of the nozzleman that is the person whose operating the nozzle. So, this is similar to that of a diver the role that nozzleman place as far as shotcrete is concerned, is similar to that of the diver as far as under water concreting is concerned as we saw in the previous discussion.

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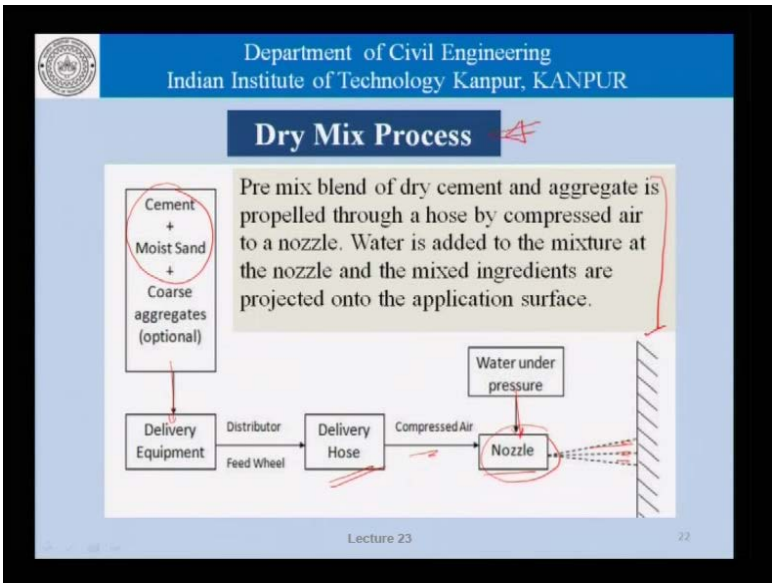

So, the workmanship is of critical importance in a quality control plan. In shotcrete construction in principle there are two methods of placing shotcrete, one is the dry mix and the other is the wet mix process. What these processes are, is almost self-exploratory. For example, if it is are dry mix process, what we have is cement moist sand and coarse aggregate, which may or may not be there in certain cases. We use simply mortar that is placed brought into a delivery equipment into delivery hose, we compress it take it to the nozzle and at the nozzle we add water under pressure.

So, there is no real mixing of the dry material with the water prior to coming in contact at the nozzle at the very end and then the concrete is spread on to the surface. So, the premix blend of dry cement and aggregate is propelled through hose by compressed air to a nozzle and water is added to the mixture at the nozzle and the mixed ingredients are projected onto the application surface.

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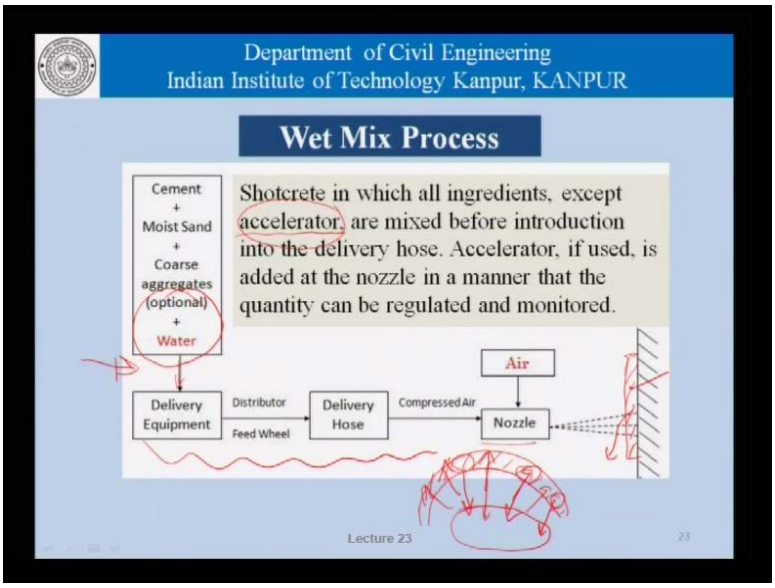

Now, the fact that no initial mixing is being done with water mix, this concrete procedure or this process, the dry mix process of placing shotcrete in contrast to this the wet mix process involves shotcrete and which all ingredients except the accelerator. Now, that accelerator is a chemical admixture. So, all the ingredients of concrete other than the accelerator are mixed before introduction to the delivery hose and only an accelerator if required is added at the nozzle, in a manner that the quality can be appropriately regulated and monitored.

