Development and Applications of Special Concretes
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Lecture 13
Special Topics: Importance of Right Methods and Specification

Welcome back to another lecture in our series on development and applications of special concretes. Having started this week with a lecture on curing continuing with that with cold weather and then hot weather I would like to close this week with a special discussion on the importance of having the right methods and specifications that actually suit the method of construction.

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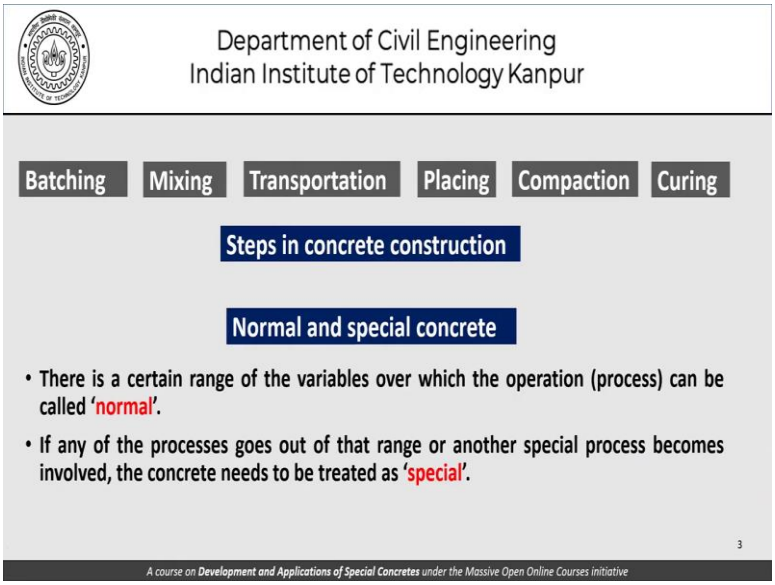

Now as far as the right the specifications and the right methods are concerned, they start with normal concretes and have to be adapted or new methods and specifications have to be given for special concretes. Now let me start the discussion by just reiterating that the concrete construction process consists of batching, mixing, transportation, placing, compaction and curing and there are different processes involved.

All these processes have certain ranges and within that range concrete can be called normal or the concreting operation is normal. And if one of these processes goes out of that normal range the others have to be adjusted accordingly and then the whole thing has to be treated as a special process. So, the discussion today would be largely in terms of how cleared our

normal specifications and methods are in treating or for treating special construction conditions of concrete structures.

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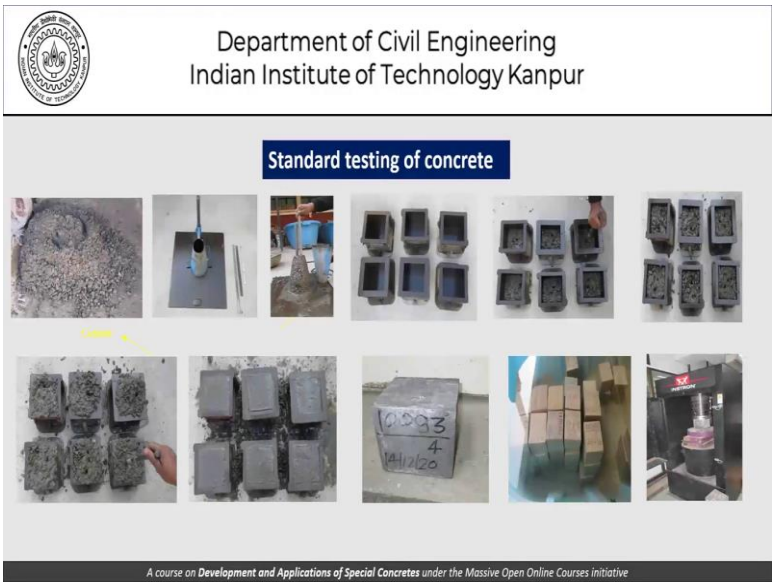

Now this is a reflection of what we do as far as normal concrete construction is concerned. We take concrete in the lab because that is where the whole process starts. We start the process by having a proportioning exercise carried out in the lab. So how is the proportioning exercise carried out we have already gone through the proportional part of it we have some concrete we mix it with a certain proportion we carry out the slump test.

The way it is shown here then we fill out these cubes, cubes we fill in India in other countries you may feel some other specimens maybe cylinders. We have them in two layers or three layers whichever is prescribed in the code tamp them the way it is shown here get to this form, get to this form finally get cubes here de-mold them cure them and test them. So, this reiterates to you or helps you recall the normal process where concrete proportioning is done the mix is determined. And the concrete is said that okay this is the mix that we will use for carrying out a normal construction.

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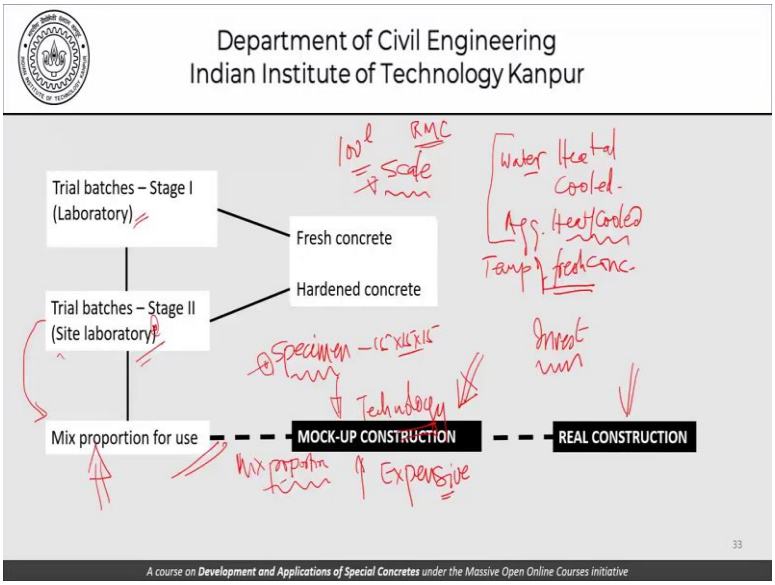

Now this is a summary of that we carry out trial batches in the lab we may carry out additional trial batches in the site laboratory and we determine the proportions for use as far as the site is concerned or as far as a particular project is concerned. And as far as these trials are concerned, we take care of the fresh properties and hardened properties that is properties of concrete in the fresh state and in the hardened state whether it is in the form of slump or it is in form of compressive strength, flexible strength or whatever it is.

Please remember that while we are trying to carry out these laboratory tests when it comes to properties of hardened concrete it might take time. So, one has to be a little careful when we are trying to do adjustments for strength because this could take about 28 days, 56 days, 7 days whatever it may take to be able to decide the mix. Whereas fresh properties the adjustments are reasonably quick because we can say that okay if we have one batch do the slump if it does not work do another batch do another slump and so on and so forth.

So, keep this in mind remember that as far as the quality control is concerned, we had talked about something that if in the project. The allowance given to me in the slump is plus minus 2 centimetres then in determining the mix as far as the laboratories are concerned, we try to have a window which is only plus minus one centimetre. Similarly, for air if I have a window of ±1%, I try to use only ±0.5% kind of a window in the lab this is my project window for air.

