Concrete Engineering and Technology
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Lecture - 1
Introduction and Course Overview

[FL] and welcome to this lecture on concrete engineering and technology.

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The subject of concrete engineering is acquiring tremendous significance as we continue to use more and more concrete in diverse conditions, we use new materials new technologies. We have more experience from previously built structures and we realize that concrete is not a maintenance free material also in recent times there is a rising concern about quality and durability of concrete construction.

So, in other word a concrete engineer needs to update the understanding of concrete as a material and its properties. We should be aware of the development of special concretes and their properties, the applications, the limitations are conscious of the limitations of the existing test methods and specifications and work towards establishing new methods and specifications as may be required for new concretes.

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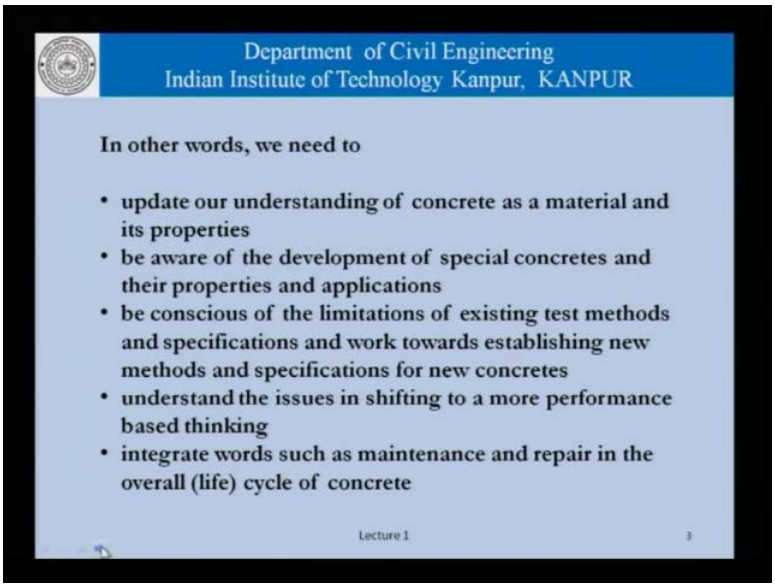

You also need to understand the issues are shifting to a more performance based thinking rather than simply a prescriptive thought process. We must integrate words such as maintenance and repair in the overall lifecycle of concrete, concrete structures are not only designed. But the need to be maintained and repaired over that service life and that is what needs to be integrated as an overall lifecycle of concrete structures.

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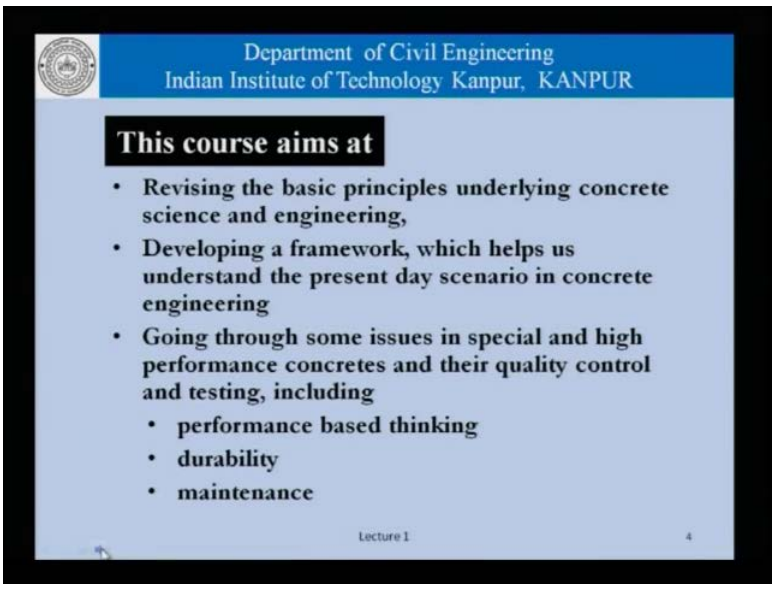

Therefore, this course aims at revising the basic principles underlying concrete science and engineering, because without that we cannot approach the subject of modern

concrete or new developments in concrete. We need to develop a framework which helps us understand the present day scenario in concrete engineering as for as testing specifications use of new materials applications limitations. We should go through some issues in special and high performance concretes and their quality control and test including performance based thinking durability maintenance. So, this is basically the outline that we will try to go through in this course.

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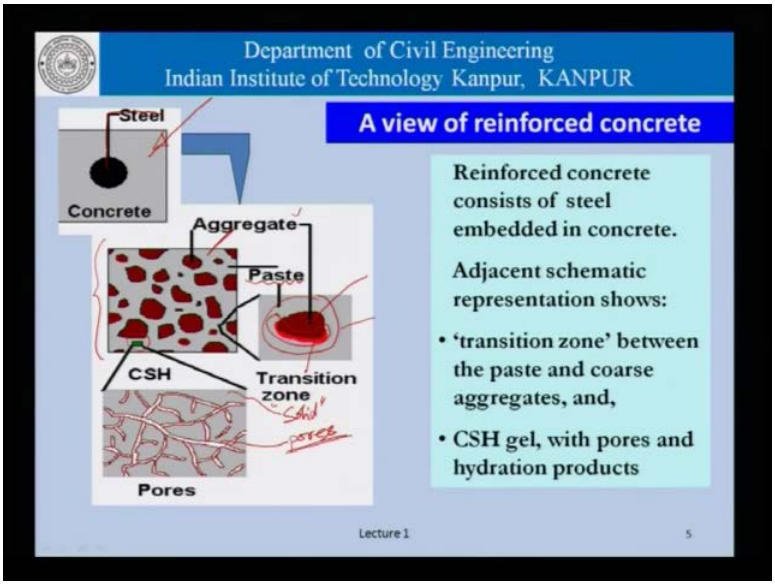

Let us review or understanding of reinforced concrete, reinforced concrete basically consists of reinforcing steel bar ashore here and that bar is embedded in concrete. Now, concrete itself it consists of as is shown in this picture here coarse aggregates which are shown as dark brown embedded in paste. Now, paste is used loosely here because actually it is molted, if this aggregate is coarse aggregate and if it is fine aggregate which is sand then this diagram refers to mortar and then in deeds and particles are embedded in cement paste. If we look at the neighborhood of a small particle, we have the aggregate particle here as shown and this is surrounded by paste.

However, in this small zone here there is the so called transition zone and this transition zone as we shall see later on, there is a very important role in determining the properties of the concrete. Now, if we look at a small element of paste which is the cement and water hydrates we find or we could model this small element as comprising of solid c s h are hydration products in which there are lot of these pores, so this pore structure. Now,

we will try to understand what the geneses of these pores are, we will try to understand what is important of these pores. And how we try to control the amount of pores, and so on. How do we measure the pores? And then try to understand how the concrete behaves as a material.

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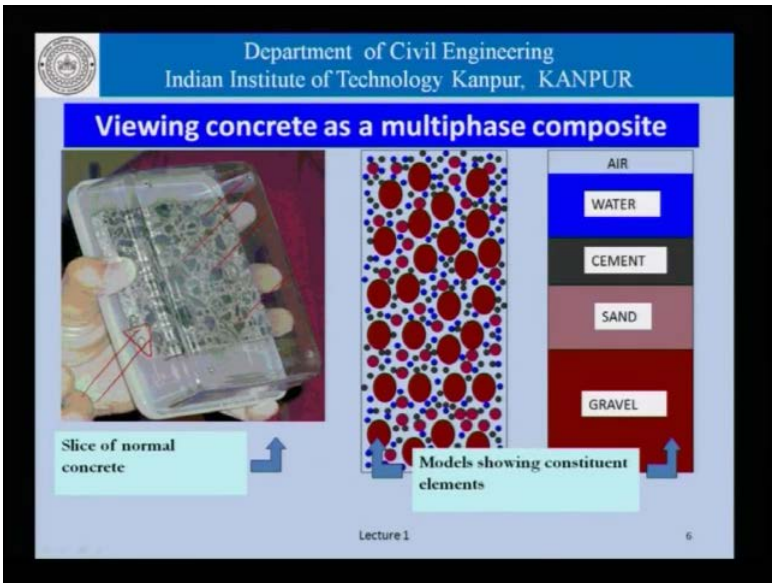

Continuing from here, let us look at this particular picture here which is a solid slice of concrete real life concrete, we can see that these are large aggregate particles all over the place which are suspended in of phase of molder which are the smaller particles somewhere here. All these smaller particles here and then there is cement paste this picture is modeled as shown here, that we have these larger particles which could be considered is coarse aggregate. We have the smaller particles which could be considered as sand then we have these still smaller particles which are cement and there is a lot of water or some amount of water which has been added to this whole mix.

If we modeled this mix in a volumetric manner that all these coarse particles here or all these coarse aggregate particles are slumped into one place here and that is what have called gravel or coarse aggregate. Then all these smaller particles coming here as sand cement particles find a place here water find its place here. We will find some amount of air or wide space is always an integral part of concrete, what this picture shows is the as for as concrete is concerned no matter when the normal concrete or a special concrete or other concrete for a given volume of concrete.

We have a certain volume of a coarse aggregate a certain volume of sand cement and water and there is some air the importance of this air component, we will discuss later on. We will also discuss how the constituents such as cement sand and coarse aggregate changes in special concrete and this change that we make in the concrete materials makes a concrete behaves in different manner.