So, we have all the ingredients of concrete in the initial stages itself, concrete has been mixed in a normal manner. Finally, being taken to the nozzle and spread on to the surface, where it is going to be applied or where its need to be applied. Now, what about the role of this accelerator in a normal concrete when it is being placed against formwork? We had in no real hurry that the concrete should hardened accept that, yes we want that concrete should hardened as soon as possible after it has been placed.

So, that other activities can follow, but in the case of shotcrete where the concrete can be placed against a surface like this, which means that we want a deposit a layer of concrete like this or for that matter if we are talking of a tunnel where we are trying to deposit the concrete in this form in a layer like this, we have the problem of concrete being simply falling off if it is left to hardened for a long time. So, in the case of shotcrete, the fact that

it is not being cast against formwork, the fact that it is not supported in the initial stages by formwork, while it hardens makes it important.

That once it is placed it hardens very, very quickly to reduce what is rebound of this falling off of the concrete can be called rebound or simply a separation and so on. In order to minimize, that what we need is that the concrete once it is placed in position should hardened very quickly and that is why we need an accelerator. Now, we cannot use an accelerator in this stage here because we do not want the concrete to harden, while it is in the system here rerun the concrete to hardened only after it has left the nozzle and it has been deposited.

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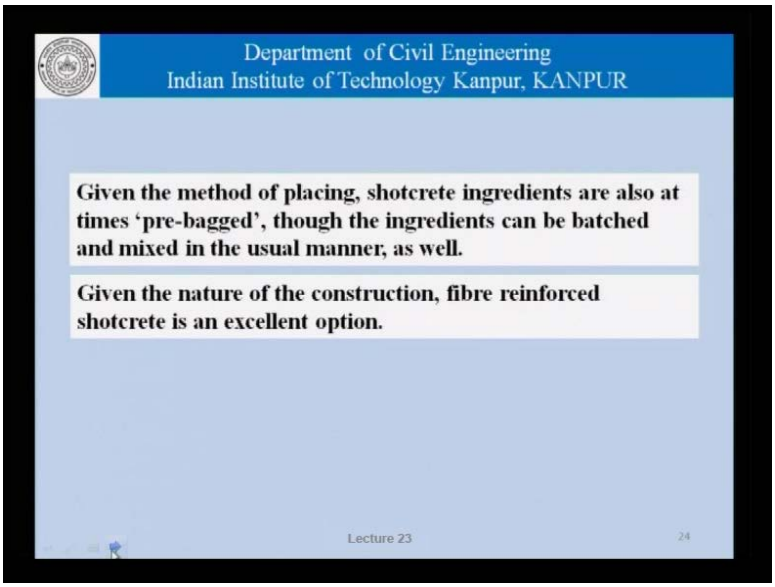

Now, continuing with our discussion as far as shotcrete is concerned, given the method of placing shotcrete ingredients can also be pre-bagged, though all the ingredients can be batched and mixed at site in the usual manner depending on whether we are using the dry process or a wet process. We can use pre-bagged materials, which takes away any kind of variations, that are likely to happen.

When we are talk in terms of mix proportions or batching of different ingredients to some extent, it gives us better quality control in terms of the choice of the ingredients and so on. But if we do not want to do thatm we can actually use normal concreting process and mix the concrete in a usual manner accepted the method of placing is not normal and we are trying to spray the concrete on to a surface.