And I use a narrower band have a stricter quality control in the lab environment because only then we are trying to buy an insurance against some variation that will arise out of the changes in the material properties being used at site and so on.

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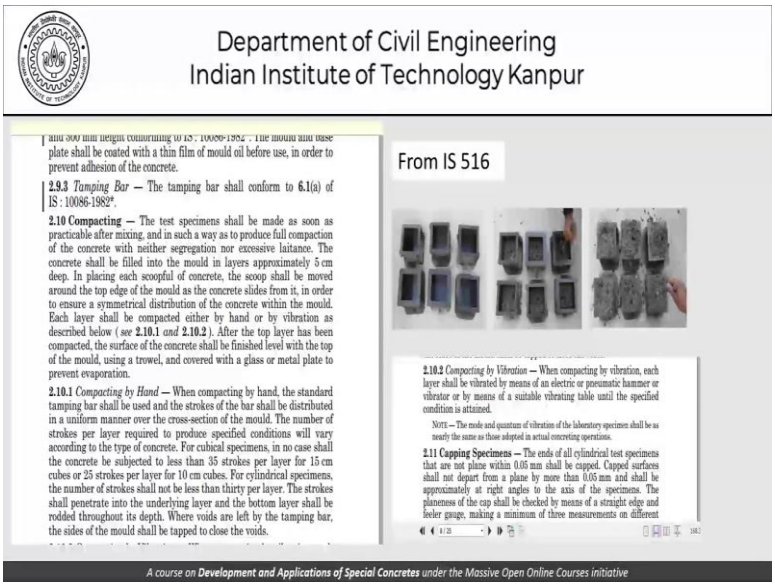

Now this is an example from IS516 which gives you in great detail what kind of a tamping wire should be used how should the compaction be carried out. If it is being carried out by hand if it is being carried out by a vibrator how should the specimens be capped? So, there are a huge amount of details given here 35 strokes per layer for 15 centimetres and 25 strokes per layer for 10 centimetres cubes.

So, these are the kind of details which are laid down as far as preparation of the specimen is concerned for normal conditions. One thing you should remember always that the concrete that we are trying to test the concrete proportions that we are trying to determine and finally the concrete that we test for strength or slump or whatever it is the idea is that the concrete should be suitable and it should serve the purpose in a given structure.

So, all these cubes that we take are of course not a true representation of the strength that will develop in concrete in actual structure. So that is something which is known to us and that is why we say that this is the cube that is being used for quality control of concrete. Now if somebody wants to know exactly what is the strength of the concrete in a beam that has been cast. The answer is that these cubes are only a reflection of that strength they are not the true strength of that concrete.

Because the curing conditions are different the placing conditions are different the compaction conditions are different and therefore in the strict sense, a quality control engineer or a concrete engineer can never say that these cubes truly represent the strength of

the concrete as developed. This is something which is known in the profession and within that knowledge within that limitation or within the limitation of that knowledge we carry out our design we carry out our construction and we are doing reasonably all right as far as we are concerned.

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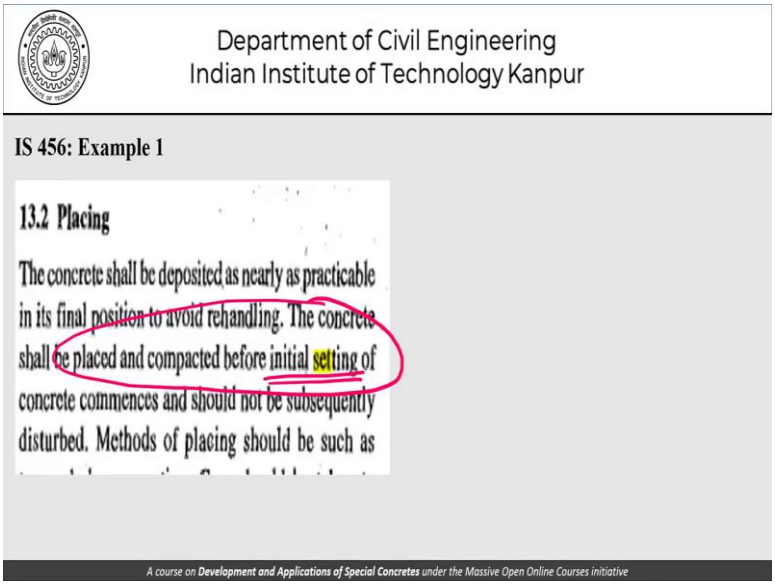

Now having said that where the specification was very clear about the tamping rod and the kind of tamping that should be done and so on. There are places where the specifications may not be very complete. Here is an example of that IS456 at some place says the concrete shall be placed and compacted before initial set of concrete commences and should not be subsequently disturbed.

Now here the specification clearly says or the document clearly says that we are talking about the initial setting time of concrete and not of cement. Of course, it is clear that cement is the only reactive material in component the reactive component and there will be a relation between the setting time of cement and the setting time of concrete. But please keep in mind that the setting time whether the initial setting time or the final setting time of cement is a quality control parameter of the cement it has nothing to do with the actual setting time of concrete.

Because the mixed proportions are different you are not using the same quantity of cement everywhere. The placing conditions are different the temperatures at which you are placing the concrete is different. And therefore, it stands to reason that the setting time of concrete should be independently determined. We have talked about how initial setting time of

concrete can be determined but that should have been reflected in this specification if it had been added that the initial setting time of concrete as determined by such and such then it becomes so much easier.

There is no mention of how the initial setting time of concrete is to be determined as far as the specification here is concerned. So can the setting time of concrete be taken as the same as that of cement I have already given you the answer the answer is clearly no.

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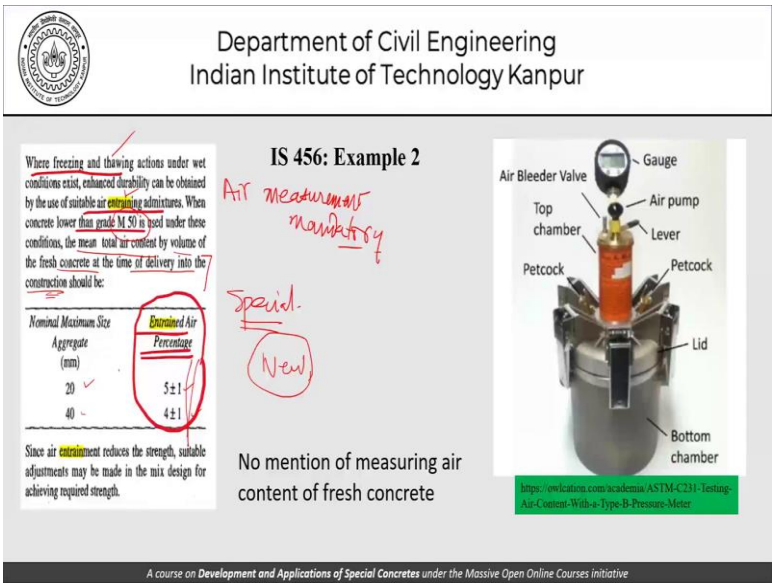

Another example again from IS 456. It clearly says that where freezing and thawing actions under wet conditions exist enhanced durability can be obtained by using suitable air entraining admixtures when concrete lower than M50 is being used under these conditions. The mean total air by volume of the fresh concrete at the time of delivery into construction should be given here. So, if the maximum aggregate size is 20 is 5±1.