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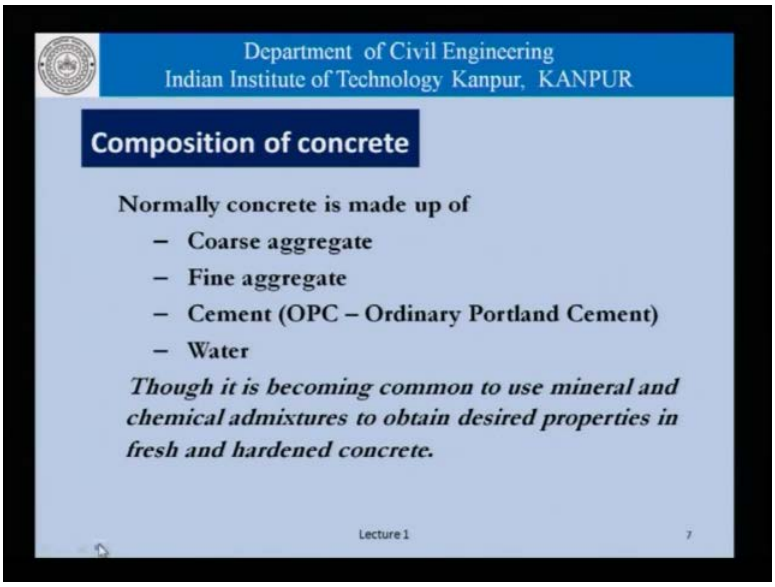

In other words, what we are saying is that normally we can consider concrete to be made up of coarse aggregate fine aggregate cement which is O P C for all practical purposes begin with and water. However, increasingly mineral and chemical admixtures have been used in concrete as part of the materials to obtain or engineer the properties of fresh and hardened concretes. Concrete as we see in the series of lectures has different properties that we need to assure that it has properties in the fresh state. The properties harden states and the given mix that we have should satisfy the properties not only the fresh state, but also the harden state.

To reiterate or concrete engineers talk about paste is cement and water mortar is sand added to this paste that is mortar consist of cement water, and sand concrete our normal understanding sense is coarse aggregate added to mortar. That is concrete basically consist of cement water sand and coarse aggregate this is largely understood.

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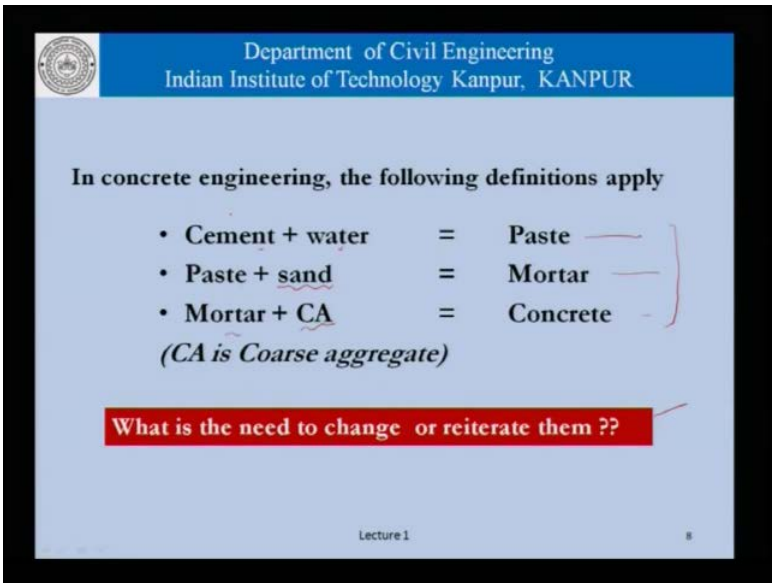

However, what is the need to change or reiterate this at this point in time the idea basically is that ones we understand this, then when we add special materials or new materials to this old combination of cement water sand and coarse aggregate. Then we have to understand or we have to decide, whether it will be counted towards the paste volume or the mortar volume or the coarse aggregate volume and so on. So, keep this in mind as we go long in these lectures.

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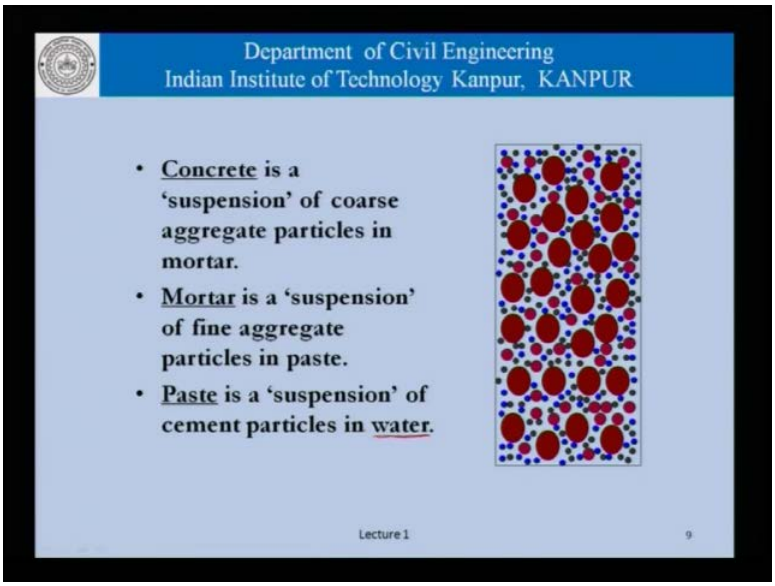

Once again, this picture only reiterates what we talked about earlier concrete is a model of suspension of coarse aggregate particles mortar, mortar on the other hand is a suspension of fine aggregate particles in paste and paste is a suspension of cement particles in water. So, in another words the only fluid component in the whole the only fluid component in concrete is what we add paste we add cement make paste. Then we add sand to that we get mortar and we add coarse aggregate to that and then we get concrete. So, this is basically the model that we will follow as we go along this course.

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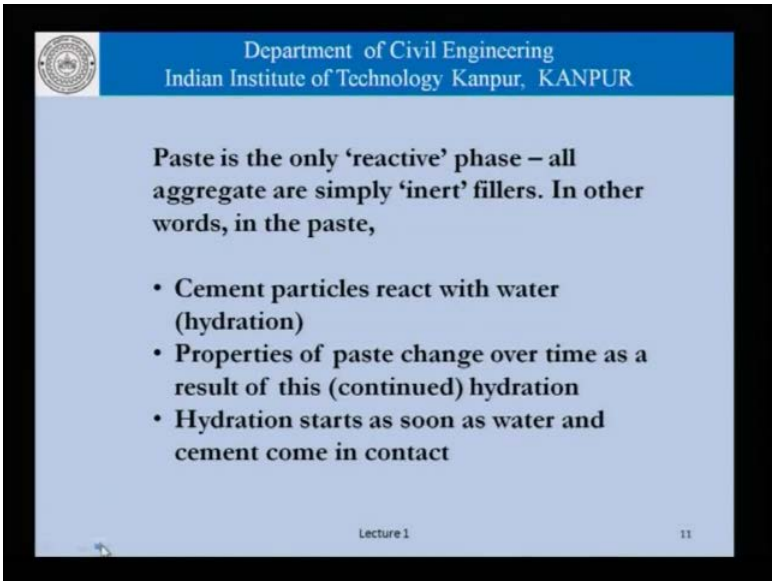

The suspension as included here deviates from a normal understanding of the word in the following ways concentration of particle is very large making it almost a paste. Now, differentiate between the word suspension and a paste, a paste in the normal usage of the word is a thick viscous material which may have a large concentration of solids. In the case of cement paste the particles suspended in water also react with it, so that is to say that the paste is made up of reactive particles. And because of this reaction the composition and properties of the paste need to be understood to be time dependent.

As time progresses more cements reacts with water less cement is available for further reaction with water and the formation of hydration products alters the properties of paste. It is not a paste in the sense that we have water and we have certain particles suspended in it and the properties of that composition or the composite do not change with time. In this case, we have those particles reacting with water all the time or at least sustain with

hydration reaction complete. And this reaction leads to assumption of those particles, and formation of new hydration products and that alters the properties of the paste.

So, what we understand this it helps us greatly and understanding the properties of concrete in all substances. In other words paste is the only reactive phase all other aggregates which is whether sand or coarse aggregate are simply inert fillers which means that cement particles react with water. As we have said the properties of cement change over time as a result if this continued hydration and hydration starts as soon as water and cement come in contact.

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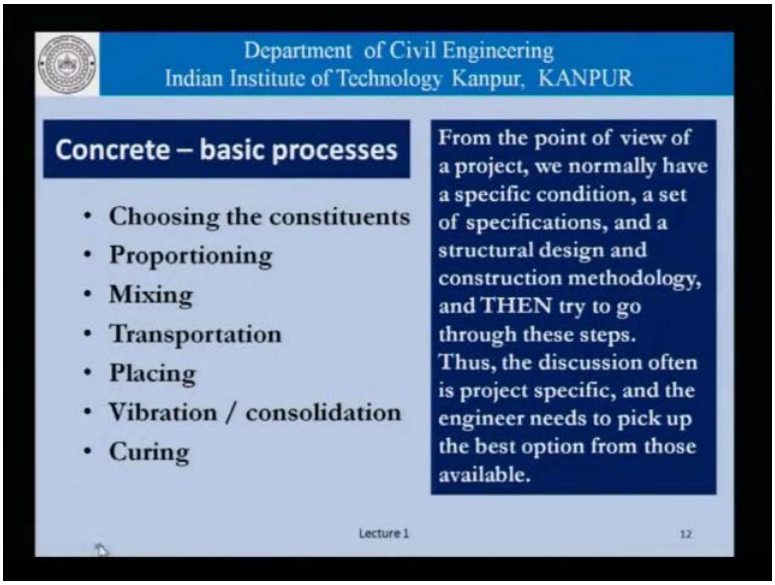

Now, let us look at the basic process in concrete engineering from the point of view of the project, we normally have a specific condition or set of specifications and a structural design and construction methodology and then try to go through these steps. Now, what are the steps we need to choose the constituents what kind of cements what kind of coarse aggregates what chemical admixtures or whatever is they have been used purposely, which means how much each of these constituents will be used mixing those constituents. How will they be mixed transporting these constituents from the site of mixing to the site of placement placing?