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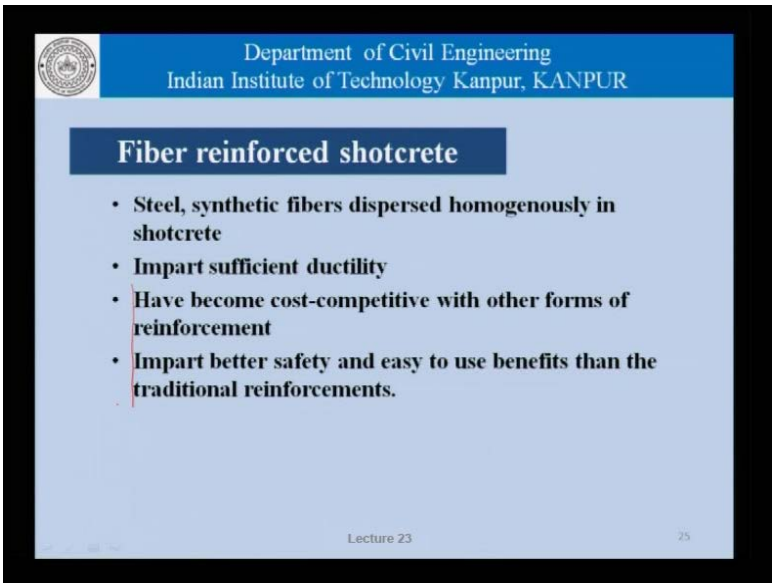

Now, given the nature of this construction fibre reinforced concrete emerges as a excellent option, so we will find in literature that very often we talk in terms of we find applications of fibre reinforced shotcrete. Why fibre reinforced shotcrete gives us excellent options? We will talk about in a minute as far as fibre reinforced shotcrete is concerned, we could use steel synthetic fibers dispersed homogeneously. In shotcrete it imparts sufficient ductility and fiber reinforced shotcrete have become cost competitive with other forms of reinforcement and the impart better safety, and easy to use benefits than traditional reinforcement.

Now, only in certain cases this discussion is true because fibre reinforced concrete most of the time cannot really replace normal reinforced concrete fibre, reinforced concrete as we have talked earlier. Really just alters the properties of the concrete makes it more crack resistance, makes it more difficult for cracks to propagate through the concrete the normal process of reinforcement is quite a different mechanism. But as far as concrete is concerned, where concrete is actually deposited in layers, there fibre reinforcement is a great help, because it prevents any kind of crack formation in those layers. Well not it really prevents in the absolute sense, but minimizes.

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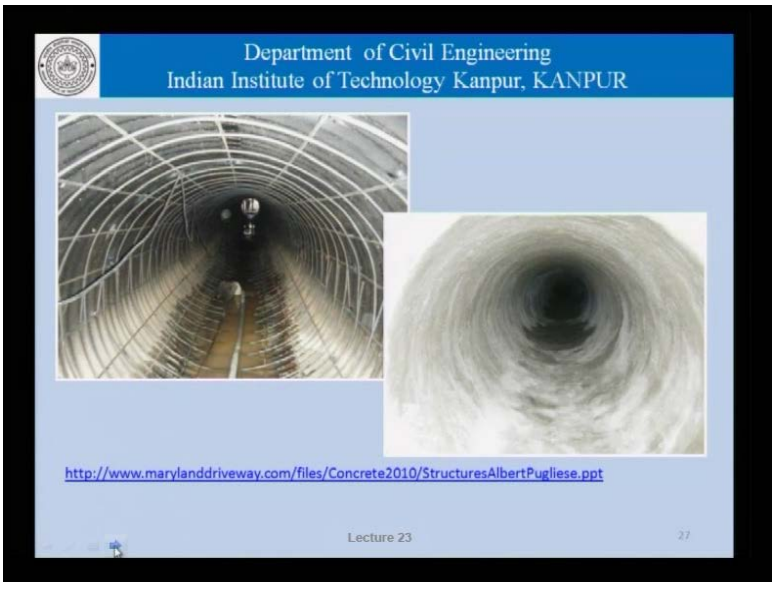

Now, these are some examples of shotcrete applications. These are application here is that of deteriorated corrugated steel pipes, so we can see that its rehabilitation will require a lot of effort. If we look at this picture here, we find that the shotcrete has been placed on the surface of the deteriorated corrugated iron sheet and we get a reasonably clean looking system.

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Coming to a brick sewer, if we look at this brick sewer here, we find that its highly deteriorated and once we are able to apply shotcrete on the surface here, we get a system which is rehabilitated or which is repaired.