If it is 40, 4±1 it also says that since air entrainment reduces the strength suitable adjustment may be made in the mixed design to achieve the required strength. So, once we are writing this kind of document certain things are clear. It says that for less than M 50 grade concrete because M 50 is possibly a limit which the code is telling you that beyond that please do not rely on this document try to do your own research as far as this document is concerned it is up to M 50.

At the time of delivery into construction that means it is not talking of the concrete properties at the ready-mix concrete plant. It is talking of certain air percentages but it does not make

the air measurement mandatory. See unless you have air measurement and its method mandatory and especially in this day and age where air entraining admixtures can be used for other purposes or other conditions than let us say freezing and thawing.

It is very difficult to control the properties of concrete. So certain undesirable things may happen so there is no mention of measuring air in fresh concrete the test method involved of course it is a very simple apparatus we all know that we have talked about it in the previous discussions when we are talking about mixed proportions. So, the idea basically is that the specifications have been written for normal constructions.

When it comes to special constructions the onus shifts a lot to the clients to the contractors to the user's regulators everyone to develop new specifications to kind of come up with more appropriate test methods, more appropriate specifications, more appropriate kind of proportions and sampling procedures possibly which ensure that the concrete that you collect the concrete you test is actually representative of the concrete that is cast.

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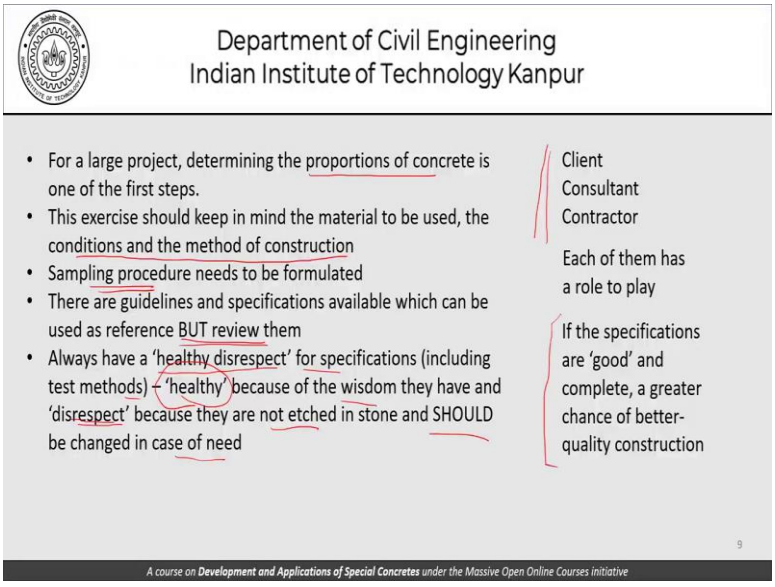

So, the discussion today would be in terms of large projects where the proportioning of concrete is one of the first steps. And once the proportion of the concrete that is the different ingredients established a lot of other things have to be done. Now this exercise as far as the proportioning of concrete is concerned should be carried out obviously keeping in mind the material to be used the condition and the method of construction.

I am going to highlight this part when it comes to some of the examples that I am going to take up today. The sampling procedures need to be formulated reformulated and brought in line with the conditions and the method of construction. The sampling procedures have also to fall in line with the conditions and methods of construction as I will explain to you with some examples. There are guidelines and specifications available which can be used as reference. But we need to review them.

My advice to you is always have healthy disrespect for any specification including test methods it should be healthy because there is a lot of wisdom in each line that is given there it helps you standardize the process. It helps you make it more robust but we have to have a little amount of disrespect with it because they are not etched in stone and should be changed in case of need. See for example even for IS 456 if we feel that yes there is a need to change it the engineers should be free to change it.

For a particular project and that freedom is always available to you in the documents in the contract documents it does give you the freedom that okay IS 456 is mandatory. But anything over and above that is always welcome. And once that becomes the norm it will be practiced in more and more sites. Of course, there are client's consultants and contractors involved in a project and each of them has a different role to play.

Somebody can say that I am only a contractor and this is the specification, told to me, now we are not talking in this set of lectures of a scenario where we have this kind of a closed mindset. We are talking of an environment where true professionalism is working and it is only a matter of time that the true professionalism will come in and has come in in a certain way where we say that this method is not applicable here.

And therefore, let us try to do this method which is more applicable. If the specifications are good and complete a greater chance of better-quality construction. So, whether it is proportioning of concrete mixes whether it is testing and sampling of concrete the procedures involved therein if sufficient amount of homework has been done in order to lay down the right kind of methods the right kind of sampling procedures.

The right kind of planning has gone into the project, special concretes and the special projects are more likely to succeed. If we jump into those projects start those projects with inadequate preparation it is more likely to run into trouble than otherwise.

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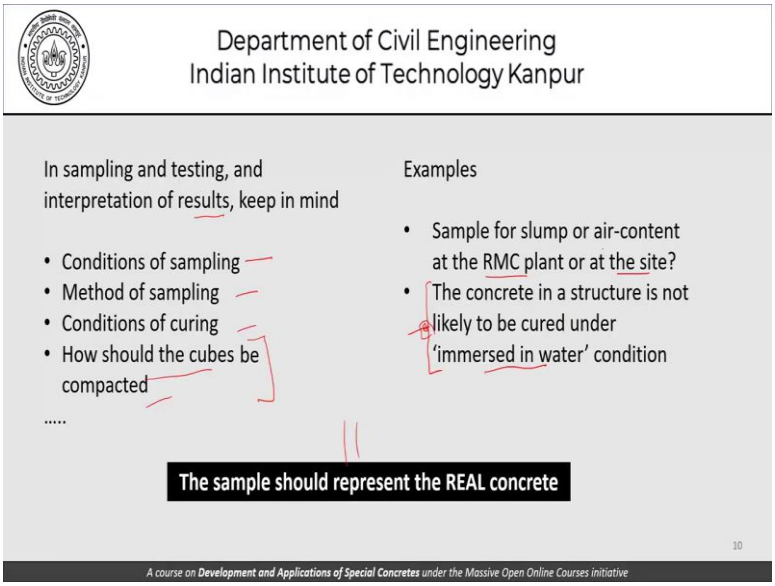

In sampling and testing an interpretation of test results keep in mind the conditions of sampling, method of sampling, curing conditions how should the cubes be compacted I mean these are the kind of things which are very, very mundane which are very, very obvious somebody will say what is the big deal about it but if you see the site if you think about it there will be a specification which tells you to tamp the cubes or vibrate the cubes.

In certain cases, it is not possible to do that then how should the cubes be taken? Somebody has to think about it somebody has to come up with a procedure so that it can be still robust as far as that particular project is concerned. Simple questions like sampling for slump or air content should be at the RMC plant or at the site as far as 456 is concerned for air it was very clear that it should be at the site of construction.