Now, placing refers to the concrete been placed at the actual site of placement if a building is been constructed the building site is the site of placement. However, the concrete is placed in a particular beam or a slab or a column which may be at a height, if

it is a foundation it may be at a depth and so on. So, this placing here refers to the process by which the concrete actually brought to the site of placement, which is the building construction site is actually placed in the final place, or the final location where the concrete needs to be set after the concrete has been set.

It needs to be vibrated or consolidated what process will be use there and finally, the concrete needs to cured that is we need to be mixture that enough water is available to the cement to ensure complete hydration or as complete the hydration as is possible. So, in a project after this specific conditions and specifications the design and construction methodology an engineer tries to understand or tries to look at how all these process is will be managed. Thus, thus the discussion of this project specific and the engineer needs to pick up the best option from those available.

So, for a particular project one may choose a particular method of transportation for a particular project one may choose a specific constituent, a specific method of vibration sometimes vibration is not possible. Therefore, you need to change the constituents of the material and so on and so forth. So, concrete engineer really needs to know the importance of all these processes and how they are interconnected and that precisely objective of this course.

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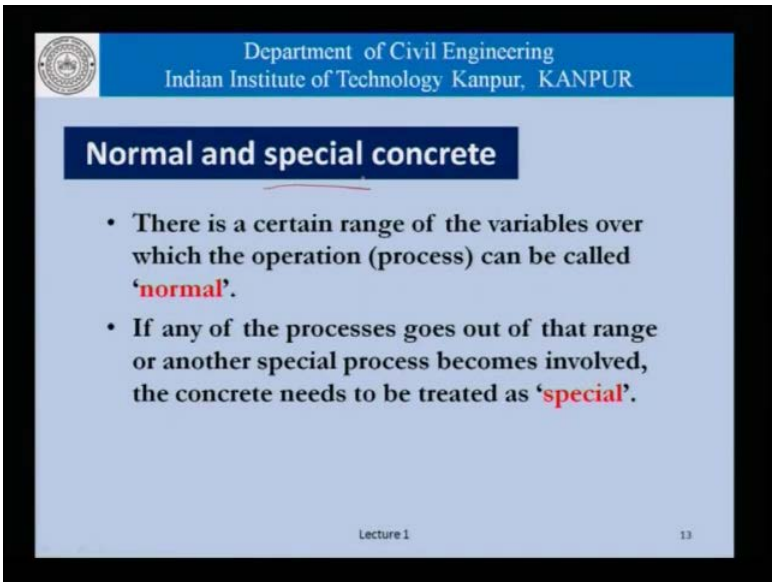

We often use the word special concrete now what is special concrete given the fact that there are several process is involved there is a certain range of the variable over which

the operation or the process can be called normal. Now, if any processes goes out of range or another special process becomes involved the concrete needs to be treated as special.

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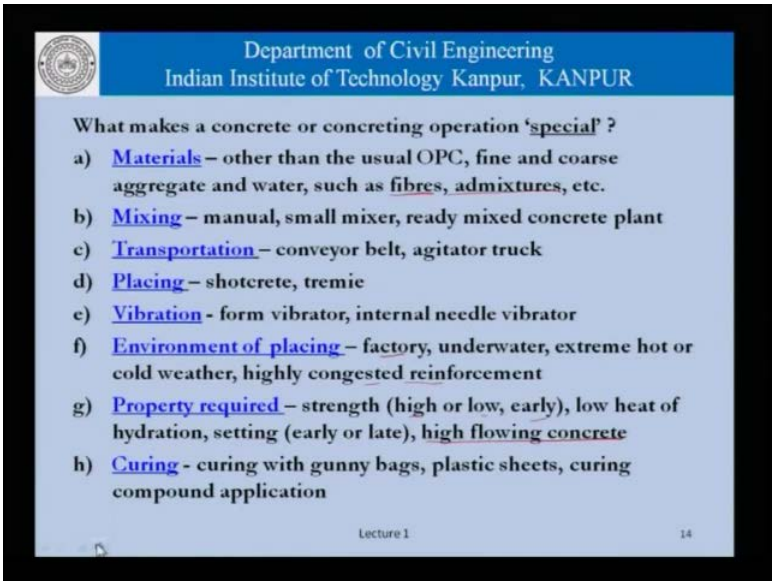

In other words, what makes the concrete or a concreting operation special it could be which are sub materials other than the usual ordinary Portland cement fine and coarse aggregated water. We could use fibers, we could use chemical admixtures or mineral admixtures and it is a concrete special or mixing can be done in different ways it could be mixed manually which is done for very small projects or very small applications. We could use a small mixture that we often do in the laboratory studies and then there is a ready mix concrete plant. So, that the mixing is done any of these places or in these places is quite different and that makes the concrete for the same ingredients.

For the same proposition, the properties will be different because the mixing process is different transportation concrete can be transported in different ways conveyor belts agitator trucks placing issues concretes placed with shotcrete or tremie vibration concrete could be form vibrated. It could be needle vibrated the environment of placing where the concrete is actually placed. For example, in a factory and that is why we make precast concrete elements, if it is under water it could be extreme hot or cold weather or if their structures happen to be highly congested.

Then the kind of concrete that is required in any of these environment by different the property that we require for concrete we may require high strength or low strength, we may sometimes require early strength which is especially for this case. For example, in a repaired project we may require a low heat of hydration which is the case and case of mass concrete project and so on. Sometimes, we use high flowing concrete when the reinforcement is very congested as we should see in this course curing conditions gunny bags plastic sheets curing compounds so on. So, the point is that wants that any of these conditions or any of these processes goes out of a normal range, we would call the concrete and the concreting operation especially.

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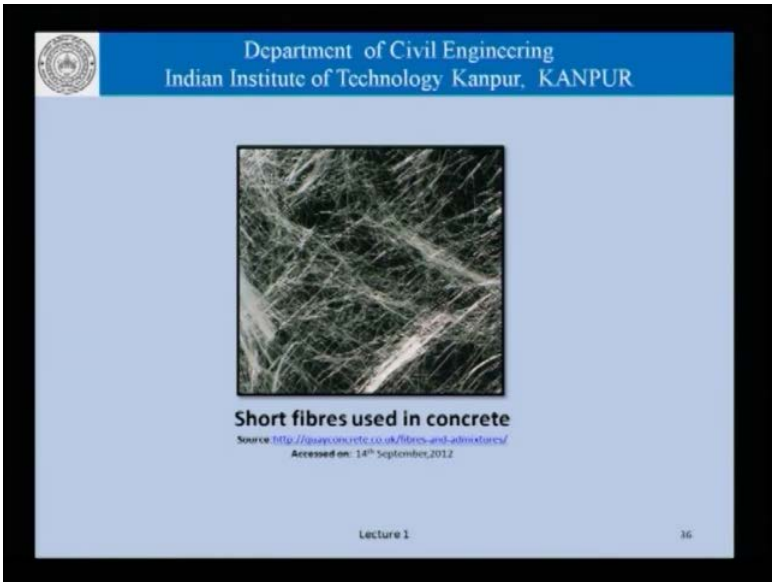

Now, let us look at some examples of this slide as look at materials. Now, this is the moment we add is fibers to concrete the properties change, but so also we need to change the properties of the mortar the properties of the materials that we have otherwise selected for the normal concrete. Let us look at mixing this is the process of manual mixing.

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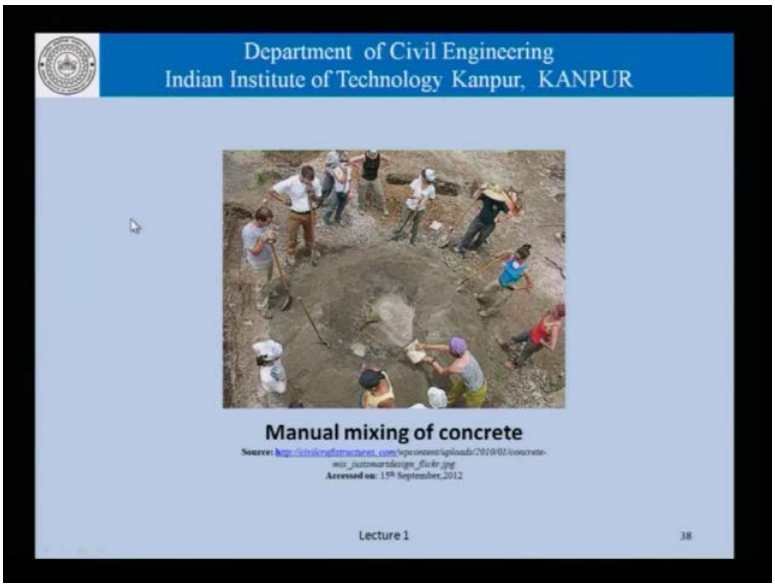

So, that you can see that water is been dumped into this larger pile here, where all the ingredients have been put together and a kind of mixing process is as that will be completed in this it will be different.

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If the same proportion and the same material was mixed for example in a small laboratory mixture or for example, in a R M C plant.

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Mixture that is a ready mix concrete plant the concrete is makes for commercial applications, so that is about mixing.