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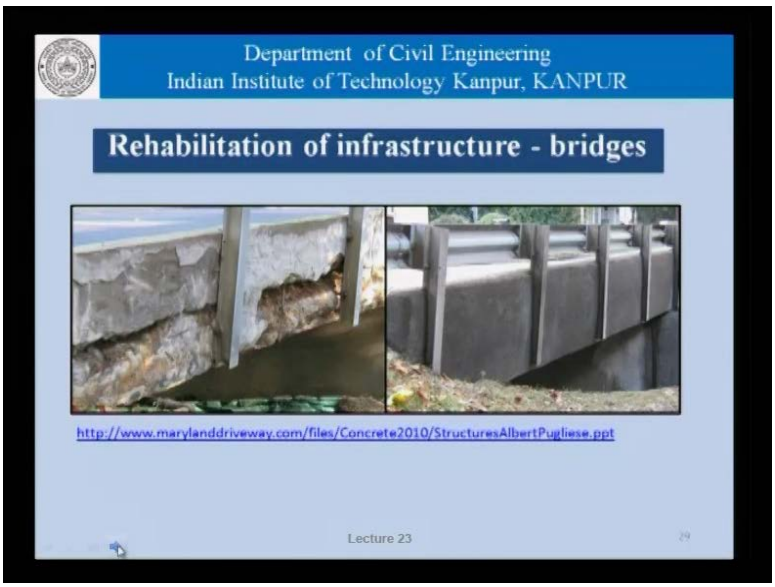

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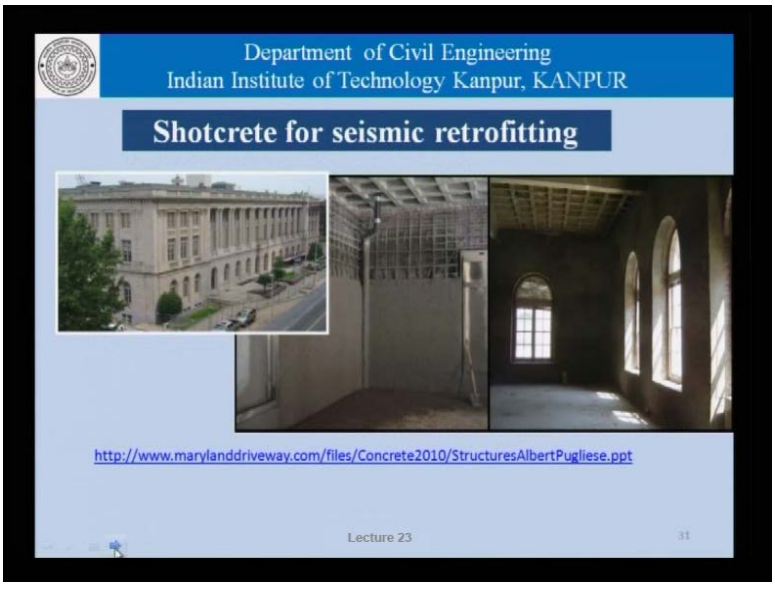

So, what we do is apply shotcrete on the surface of this sewer here, including the top and so on. We get a refined or a different surface of the concrete or a different surface of the sewer. This here a pictures of a rehabilitation of in the infrastructure projects in terms of bridges, in terms of marine structures, in terms of seismic retrofitting. One must remember that concrete structures, though they are easy to build they are not so easy to demolish and the resolve is the temptation to extent the service life.

That temptation to increase the service life or keep extending their service life, leads us to solution such as application of shotcrete and so on. So, if we have an existing concrete structure, we want to increase its cross section. We do not want to demolish their structure and build a new structure. The option is shotcrete because at the end of it, what we want is just to increase the thickness and to increase that thickness and try to place concrete in a normal manner. Sometimes is not possible because the fact that then concrete requires to be flown in very narrow spaces. That may be not possible except for using self-compacting concrete and so on.

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So, at choice of an emerges in terms of whether using formwork and self-compacting concrete or using shotcrete. This is another of those rehabilitation case studies, where we have a retaining wall being repaired using shotcrete. Now, if we look at this picture closely we will find that shotcrete surface or a shotcreted surface is not necessarily very plain or a very smooth surface and it will be that, because the method of placement is such that the thickness of concrete deposit may vary, depending on the skill of the nozzleman. That is what causes variations in the thickness of the concrete deposited.

