Concrete Engineering and Technology
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Lecture - 37
Considerations in repair of concrete structures (Part 1 of 2)

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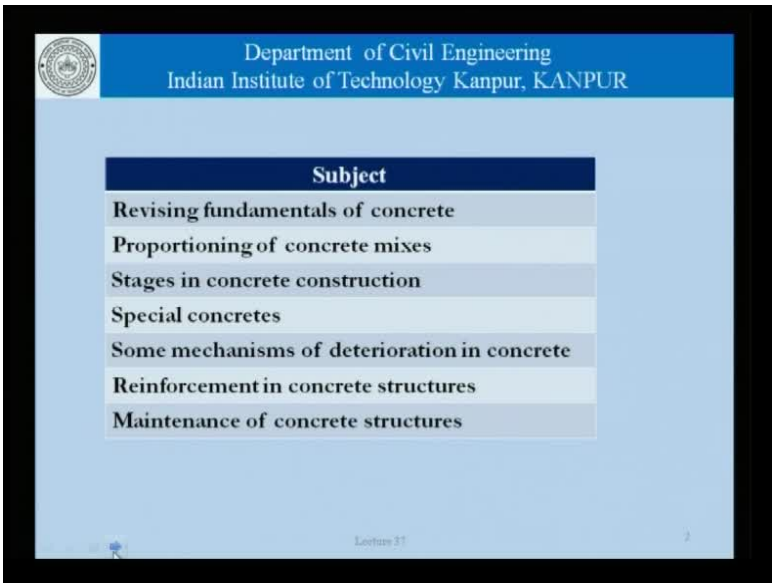

(( )) and welcome to one more lecture in the series on concrete engineering and technology, where we are talking about subjects ranging from concrete fundamentals, to proportioning of mixes, stages in concrete construction quality control, special concretes mechanisms of deterioration, reinforcement in structures and also maintenance of these structures.

The subject that we will discuss today covers mostly the fundamentals of concrete design from the point of view of maintenance of these structures. Another thing that will get included in our discussion is deterioration of concrete and it is manifestation in concrete structures, primarily by way of cracks.

So, getting started with our discussion today, which will largely focus on developing or discussing the conceptual framework for the maintenance, and repair of concrete structures. It has been realized that concrete structures are not maintenance free; concrete is not a maintenance free material. It is not that we make the concrete structure once and

then it continues to serve the purpose for which it was designed without any maintenance, without any intervention during its service life.

So, now how do we address this issue of maintenance of concrete structures, and what is the kind of intervention that we make during the service life of such structures; that needs to be discussed in a conceptual framework rather than adhoc manner. We just cannot do things adhoc. We see a concrete structure, see some signs of deterioration and take some corrective action. This is the last thing that we would like to do, if we want to be scientific in our approach; and that is the conceptual framework, that will be talking about today.

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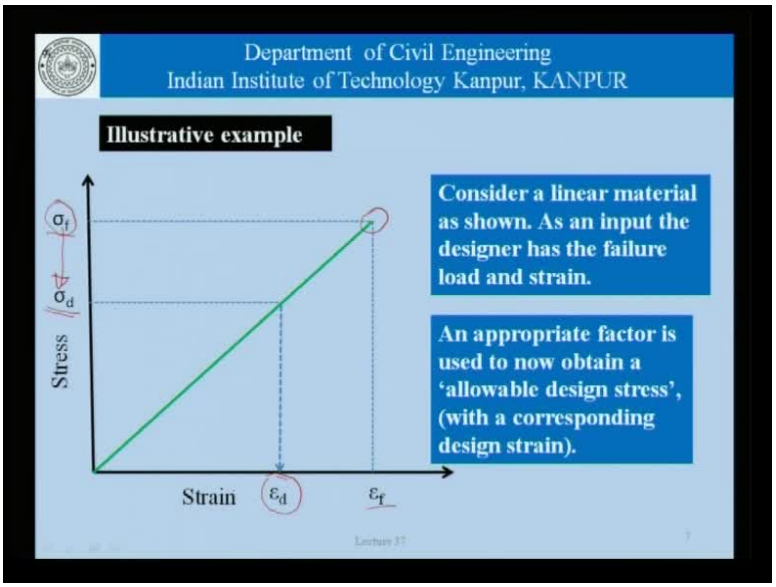

Let us take an illustrative example as to how the design process really works. Here is the stress strain curve of a linear material and as an input; the designer has the failure values here. The failure stress and the corresponding failure strain. Now what we really do is an appropriate factor is used to obtain an allowable design stress with a corresponding design strain.