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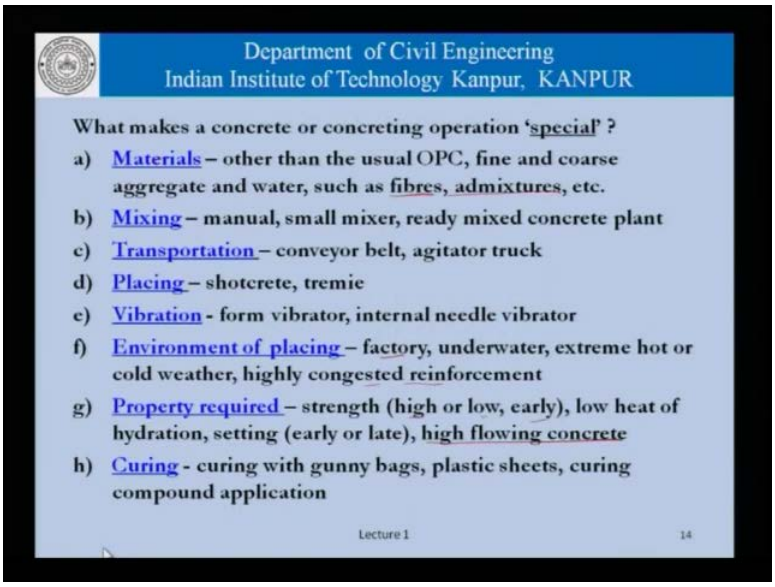

Now, let us look at transportation how concrete is transported. This slide here shows transportation of concrete using the conveyor belt this picture here on the left shows concrete transported with an agitator truck, this drum here has to kept rotating in order to ensure that the concrete does not set and stick to the sides of the drum depending on the time of travel. Some chemical admixtures are some thing is to be added to ensure that the

setting process does not get started to an unacceptable level because hydration anyways starts as soon as water and cement are in contact.

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It is only matter of delaying that process, if we are transporting in a conveyor belt then concrete is being exposed to the atmosphere that is it is liable or it is likely to get ride in the process of the transported. These are the things which could be corporate in our thought process when they are choosing the proportions when the materials and so on. Let, us look at placing this process here.

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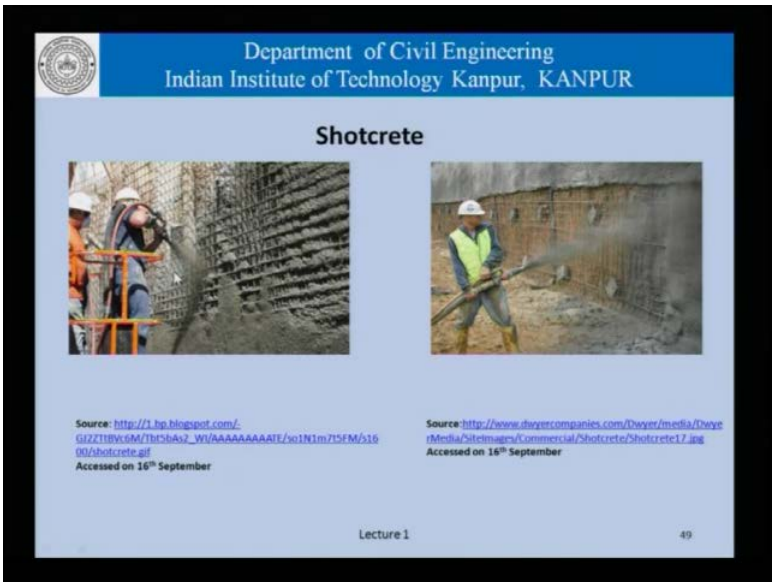

Both of them they referred to shotcrete, shotcreting as you can see here is a process where the concrete is being deposited on the surface without any form work on the other side this makes this concrete very special. We cannot use the kind of concrete here for normal construction, on the other side, if we want to concrete using shotcreters the processs, we cannot use normal materials and process.

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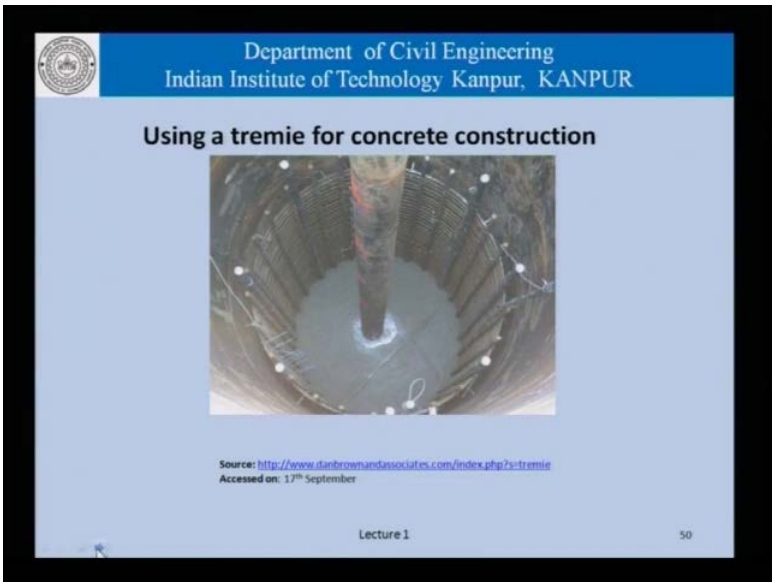

This slide shows construction of concrete with the tremie, now in this case concrete is being deposited at depth possibly under the water using a tremie. Now, the concrete is been dropped all the length of this pipe and it is ensured or it needs to be ensure that the pipe is always embedded in the concrete as more and more concrete is dumped.

In the concrete rises in this form work here and the construction process is completed this slide shows, concrete construction using a tremie concrete is allowed to fall through the pipe. It needs to be ensuring that the pipe is always buried in the concrete that has been placed as more and more concrete is placed into the form work, it raises up and gradually fills the total space completing the construction process.

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Let us look at vibrations we have form vibrators we have needle vibrators and sometimes we use rural compacted concretes and we have form vibrators which are the stuck or which are applied on the form work and the concrete within is vibrated. We have internal vibrators which is the normal concrete practice with the needle is inserted inside, the concrete that to be placed and the concrete is consolidated into the air and so on, the environment of placing.

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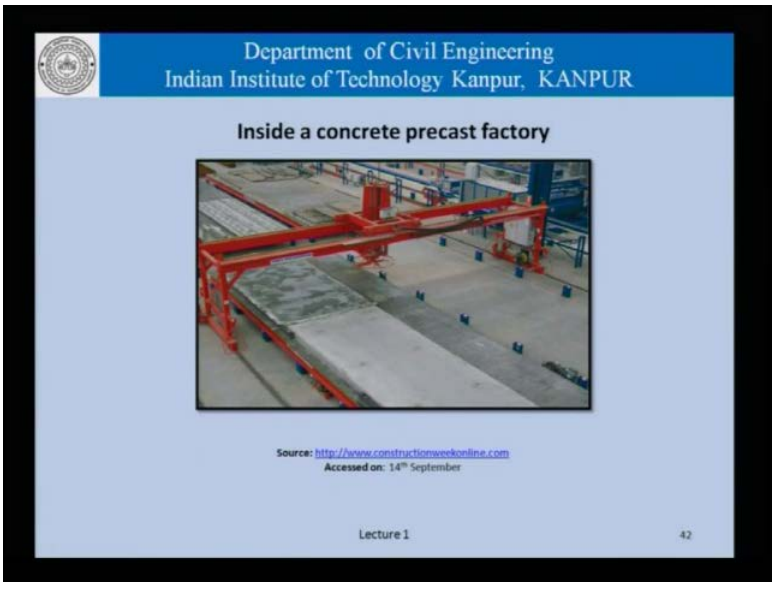

This is the factory environment of concrete placement where we use where we get precast concrete elements. So, the environment here is largely controlled that is not exposed to rain, it is not exposed direct sunshine and so on.

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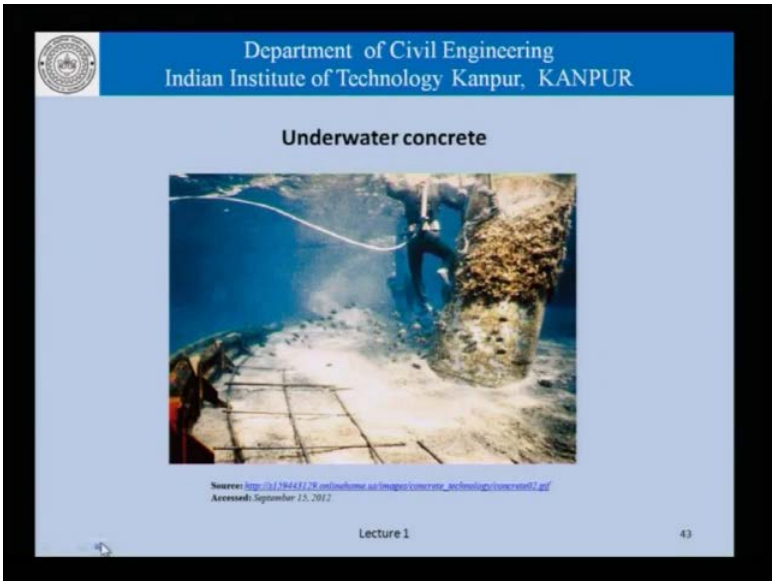

Whereas, this is a completely different environment concrete is been placed under water. And we can see the diverse are involved in the process, these are the reinforcing bars that you can see as concrete is been placed.

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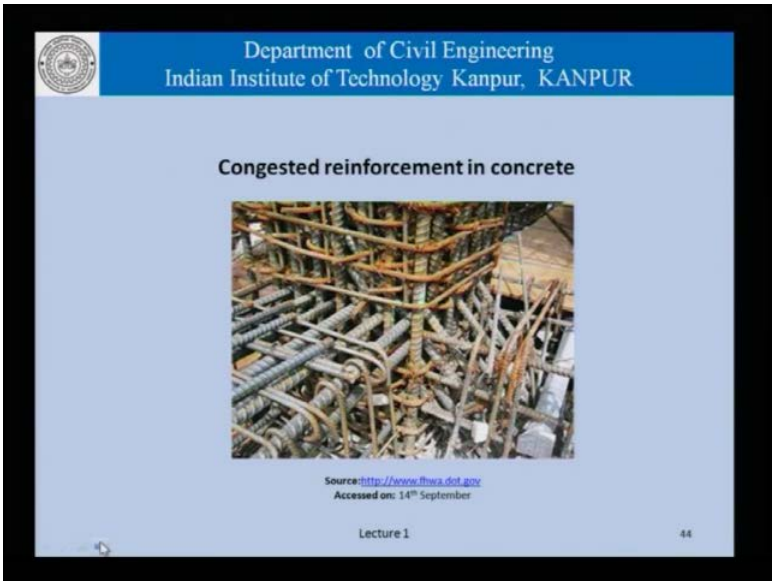

This is an example of congested reinforcement in concrete construction, now you can imagine that if the concrete has to place around this structure or around this part of a structure how difficult it is for a concrete is to flow. So, all these gaps are a still or as the concrete flows through these gaps, how it will be vibrated. So, it requires a special concrete to be used so that concrete find its way through the gaps, these reinforcing bars which are very close to each other and still we compact it.