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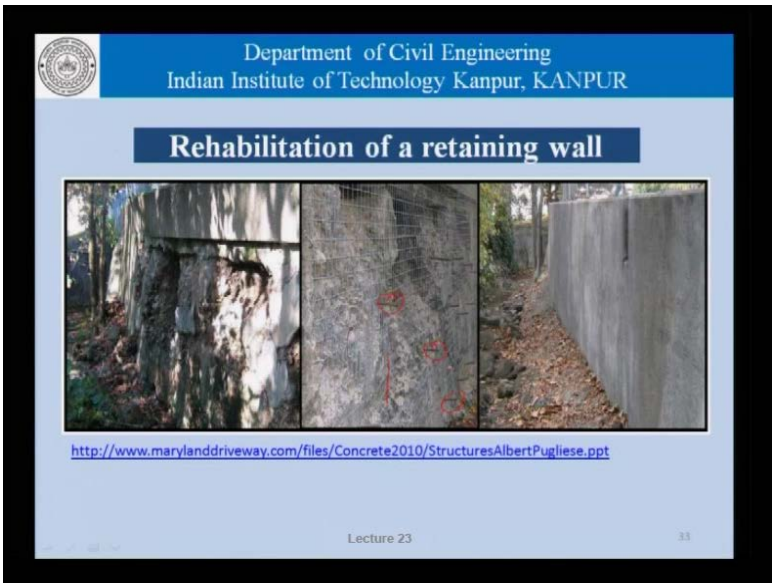

In certain cases where the thicknesses of critical importance and we really want to measure that thickness as a part of quality control, we need to have methods by which the thickness of this deposited. Shotcrete is properly determined and recorded, so that we know that what we had set out to achieve is what we have achieved. This again is a picture of retaining wall with rehabilitation. Here we can also see the application of a reinforcement net and also nails to anchor the shotcrete to the existing retaining wall.

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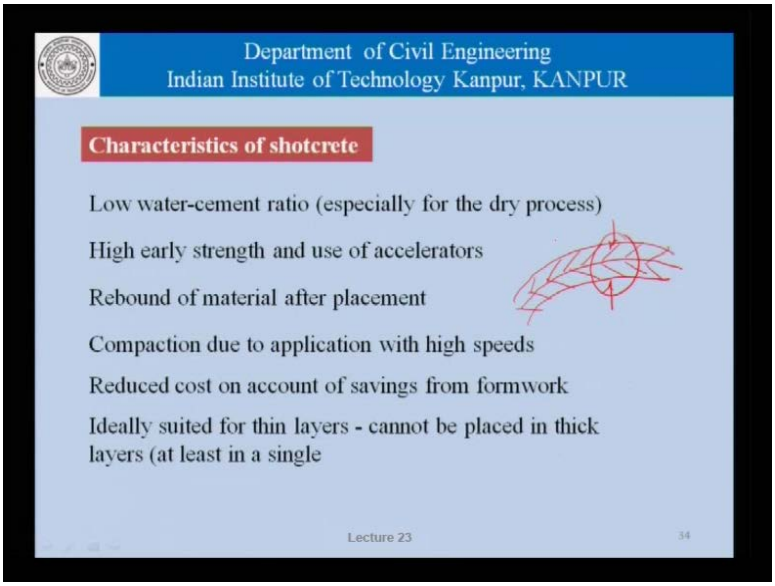

Now, coming to the characteristic of shotcrete, very often the material is characterized with a low water cement ratio, especially in the dry process. That has its advantages in terms of strength development and so on, because of the fact that we use accelerator, we also have high early strength in the case of shotcrete. We also have a lot of wastage of the material by way of rebound after placement. So, a certain amount of rebound is unavoidable when we are talking of shotcrete construction and that is something, which an engineer must account for with a scale of the nozzleman.

The rebound can be minimized, what it cannot be eliminated as I said before the compaction in this kind of construction, is on account of application of concrete with high speeds. We might sometimes have reduced cost in shotcrete construction, as we do not have any expenditure to make on formworks.