Similarly, you can have a specification that even at the plant it should be such and such because at the end of it there is a lot of funding at the end of it there is a lot of money involved. All these decisions at site involve rejection of concrete reconstruction of the structure and that is an extremely expensive affair. It must be avoided and it can be avoided only if we have good specifications.

We have as many checks and balances as possible in our construction procedures. The structure is not likely to be cured and immersed in water conditions and therefore we understand that. So, this part we clearly understand and we know how to handle it. But there are so many other things as we will see in the discussion today that need to be accounted for in our sampling process.

Bottom line never forgets this the sample should represent the real concrete we understand that it will never be the real concrete. It has never been all this business of testing cubes and cylinders curing them under water to get 28 days strength does not reflect in any way or form the actual strength of concrete in structures. But that is something which we know about and we have learned to live with it. The issue is that as we are trying to get into more and more special constructions or special kinds of admixtures and concretes, we need to be aware of more issues.

Once again this is just a reiteration that some of these things change a lot of the others in fact most of the others will need to be appropriately adjusted. Here is an example now we will take three examples today.

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Here is an example of PQC being unloaded at site which you see is pavement quality concrete. Now concrete is being brought to the site using this kind of a dumper and is being unloaded the way it is shown. Now from here you can probably get an idea that okay is this the way we had foreseen the concrete will be placed when we tried to do the mixed design in

the lab. What is the kind of workability that we have and how was the workability measured in the lab and so on?

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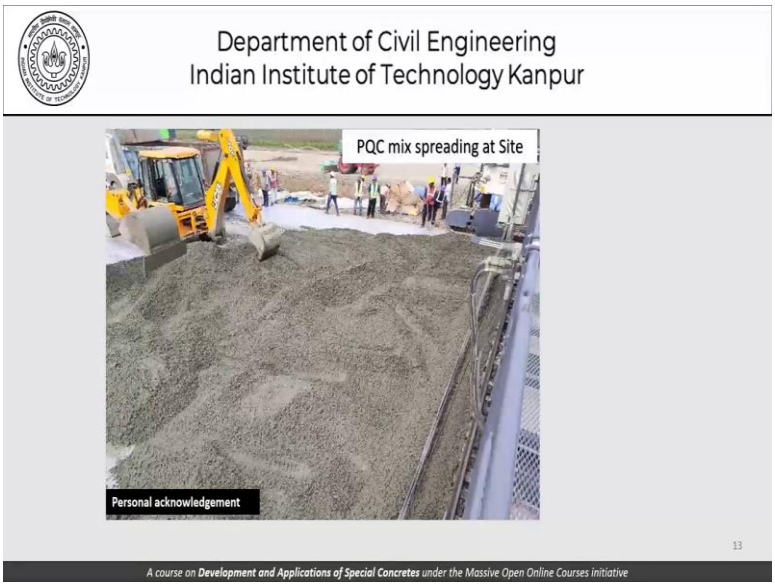

This is the way PQC is being spread at site is this the thing which we had thought will be done in the laboratory tests to determine the mixed proportions. Sticking with PQC this is the start of paving using an automatic paving machine paver this is the paver machine.

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Back side of it when it is not operational.

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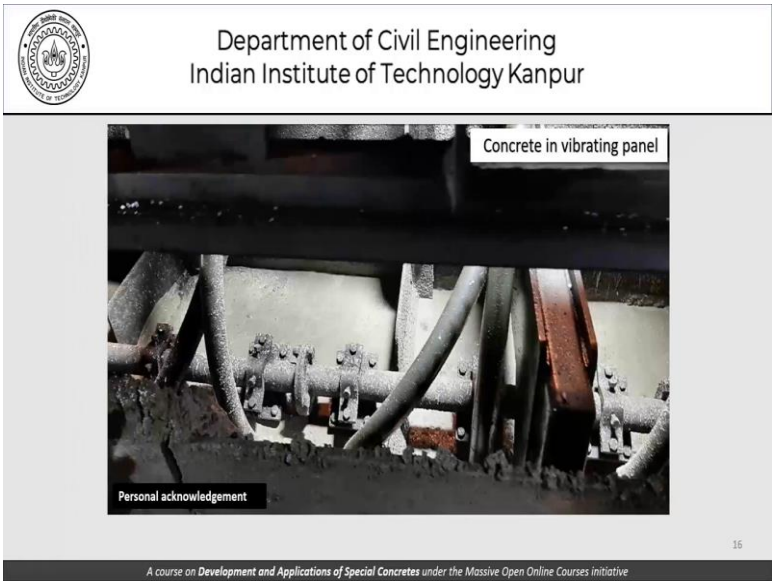

This is how the concrete is being vibrated using the vibrators in the paving machine itself. So, there is this large panel of vibrators and as the paver moves the concrete is vibrated along with the movement.

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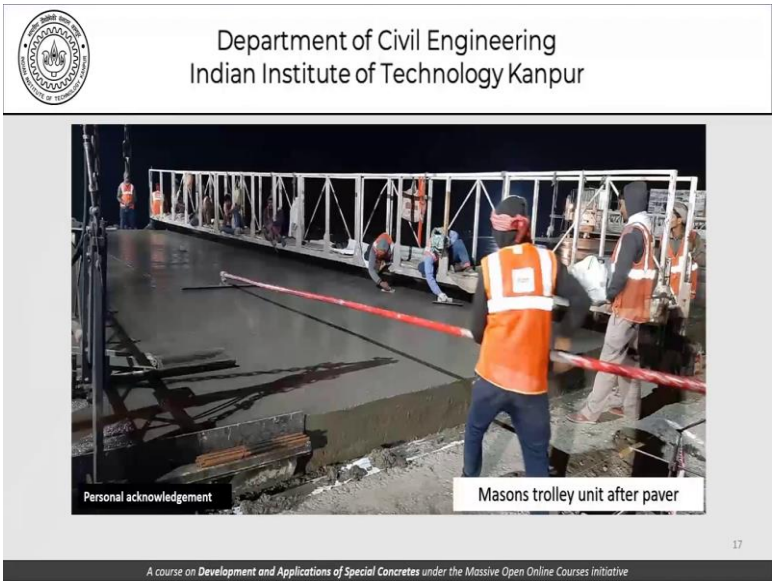

This is how it is being finished using a trolley on which you can see the masons doing the finishing works.

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This is another operation which is very typical of pavement construction which is texturing and curing. Curing of course we know but texturing is something which we try to do on the surface of which PQC to impart the right kind of friction so that we have a good grip as far as the tires are concerned and so on. That is something which you know from your rigid pavement design and rigid pavement analysis.