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An example of its special properties of concrete, these two pictures here shows high workability concrete and the method that we use evaluate the workability of such concretes cannot be the normal method such as the slump of the compaction factor. There are be the steps like slump flow of the U tube test which is used, we will discuss this later in detail, but we can see that the slum flow here is nothing but how much is the spread of the concrete was the slump cone is removed.

This is the U box test that the concrete is filled in one side of the U and the barrier in the bottom is removed and the concrete flows to the other side. If the concrete was to behave with the perfect or a fluid then at the end of this process of the concrete moving from one side to the other. The two sides will be exactly at the same height in normal concretes we do not even expect the concrete is able to flow through the barrier here as far as the curing is concerned.

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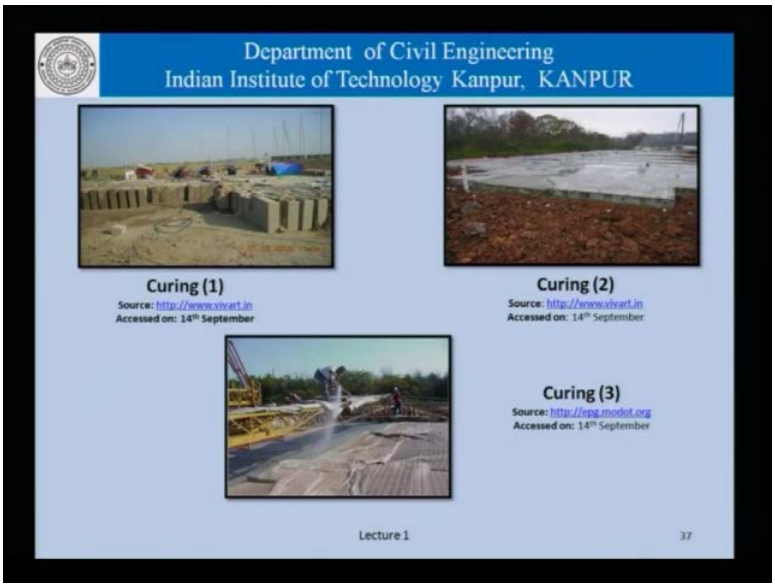

These pictures here show three example where curing is been done with gunny bags or plastic sheets or application of water in curing compounds from outside and so on. So, what the model of the story is that each of these processes has a normal range and ones we deviate from that range this construction process becomes special. Therefore, we need to have special concretes we need to use special materials and be aware of that in our thinking as for as quality control and specification test methods are concerned.

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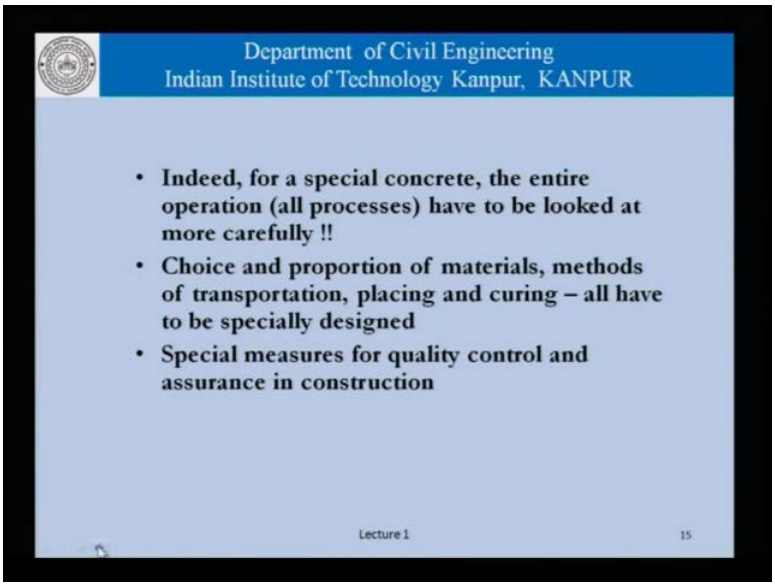

Indeed for a special concrete the entire operation all that processes have to be looked at more carefully, the case. And proportion of materials methods of transportation placing and curing all have to be specially designed and special measures need to be taken for quality control and assurance in construction.

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Now, what are the properties of fresh and hardened concrete as for as the properties of fresh concrete is concerned workability air content segregation resistance temperature, and setting time these are some of the fundamental properties.

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That we will take about in this course as for as the hardened concrete is concerned characteristic compressive strength is something we aware of tensile and or flexural strength is a requirement. In a special cases modulus of elasticity stress strain curve creep shrinkage permeability durability, all these are different properties of hardened concrete and they need a special methods or specific tests to be carried out.

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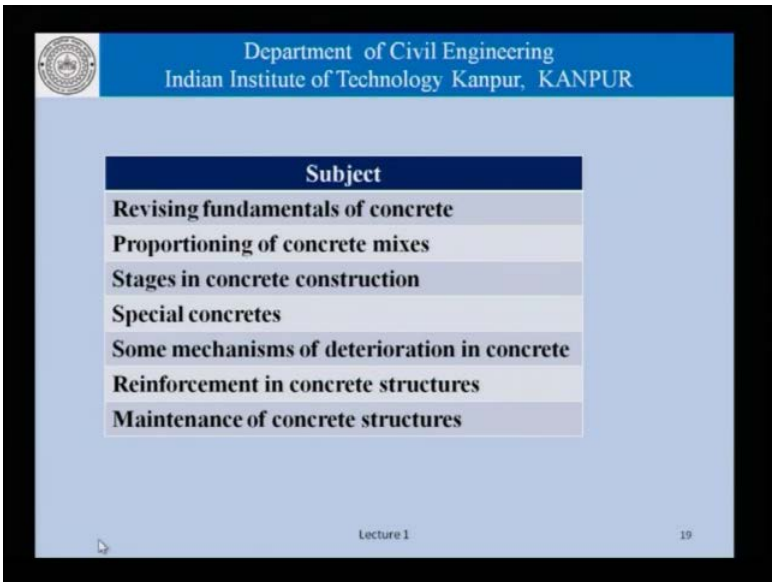

In order to make sure that the concrete needs the requirements coming to the contents of this series of lectures. What we will try to do is the revise the fundamental concrete, we try to propose the concrete mixtures. We will go through the stages of concrete construction we talk about special concretes, we will discuss a little bit about mechanisms of deterioration in concrete we will talk about reinforcement in concrete structures. We will talk a little bit about maintenance of concrete structures in other words we will try to go through the subjects which are concrete engineer of the present day is often required or expected to know this set of discussion here.

The discussion here will help one who wants to study more about any of these issues in rate a detail at any of the point in time. Please note that the discussion in this set of lectures will assume that this is not a first time that you are hearing about the concrete and perhaps this is not the last time you are hearing of concrete. I hope that in this set of lectures you are able in to still ensure a sense of curiosity and better understanding as for as behavior of concrete is concerned.

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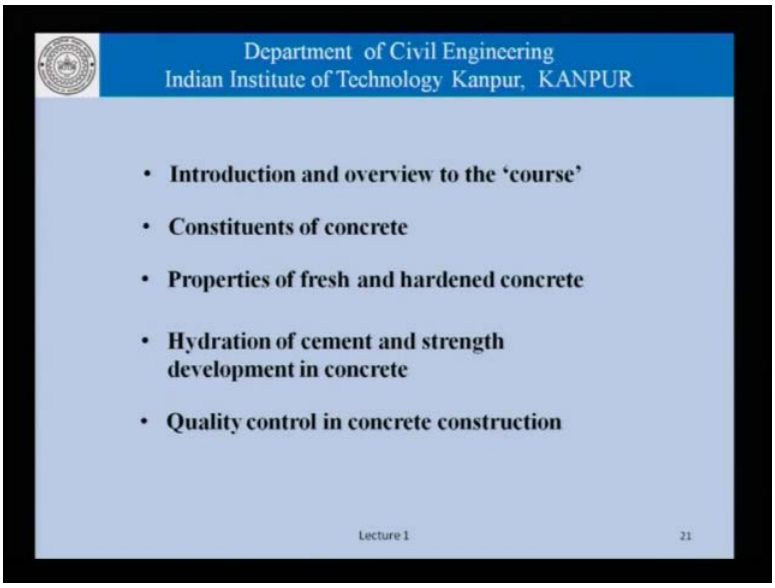

Now, revision of fundamentals of concrete what we will try to do is overview of the course which is what we are doing today. We will talk in detain or in some detail about constituents of concrete properties of fresh and hardened concrete hydration of cement and strength development of concrete. We will talk about quality control and it quality assurance in quality control construction coming to proportion of concrete mixes.