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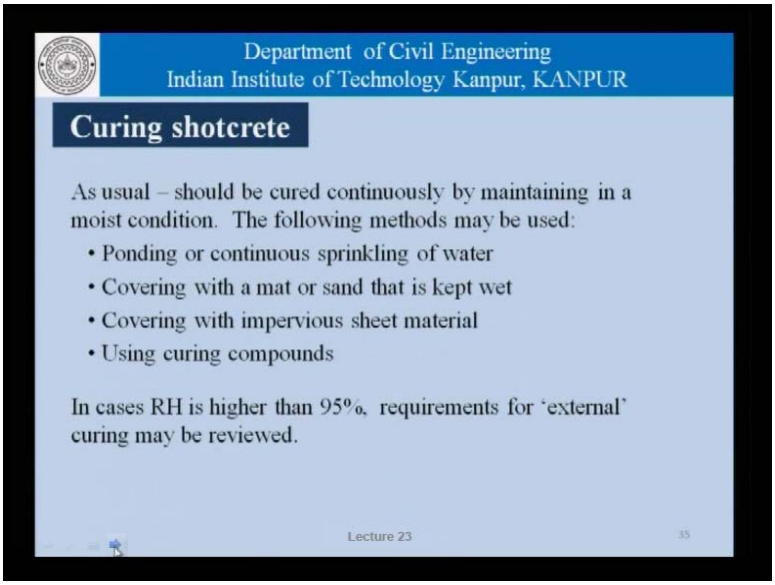

Shotcrete construction is ideally suited for thin layers, it cannot be placed or shotcrete cannot be placed in thick layers at least in a single go. So, what we can do is to have one layer of shotcrete and then another layer of shotcrete. But it is difficult to have this whole thickness being shotcreted in one go as far as curing of shotcrete is concerned. It is the usual process, the concrete needs to be cured continuously by maintaining a moist condition, which could be by way of ponding or continuous sprinkling of water covering with a mat, which is kept wet covering that concrete with an impervious sheet, all use of curing compounds.

Of course, if the relative humidity in the atmosphere is higher than 95 percent or something, then of course, requirements for external curing may be reviewed. Because in the end of it curing is a process by which we try to eliminate or minimize any loss of moisture from the surface of the concrete. We want to provide as much water as we can for the hydration and strength development of the material.

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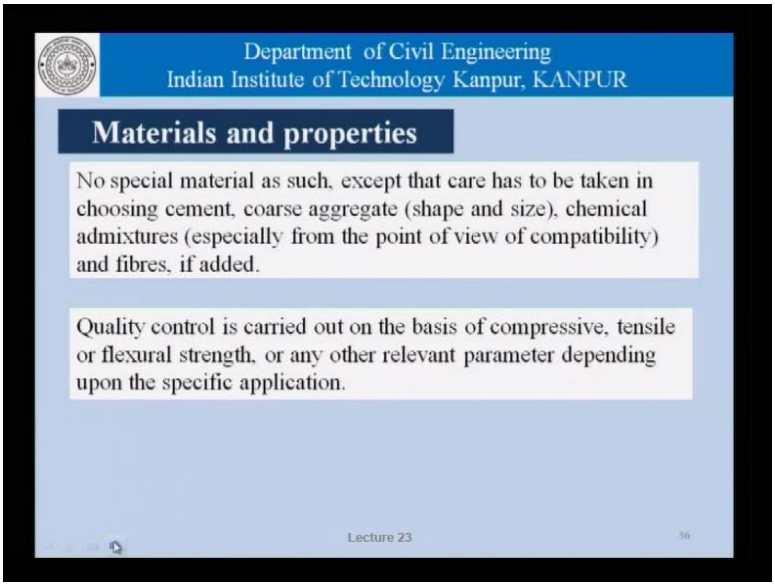

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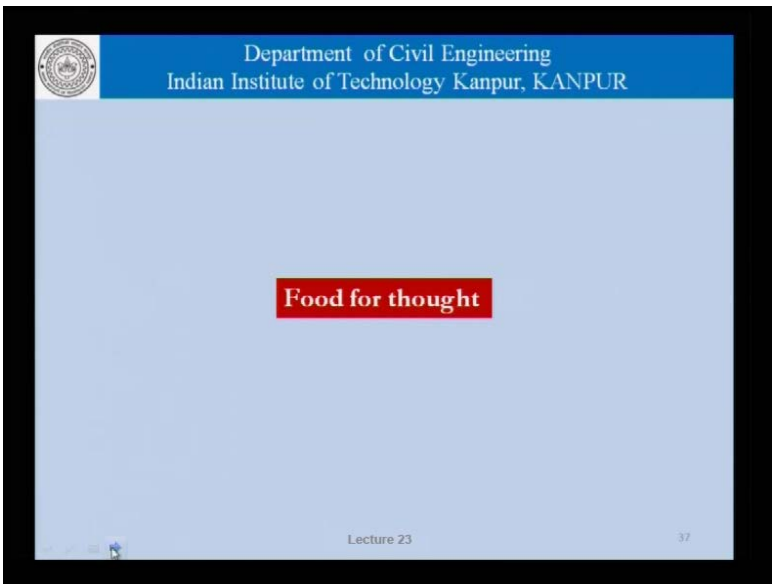