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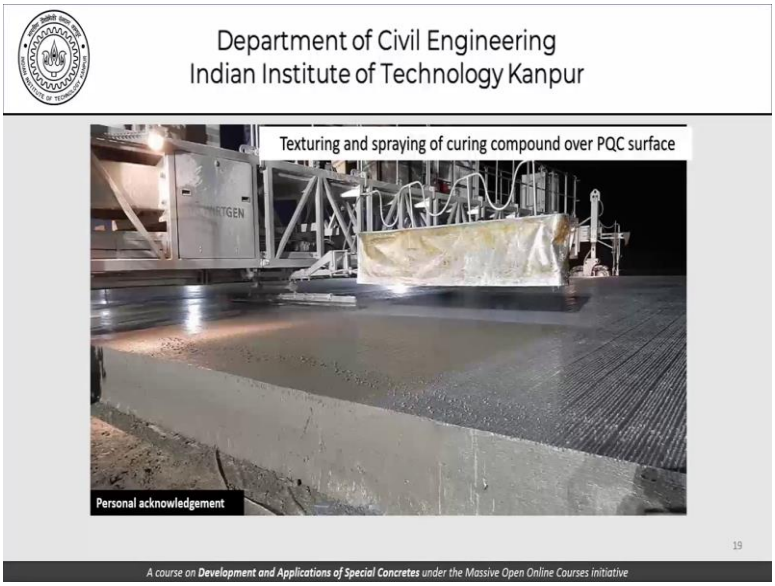

This is texturing and spraying of curing compound being carried out now the question for example would be that how do we do the texturing as far as the laboratory is concerned? Somebody asks at what time should I do the texturing? Should I do it immediately after placing should, I do it after 30 minutes because that is something which beside people or the person who is operating the paving machine would like to know.

In order to be able to give that answer somebody has to try a couple of things. I am leaving it to you to think as to what are the things that are required to be tried out for that. But we have to do some experiments. Now is a cube kind of a sample good enough to do texturing. It can be understood that yes texturing in the laboratory will be at a different scale but think about it will that represent the real concrete that we have placed and what is the solution. We will talk about it briefly towards the end of this discussion just think about it.

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Here is another example where we are trying to do underwater concreting using a tremie.

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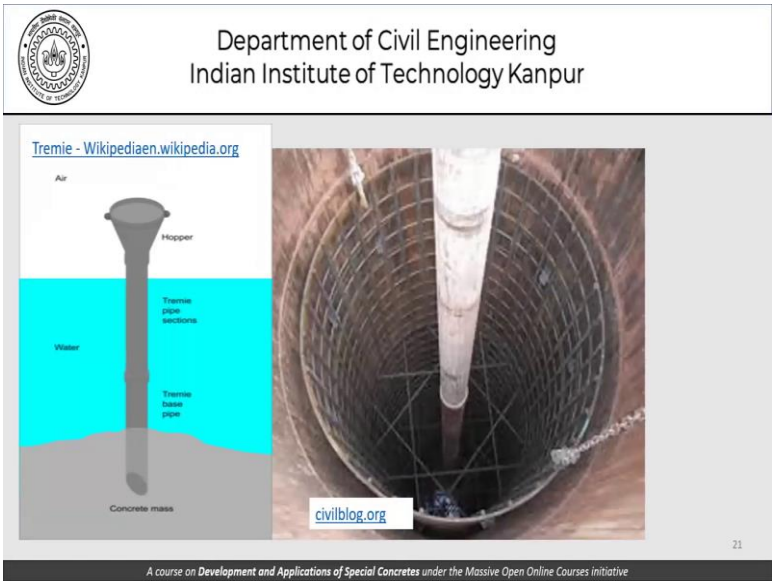

What happens there is something like this that we have a deep structure where we are trying to place this concrete mass using a tremie. So, we will talk about this tremie construction a

little bit later. But today the discussion is focused on only to highlight that this construction is not something which we had bargained for when we tried to do the normal mixed design.

So, when we are trying to do the tremie kind of mix design we can say that ok. As far as the flowability is concerned as far as the workability is concerned this is what we want because this is how we want to place the concrete that is all right. But this, concrete the fact that it will fall through. So much the fact that the concrete will be here and this is the concrete which needs to be represented as far as my fresh concrete is concerned and the hardened concrete is concerned.

How should we sample this concrete? How should we carry out the tests for workability is there something special that you need to do?

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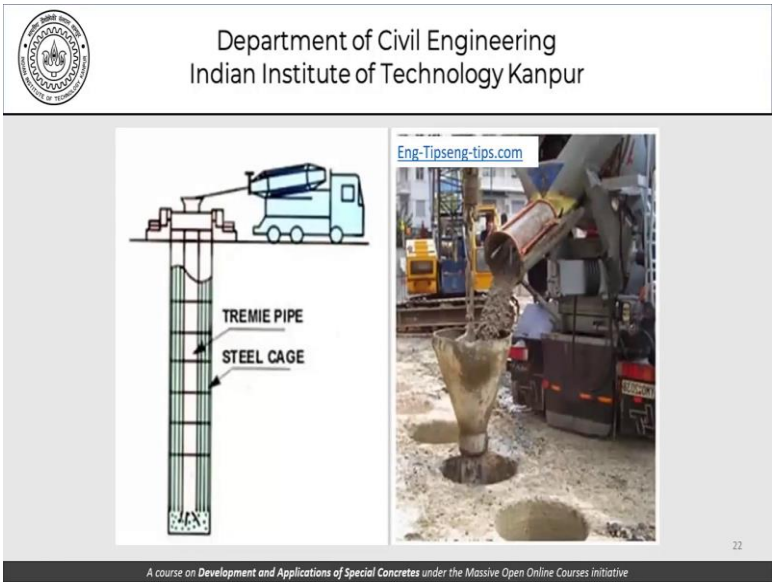

Here is a live photograph of that where you have a tremie pipe here this is schematic sketch this is the photograph. So, there is a tremie pipe there is a steel gauge you are trying to put the concrete being placed here and that is what you are trying to do here through your agitator truck you are trying to dump the concrete into this hopper kind of thing here and it is going down.

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Coming to the third example of special conditions of construction. This is a tunnel short creating so this is a shortcut kind of an operation where concrete is being gunned onto the surface. The same thing is being done here concrete is being gunned or placed under pressure against a surface. So, there is no real formwork involved there is no real curing which is possible as far as underwater curing is concerned.

We might try to have curing compounds. We might try to keep it wet through a hissing cloth and so on. But is this the kind of concrete that we had in mind when we did the mix proportioning in the lab. In the lab when we placed the concrete how did we place it in the lab how did we determine the strength of this concrete this concrete here has been placed not the way it was placed in the lab.

But it has been gunned onto a surface and if we try to do the regular cubes does it really represent this construction condition the answer clearly is no. So, then what should be done we will have another couple of photographs about short creating and there are a couple of things which you would learn.

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Here is another kind of shotcreting going on where the shotcreting is on the top that means the shotcreting will happen from the bottom which means there will be a lot of rebound. So, these are things which we can discuss during the shotcreting methods. In the shotcreting proportioning of shotcrete because we need to have a certain type of property and so on which is fine but the issue today is how do we develop the right kind of specification to be able to ensure that the strength at some place here and the strength at some place here is all in order.

The designer expects that the strength if it was a tunnel like this the strength of the concrete here and the strength of the concrete here is both a certain number. It may be the same it may be different those are design conditions but as far as the concrete is concerned how did we place it? We placed it quite differently here than here. How was this factor incorporated if at all it was incorporated in our laboratory studies which were used to determine the mixed proportions?