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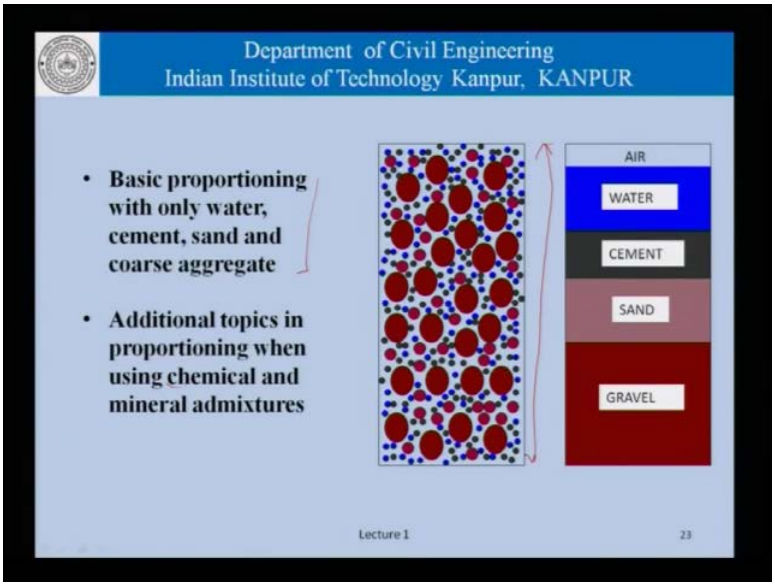

We will go back to this picture and we will talk of basic proposition were only waters cement sand and coarse aggregate is involved and we will talk about additional topics or

special topics proportioning when chemical admixtures or mineral admixtures are used. I would like to reiterate that at the end of it, it is of fixed volume of material and within that fixed volume. It is our responsibility as concrete engineers to proportion the different constituents whether it is the only basic constituents as shown here or any other special constituents that we may choose to add in the concrete mix.

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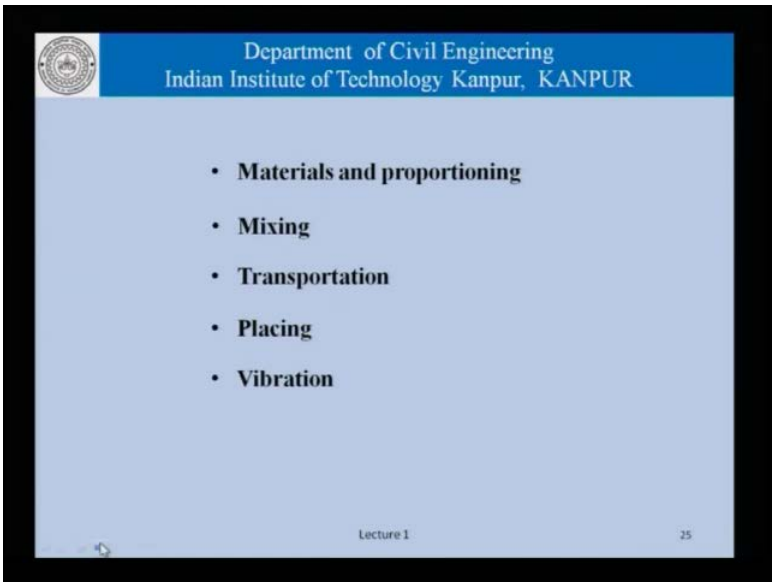

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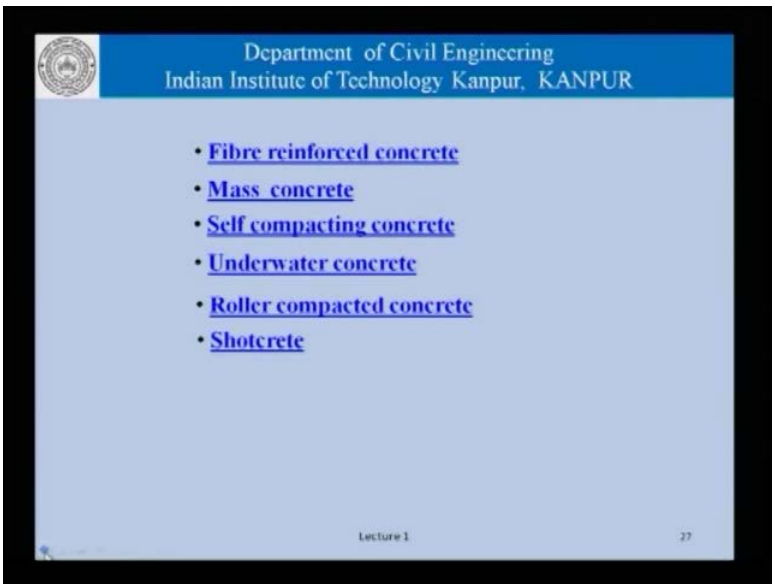

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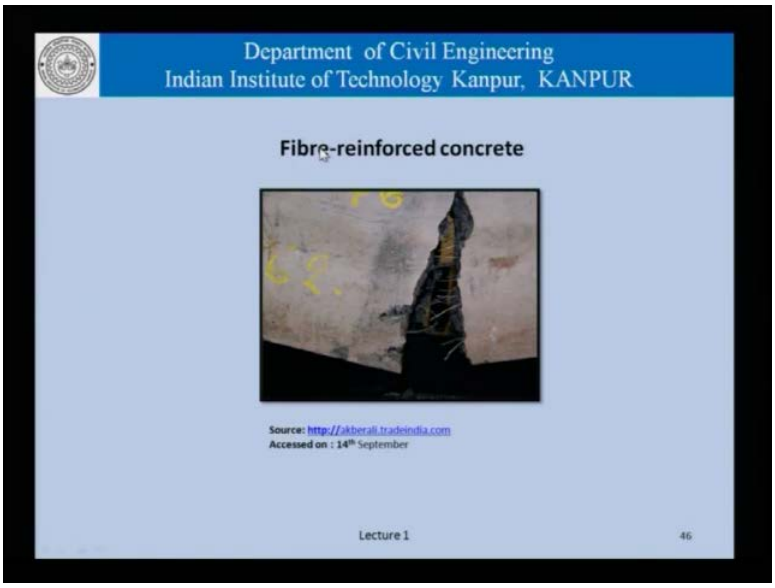

As far as the stages in concrete is concerned, we have already gone through it the materials, and proportioning mixing transportation placing vibration curing coming to special concretes. There is fiber reinforced concrete mass concrete self compacting concrete underwater concrete roller compacted concrete and shotcretes. These are some of the examples that we need try to cover in this set of discussions here.

Now, let us look at fiber reinforced concrete for example, I am not sure whether the picture is very clear, but what is shown is the fibers that are sticking out here between the two fractured phases of concrete. That is what makes these concrete special normal concrete were just fractured, but fiber concretes because of the presence of small fibers here does not fracture in a brittle manner, it still carries some load after the concrete has largely filled. Now, these are the ideas that are important where concrete has largely filled means there has there is perhaps a large amount of deformation which has occurred, but the concrete can still sustain at least some load.

Now, let us look at mass concrete mass concrete these are examples of dams or hydraulic structures these concrete structures are very large in scale in geometry and so on. Placing concrete in these structures has certain special problems, one it is not very heavily reinforced. Number two, we may choose to use large aggregates number and three we may choose to use large volumes of concrete in a single port.

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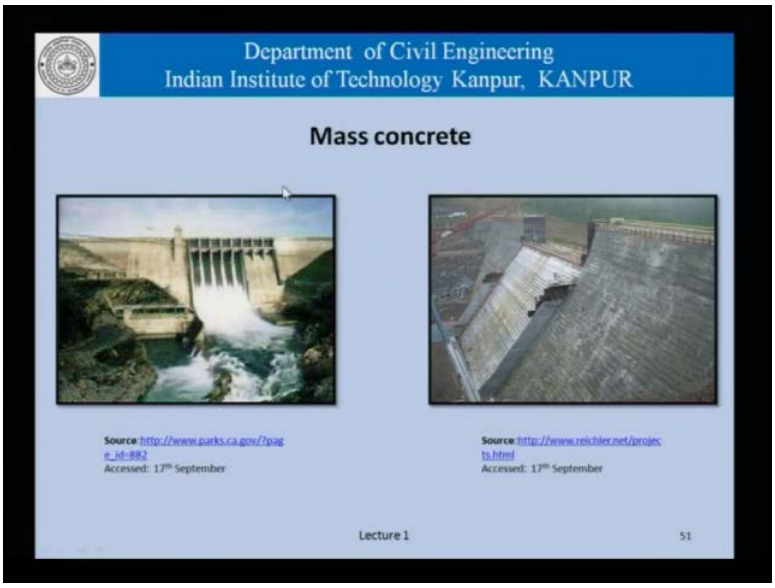

Now, the moment we decide to use large volumes of concrete in a single port, we have the problem of heat of hydration and related thermal stresses. So, once we start talking about a concrete were specials efforts needs to be made to handle the heat of hydration of cement that concrete is basically called mass concrete. And that is what we will try to study in one of the discussions that we have coming to the self compacting concrete.

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We have shown this picture earlier were this concrete is almost like a fluid it flows. And we use slump flow or the U tube or the U box test to measure its properties under water concrete, we have also seen this picture.

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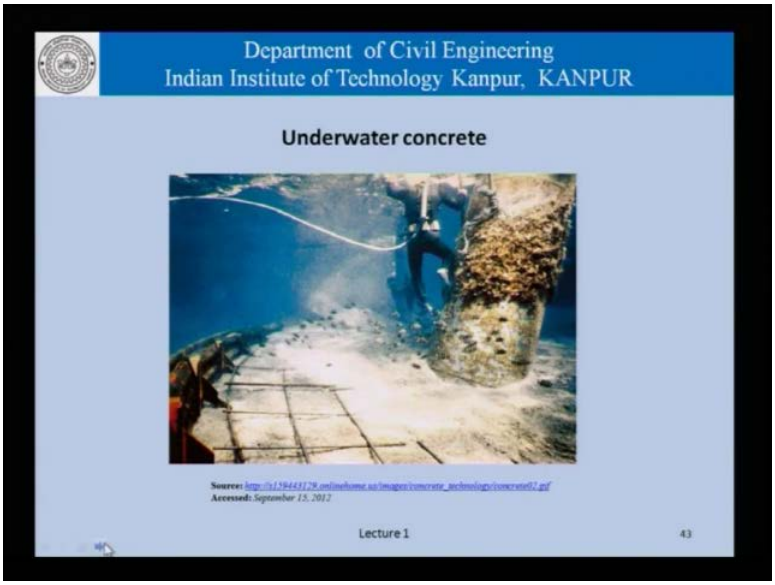

You can imagine that it requires a very different kind of concrete which will be required for this kind of placing. The concrete has to be highly segregation resistance that is the cement particles that should not just get washed away, and should not move away roller compacted concrete.