So, the basic understanding of cement concrete does not alter when we are doing shotcrete kind of construction. As far as materials and properties are concerned, I have

already stated that concrete construction is economical only to the extent, when most special materials are used. Therefore, even in this case, no special materials are such except that care has to be taken in choosing the cement coarse aggregate in terms of its shape and size, chemical admixtures from the point of view of compactability and fibers.

If added we have to be careful in the choice of the materials and ensure that, we do not have a problem in terms of rebound, in terms of courage, in terms of the distance, through which the concrete has to go in air before being deposited. Quality control has to be carried out as usual on the basis of compressive tensile and flexural strength or any other relevant parameter depending upon the specification application.

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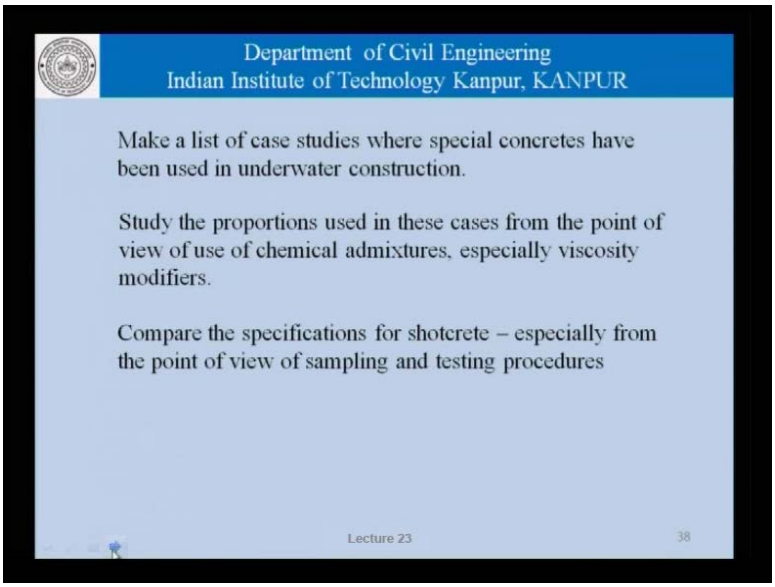

Having gotten this overview of shotcrete, let us try to close the discussion today with a series of questions. We could make a list of case studies where special concretes have been used in underwater constructions. What we are talking about is the application of anti washout concretes, as we have seen in the first part of the discussion. We can make a list of the proportions that have been used in these cases from the point of view of chemical admixtures, especially viscosity modifiers in terms of their chemical nature or the chemistry of the viscosity modifiers.

How it acts from the cement hydration and its compactability and dosage with different levels of strength coming to shotcrete. One could compare the specifications from the point of view of sampling and testing procedure. One thing which we have not covered

specifically here, now I would to like to leave it as an assignment is the sampling process. In the case of underwater concrete for example, how should the cubes or cylinders be cast?

The concrete is normally brought to site in an agitator truck and would we like to take the cubes or cylinders, for monitoring the strength development in air in the normal manner or we should do it under water would be help of the diver, that is something which needs to be decided by the engineer. We could do both and that is something which you can decide or you can think about if you were the site engineer, where underwater concreting is being carried out. What is the kind of regime that you would like to follow? What are the specifications? What do the standard say because at the end of it, it cannot be left only to the wings and fancies of the project manager.

Similarly, in the case of shotcrete, how should the sampling be carried out? Because when we are shotcreting, it is simply not possible to actually take the a cast the cylinders or cubes. So, what usually is done is that a panel is cast other than the kind of normal casting and coarse are taken out of the panel and tested for strength. These are some of the things that may be those of you are more interested could do some reading on and educate yourself.

Thank you.