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Similarly, another application of shotcreting is in slope protection. So, you are trying to concrete a slope you are trying to deposit some concrete on the slope which could be using some amount of reinforcement kind of a material. Here which is placed like a net you could see some of those nets even in the tunnelling of even in the tunnelling operations.

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Here we can see that clearly, we can see this reinforcement which has been placed and we are trying to place this concrete here against the slope. No formworks and we are expecting that as far as shotcrete is concerned this is the reinforcement that we have placed and let us say it is placed somewhere here. And this is my surface so if we are gunning it here the concrete is expected to reach all these places at the back and have a deposit which will become something like this with reinforcement bars somewhere here.

So how is this construction condition taken care of when we are trying to do the sampling at the lab. When you are trying to determine the kind of concrete that we will use.

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The same thing is happening here just another example which shows the reinforcement and the concrete being deposited.

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Same thing with more difficult conditions as far as placement is concerned because the people who are depositing this concrete are now on a platform at an elevated location.

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You may have certain positions in which the concrete has to be placed you have to bend in order to deposit the concrete here. You will have to bend to deposit the concrete in the bottom of the tunnels or the bottom portion.

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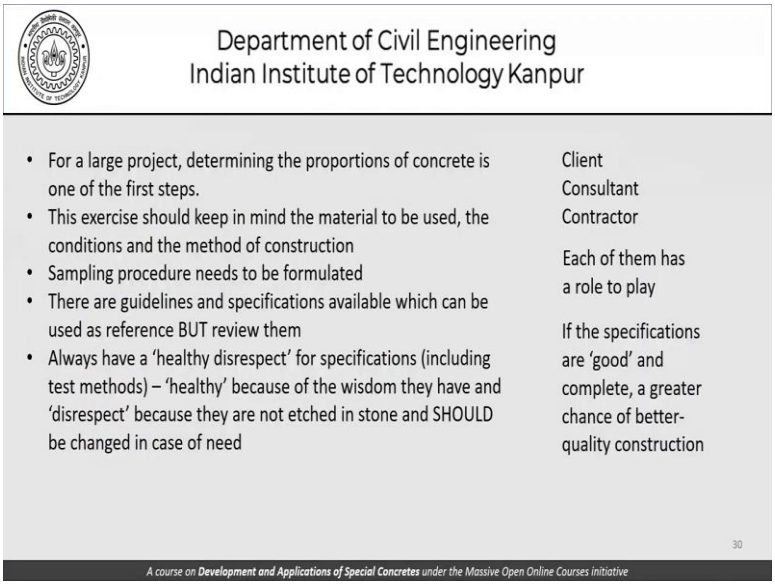

So now if we go back to this slide, I suppose you have a better idea of what was being talked about that, the proportions of concrete is the first step and this exercise has to be carried out keeping in mind the materials the conditions and the methods of construction to be used. Sampling procedures need to be formulated reformulated the review of guidelines and specifications for preparation of specimens for carrying out quality control tests need to be reviewed.

And the whole idea of a healthy disrespect that is if the existing methods do not work or they are not likely to work then are not likely to be applicable to your conditions of construction be free to change them. Of course, I can understand that it is not possible for a person who is coming out of college straight away saying that this method is not applicable that method is not applicable and therefore there is a certain amount of experience which is required in order to be able to suggest that we will not use established method.

And rather use a new method because we feel that that is the more applicable method that is something which is more relevant for a particular application. But it should always be done and as far as young people are concerned, they should always have their mind open that okay this is not acceptable this is not the best thing possibly it needs to be changed. And you need to work to implement that change and that change will come gradually.

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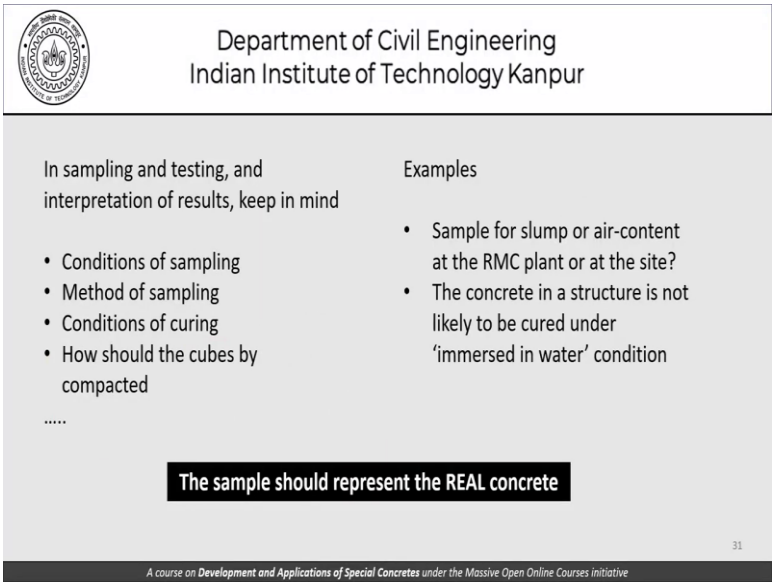

Please remember that even though I am repeating some of these slides the whole idea is that the sample should represent the real concrete. Now once again I am drawing your attention to the regular standard testing of concrete the way it is shown here. Now this is how we stop or this is where we start, we proportion the concrete through the laboratory tests come to the site lab and finalize the proportion.

Now in the lab the mixing is done more often than not by a 100 litres mixer you know how it is done. You try to think of the laboratories which you have been in and see what kind of or what scale at which they work and from the projects that I have shown you in this discussion

whether it was shortcrete whether it was underwater concrete whether it was the pavement quality concrete placement the scale is completely different.

And that scale part is taken care of to some extent by ensuring that the lab tests are appropriately repeatable and modifications are made through the site lab where possibly the mixing of concrete for example is in an RMC plant. So once the first batch or the first proportion of the first cut of proportions is made available through laboratory tests then it goes to the RMC plant.

So that is the way it should be then it goes to the RMC plants from where the concrete should be manufactured tested and found to be okay and used. Having said that that may not be enough unless we do what is called a mock-up construction. Now that is something which is coming out today that mock-up construction is the key for carrying out special constructions. if you are not sure how the things will work in a large construction project never be shy of doing a mock-up construction.

A construction which is larger in scale to specimens. So, specimen to me and my image is a 15 by 15-centimetre cube or a small beam but those are specimens. Those are much smaller in scale when it comes to a mock-up construction it is not too real scale of course you cannot do it to real scale but something slightly bigger than specimens. Of course, it will be much smaller than the real construction but it will give you an opportunity to actually test some of the technology which is used.

Doing mock-up construction is an expensive affair. Mock-up construction per se will take some money but that is a small amount of money compared to the total cost of the project just imagine that if we are able to do a mock-up the idea will also be while you are doing the mock-up that the mixed proportions can be revised. Can we revise the mixed proportions if there is something that happens in the mock-up and it turns out that the water should be reduced, water should be increased, cement should be increased, cement should be reduced some admixture should be adjusted whatever it is.

In the curing discussion which we had we said that in certain cases the water needs to be

heated or the water needs to be cooled or not only the water but there was talk of some aggregates being heated or cooled. Now if this is to be done then to do this kind of an exercise carry out the proportion in the lab is quite different from trying to do it at an RMC plant and then ensuring a temperature of fresh concrete. So, these are the kind of things that you have to do in a mock-up construction where you try to find out that you do all these things at a slightly larger scale.