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Now, when a concrete is placed in a very open space for example, in a high way of that matters sometimes in a dam then concrete need not to be very fluid because there is enough space for the concrete to be placed and compacted reinforcement is very small. We may use, what is called the roller compacted concrete and this roller here could be a vibrator roller, which act as a form vibrator to this concrete which has been to this concrete which has been placed on the surface.

So, a form vibrator is applied on the form work where as in the case of roller compacted concrete the vibrator if it is a roller vibratory roller the vibration is applied to the surface of the concrete directly. So, these for different technology cause the properties of concrete that are required to be different. Therefore, the concrete engineer is called a point to propose in the mix differently and do quality control in a different manner.

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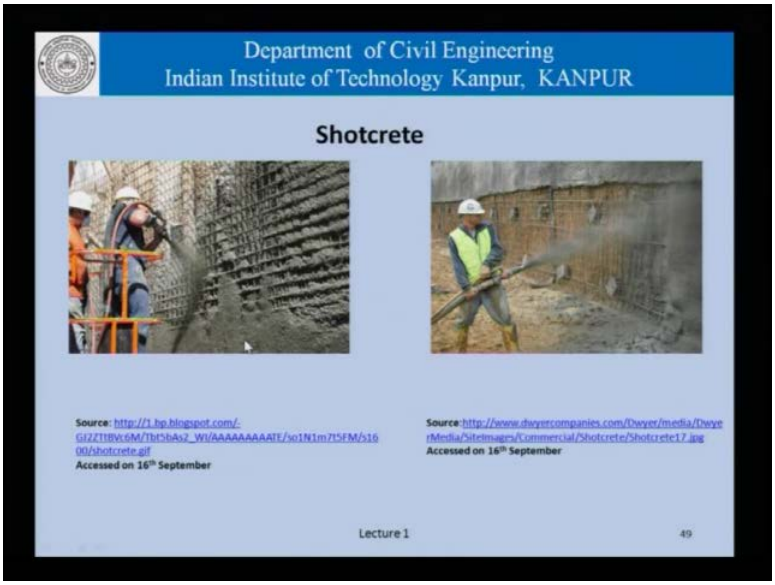

As far as shotcrete is concerned, we have already seen these pictures and we know the concrete is to be placed in this application has to be designed very differently from the concrete, which is required for under water placement or roller compacted concrete and so on.

Let us talk little bit about the mechanisms of the deterioration concrete structures, we know from our experience in the last about the 45 years that concrete is not a maintenance free material. And when concrete structures are exposed different environments the concrete deities the reinforcement corrodes. Sometimes, there is a

problem with the material that we use, and that shows up after only a reasonably a long time causing the structures to reiterate and so on.

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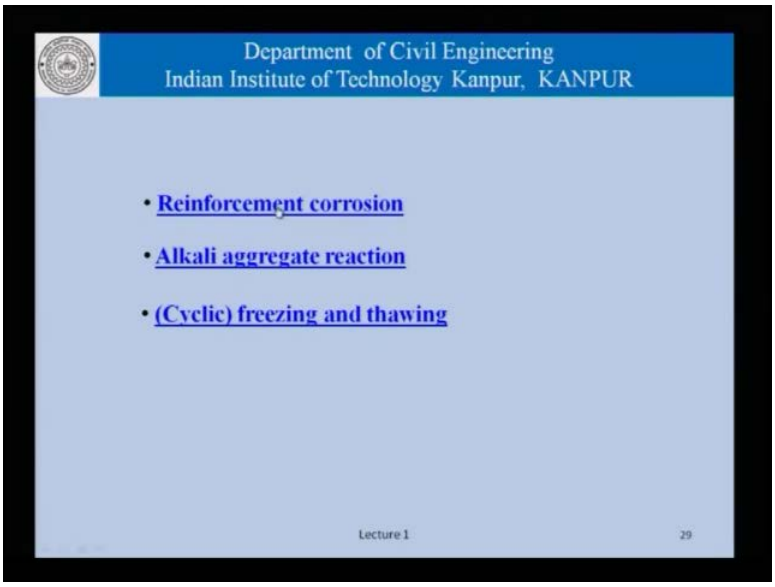

Some of their mechanisms that we take on discussion her are reinforcement corrosion alkali aggregate reaction and cyclic freezing and thawing. So, let us take a look at what a reinforcement corrosion does to the concrete structures.

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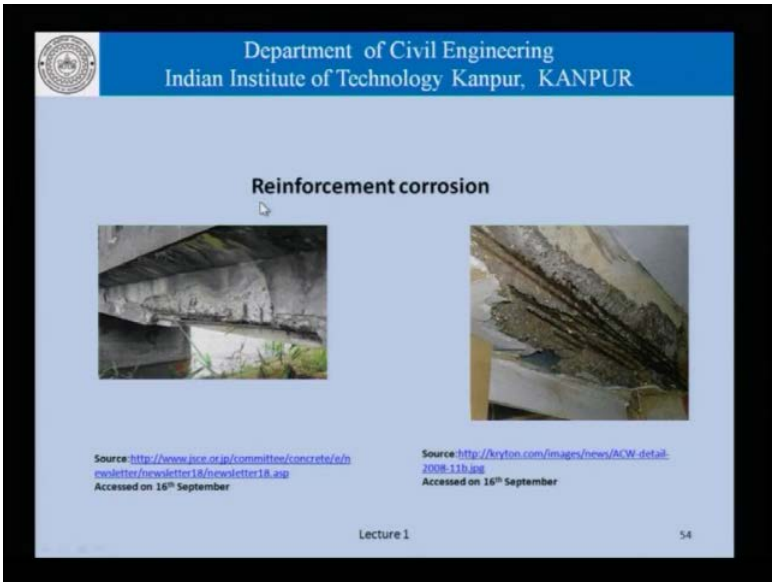

If we look at the pictures here we find that corrosion has caused lot of damage to this concrete structure. It has cause a lot of damage in this part of the structure here we can

see that the cover concrete has spoiled of has been removed and the reinforcing bars which are here have been exposed and are very much the reinforcing bars. Here are exposed and are corroded it is the corrosion of these bars has caused cover concrete to be removed from the concrete structure from this pick. This equally here that at the bottom of this reinforcing bars has cause the concrete to be removed from this structure.

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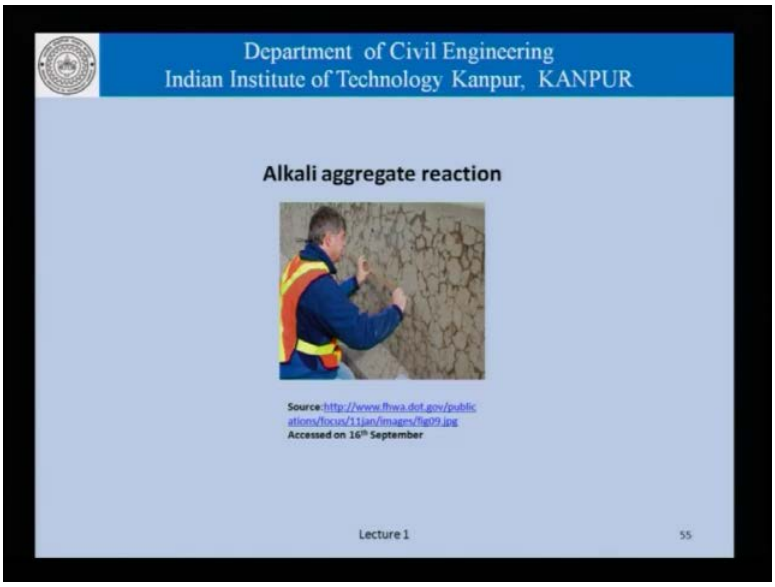

We said in the beginning of the discussion today, that aggregates are all inert fillers that is true when the normal sense of the world when the normal aggregates and normal cements have been used some aggregates. However, have be found to be reactive that is they react with the hydration products of the cement paste and that cause the concrete to deriterate and what we called that is the alkali aggregate reaction. So, what we seen alkali aggregate reaction is shown here that is a lot of surface cracks of here on the concrete and they cause the stress. They are visually unacceptable and also cause problems as for as the structural behavior of the concrete is concerned.

Now, coming to freezing and thawing of concrete structures cyclic freezing and thawing that is the concrete is placed in an environment or the structures is in an environment where the temperature of the atmosphere becomes less than zero and more than zero or higher than zero causing the water in the concrete to freeze and thaw cyclic. Now, we know that if that happens the water expands and contracts and this change in volume of the water which is within the concrete.