And then try to make sure that the proportions that have been determined are in order. Here the sampling and the quality control for strength is all closer much closer to the actual construction site and then only we go for real construction. So, this whole idea of a mock-up which comes out from a special concrete or a special construction procedure requirement is something which we need to be very, very open to and be willing to invest the kind of resources because that will be always a good experience and help us do a good quality job as far as real construction is concerned.

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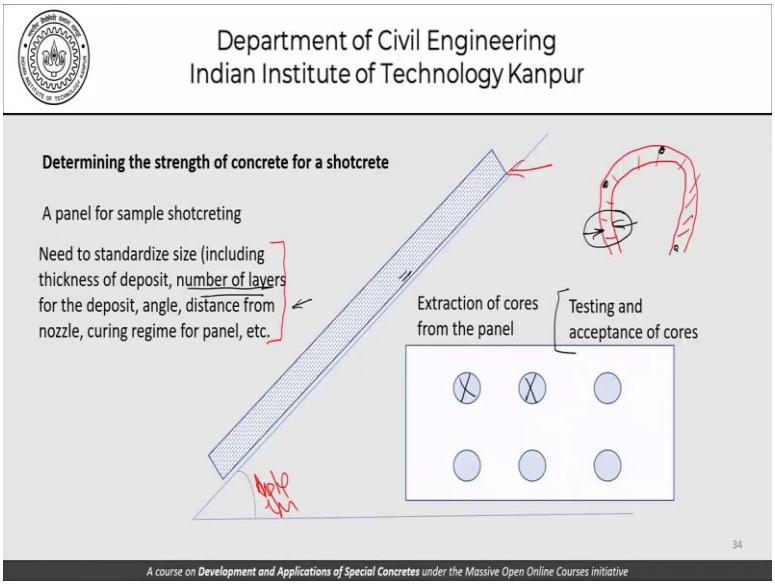

I want to show you an example of how our strength sampling or sampling for strength needs to be modified in order to do the strength for a shotcrete. Here is a panel which can be used for sample shotcreting. So, you try to deposit concrete on this panel which has been placed at a certain angle. Now this angle can be different and needs to be standardized if you want to insist that this panel should be overhead.

Go ahead and do that you have to figure out what is the standard. If you want to do it lay it out in your specifications the contractor should know that this is how the sampling will be

carried out it cannot be carried out using cubes it could be carried out through a panel like this from which cores will be taken as we will see shortly. But then we need to standardize the size including the thickness of the deposit, the number of layers for the deposit angle and distance from the deposit curing regime for the panel and so on.

So, there are all these parameters which need to be decided when it comes to laying or creating this panel which will be used to generate samples from the shotcrete concrete for strength. So, this panel perhaps more truly represents the concrete which is placed in a tunnel lining like this and we try to say that okay the concrete in a particular portion here or a particular portion here or a particular portion somewhere here it still meets the requirements.

If you want to have reinforcement in this panel, go ahead and do the reinforcement bit as well. But that has to be part of the standards. The layers when you are looking at some of the photographs you would have noticed that this thickness of shotcreting in different applications could be different and it is not necessary that the entire thickness is deposited in one pass. It is deposited in several passes at times.

Now what should be the methodology adopted to create this panel when it comes to reflecting the number of passes. So that is where engineering judgment will come in that okay these are more important factors and should be incorporated in the development of a standard for creating panels these are less important factors and let us not bother about them. Then once the panel is made, we can always take cores from these panels.

And these cores can be tested for strength and acceptance this procedure for creating the panel create taking the core and having a certain process for acceptance and certain levels of strength for acceptance this has to be laid down and made clear in your construction methodology and the specifications for a particular shotcreting project.

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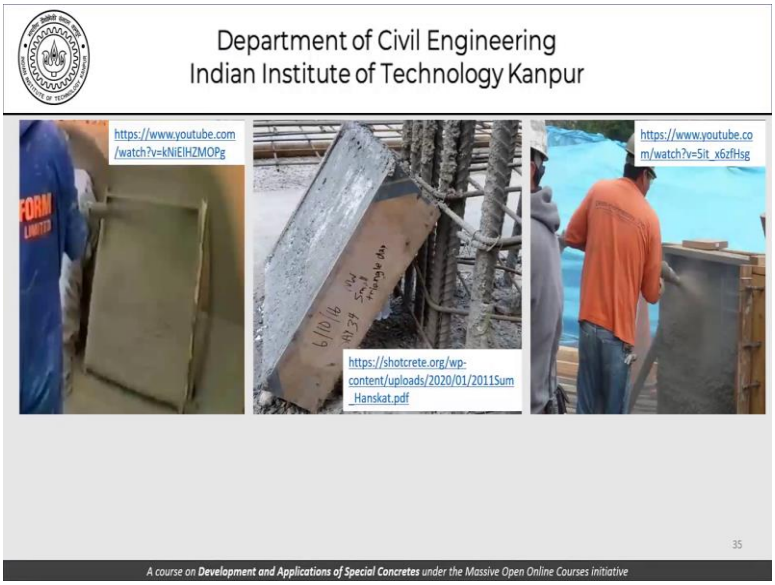

These pictures here show exactly that creation of panels in order for whatever purpose it could be for in fact testing of nozzlemen. Now what is a nozzleman? The nozzleman or the nozzle person is one who is handling the nozzle of the shortcrete. Now this is a very, very skilled job it is not easy to be able to hold this nozzle and make sure that you are able to deposit this concrete here in an appropriate manner.

This is as skilful a very different kind of skill those of you are familiar with welding you would know that. Welding also involves a very skilful operation where the welder needs to know how to have the electrode being fed into the job and at the same time moving it and even in welding the material is deposited in several passes at times. So, there are these kinds of parallels that you can draw and have testing programs for nozzle men or nozzle persons.

These are the kind of panels that can be created to check whether the quality of concrete being used or to be used if it was a planning stage in the project is acceptable not acceptable and so on and so forth. So, these kinds of panels these kinds of methods can be part of a mock-up. You take the whole process to a mock-up. A mock-up obviously involves a reasonable amount of concrete.

In a lab you can make do with about 100 litres of concrete I am leaving it to you to do a simple arithmetic that if we use a 100-litre mixer how many cubes can be cast or the other way around in order to cost let us say 9 cubes or 20 cubes or whatever it is how much concrete do we need? But when it comes to a mock-up it is a much larger exercise and 100 litres mixers from the lab will possibly not suffice.

And therefore, RFC plants have to be mobilized so the entire team from different parts gets mobilized creates the mock-up and is better prepared to do the real operation.