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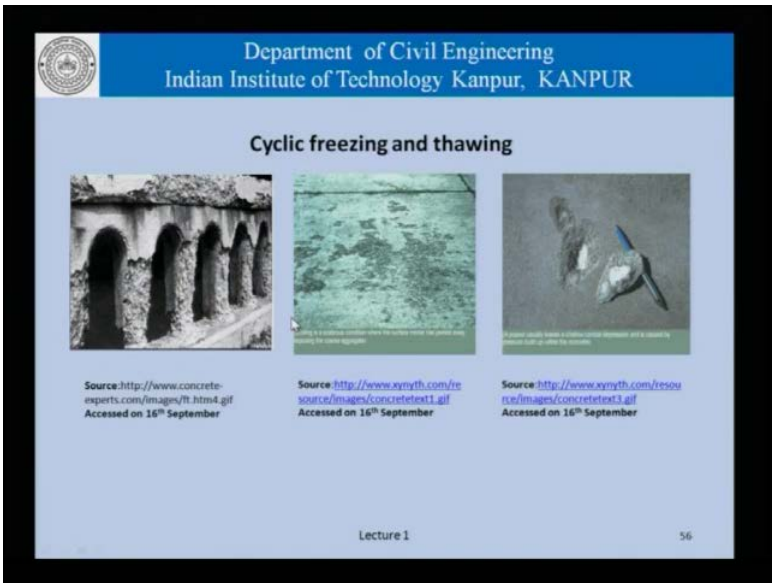

In the process system causes the kind of deiteration which is shown in these pictures; we can see that the surface of concrete has become very, very poor. Some, concrete has been upgraded we can see here that healing has occurred that is surface this mortar has been lost similarly, this case here aggregates pop outs.

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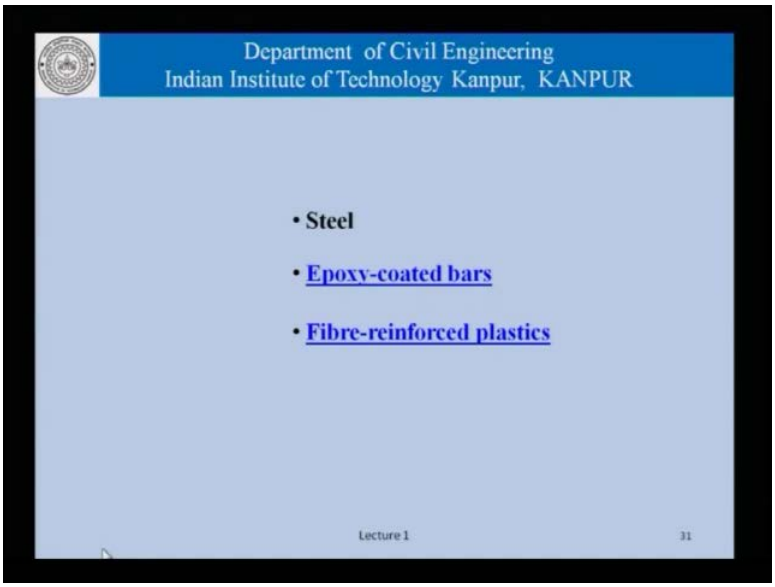

Coming to the reinforcement concrete structures, we know that typically we use steel as a reinforcing material we will not talk much about steel in this course, but we will talk a little bit about epoxy coated bars and fiber reinforced plastics. These two are alternative

reinforcing material to steel and are important for a concrete engineer to know because they are answers in cases where concrete is likely to be subjected to reinforcement.

Corrosion the steel is susceptible to corrosion epoxy coated bars are less susceptible to corrosion fiber reinforced plastics are not corrosive nature or fiber reinforced plastics are not corrosive. Therefore, an engineer should know about epoxy coated bars and fiber reinforced plastics.

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Let us take a look at epoxy coated bars epoxy coated bars are nothing but a normal reinforcing bars, like this which have at deposited coating of epoxy material. This coated material prevents the surface of the reinforcing here from corroding that is this prevents surface from being exposed to oxygen, or water which are the necessary ingredients for causing the corrosion. So, that is what a how a epoxy coated bars works and here we see pictures of how epoxy coated bars are placed the place just like a normal reinforcing bar except a certain precaution have to be taken.

This picture here shows bend epoxy coated bars because when a bend in epoxy coated bar we subject the outside phase of the epoxy coated bar. The coating here is like to crack and that causes, and that requires that the epoxy coated bar should be properly tested before they are used in a concrete construction.

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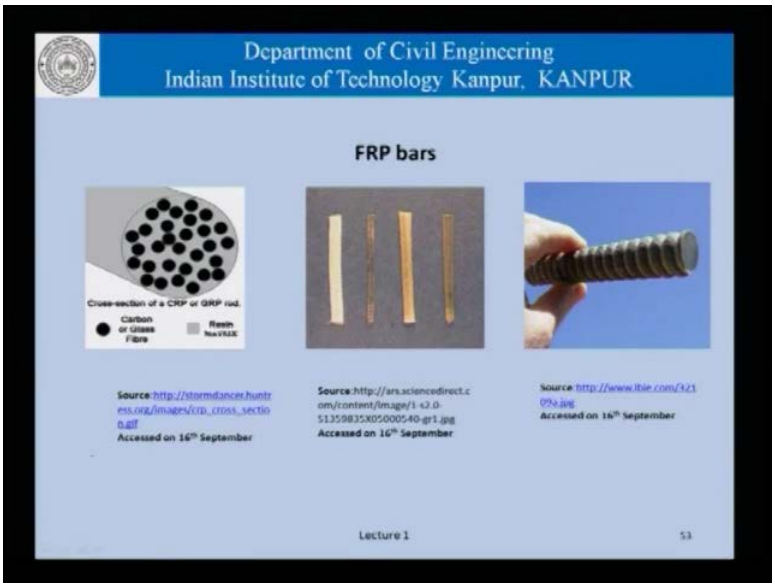

Now, coming to fiber reinforced plastics, now fiber reinforced plastics are F R P bars are basically consist of these fibers, which are embedded in or resin matrix this fibers could be made of carbon or element or glass. There are different materials that can be used for resin and ones this is structure is set then it can be commercially available, and these fiber reinforced plastic bars are available in different shapes and sizes that can we see in this picture here.

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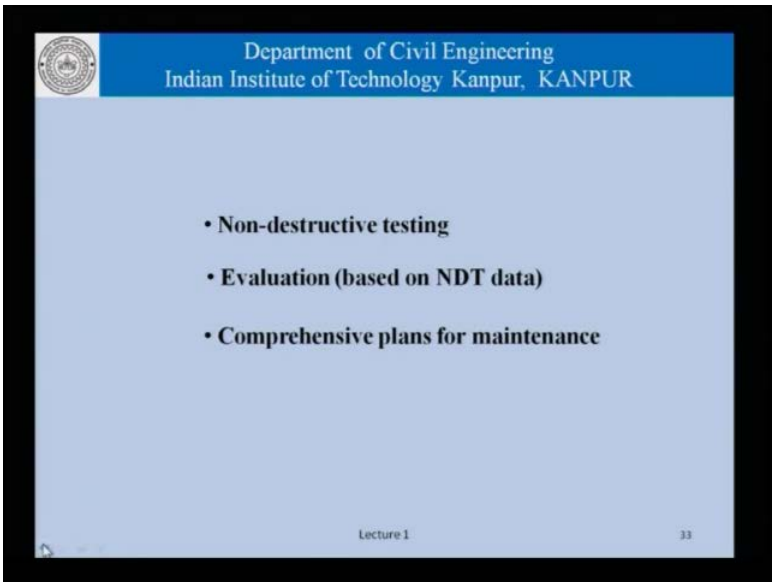

On this picture here, this one here are a typical example where the F R P bar really resembles the reinforce, or normal steel bar with all the ribs and so on to ensure that the bond between the concrete and the reinforcing bar is also compromised. Coming to the last topic that we will try to cover in this set of lectures is the maintenance of concrete structures.

Maintenance involves non-destructive testing evaluation based on non-destructive testing data and comprehensive plans for maintenance different methods are available for non-destructive testing of concrete structure. We will be familiar with test methods like sprit hammer or the ultrasonic pulse velocity and so on. We must remember that these methods give a certain numbers, and those numbers actually need to be evaluated whether that number is acceptable, unacceptable. What is the variation that is absorbed in those numbers and so on when we look at some of issues. We will talk of the thought process involved in a comprehensive plan of maintenance.

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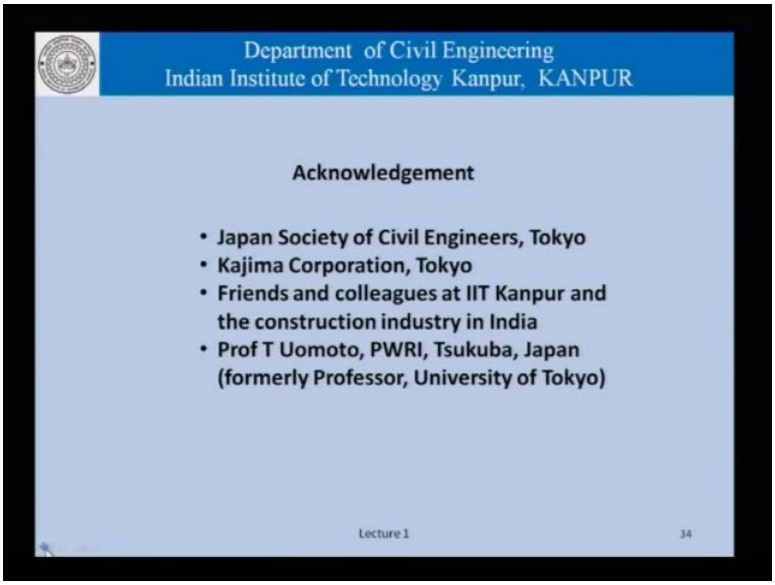

With this I come to an end of discussion today and I would like to acknowledge the help and all the support from Japan society of civil engineers. In Tokyo, the Kajima Corporation in Tokyo, friends and colleagues of I I T Kanpur, construction industry in India. And specially Professor Uomoto of the public work research institute in Tsukuba whose also whose a Tsukuba in Japan formerly professor of civil engineering university

of Tokyo, who gave me some insight into this concrete into this wonderful material concrete. I hope to share some of my experience with you beginning the next class.

Thank you.