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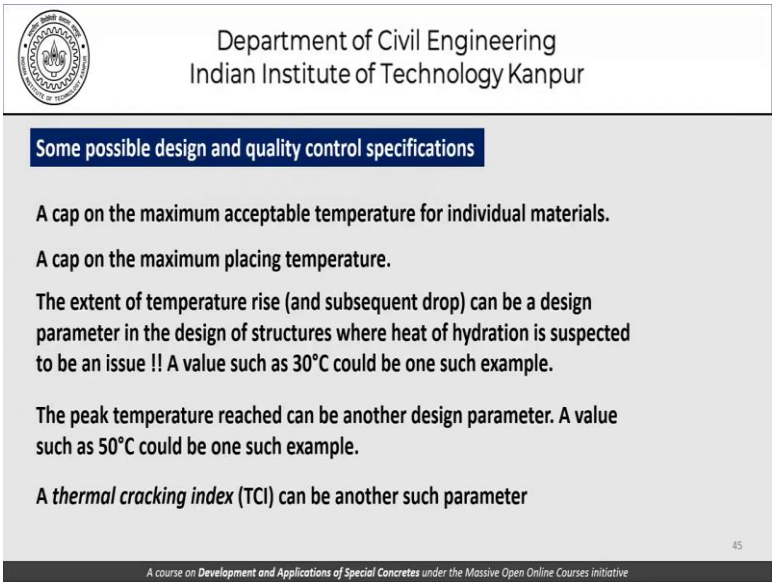

Similarly, if you are trying to do underwater concreting as far as testing fresh concrete is concerned that also needs to be tested in water. That is, we have a slump cone in water you have must have a water tank put your slump cone inside do the slump in water whether it is slump or slum flow most of the time in this kind of a situation you probably need slump flow kind of workability.

So, the initial shape will be something like this remember how much is the diameter here I am leaving it to you that diameter will deform into something and the final shape will be something like this. So, this deformation of concrete from this shape to this shape should happen not in air but in water. So, this testing for fresh concrete for underwater placement needs to be carried out under water.

So, there is no point carrying out the slump test and getting the flow values the initial value and the final value and values like the t_{500} or whatever it is in air because the concrete will be in water. And water will offer a different kind of environment by way of resistance to movement of concrete and so on. Issue will be what should be the depth at which this tank is played. The issue can always be things like how deep should the tank be.

Those are the kind of details which need to be left to the sites the standards can try to specify it and I would encourage you to try and read some of the literature and find out whether such standards have been developed I am sure there are there. Similarly, for the strength recall that when we are doing a tremie construction there is a tremie somewhere like this and there is concrete here.

So, this concrete is being deposited using a tremie and all this is water. So, we are interested to find out what is the strength of this concrete and this concrete was placed not in air but in water. So therefore, much like the test for fresh concrete the cubes also need to be taken under water demolded and allowed to remain there. Of course, for the purpose of determination of strength they will probably have to be taken out and the strength determined.

So that is where a small balance between the practice and the reality. A balance between the theory or the ideal situation and the reality can be done that we cannot possibly test the concrete underwater we take it out momentarily or for a very small period of time and test it in air but at least the sampling and the curing happens in water the sampling particularly.

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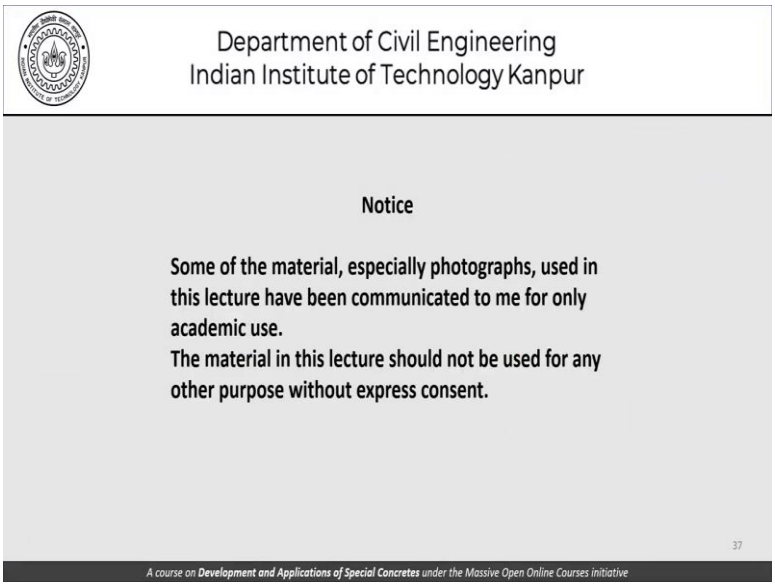

Now with this we almost come to an end of our discussion today I must let you know share with you that some of the materials especially photographs used in this lecture have been communicated to me for only academic use. And the material should not be used for any other purpose without express consent.

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Something to think about concrete volumes involved in some large projects in the world once you see that okay if a large project involves let us say 100000 cubic meters of concrete and through your mixed proportions mock-up exercises and so on and so forth. You are able to change or save 1 kg of cement just imagine 1 kg of cement is per cubic meter. Now this 1 kg per cubic meter cement in a 100000 cubic meter concrete operation saves you 100000 kgs of cement and that is not a small saving.

That saving itself will almost cover the cost of your mock-up and any other additional investment that you do in the planning stage. So, try to think about these mock-ups and the initial planning investment in that initial planning and the resources you need and use during the initial planning from that point of view. Proportions of concrete used in some of the landmark projects in the world to get an idea of how much cement was used.

What was the aggregate? What was the kind of cost involved? And details about preliminary studies including mock-up carried out as part of the preparation for some special projects in the world. There are I am sure and I know several studies several case studies which are available literature and that is the beauty of the internet that's the beauty of online discussion that you have all the information available to you at fingertips.

Try to get that information relevant information from the point of view of mock-ups actual constructions and I am sure you will be able to see the wisdom that is being sought to be communicated to you through the discussion today.

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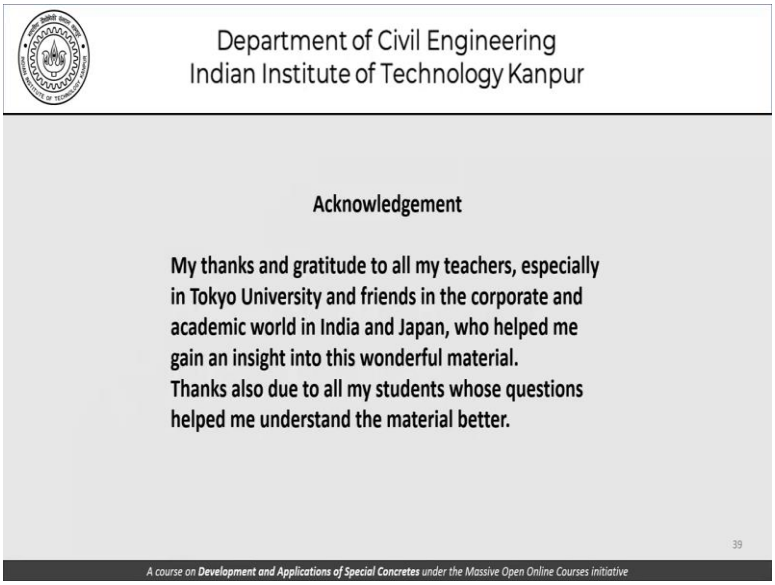

I must once again thank my friends, students and my colleagues for helping me understand concrete. And I look forward to seeing you in another lecture next week, thank you.