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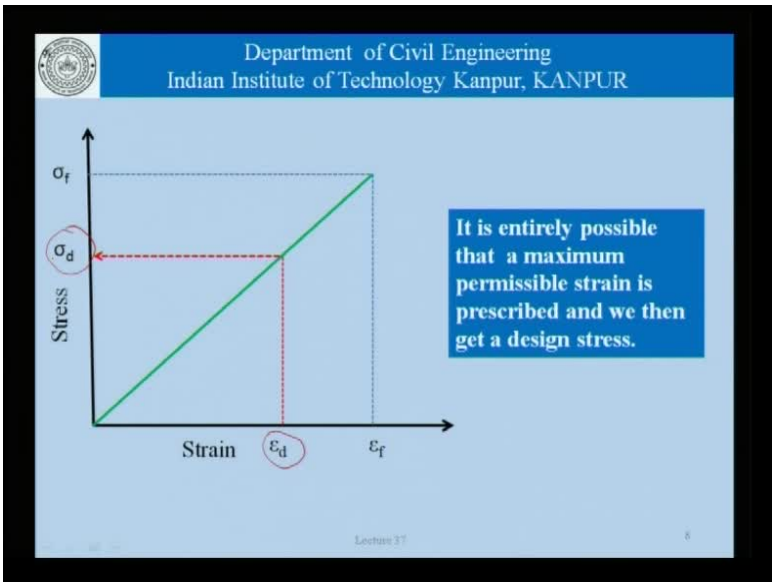

So, if the this failure stress here, we reduce this failure stress and say that this is the permissible design stress and for this permissible design stress, if we know the stress strain behaviour of the material. We have the design strain or the corresponding design strain. It is entirely possible that instead of a failure stress being given directly. We decide that we do not want the material to deform more than a certain amount; that is we give a maximum permissible strain, and from there we determine the permissible load or the stress value.

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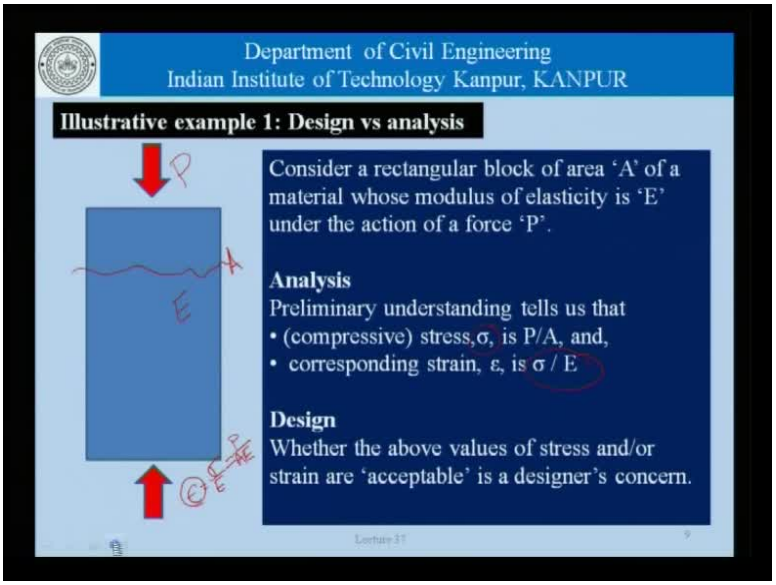

Now, let us extend our discussion to include the concept of design versus analysis. Consider a rectangular block of area A of a material whose modulus of elasticity is E under the action of load P. So, what we are talking about that the load P acts on this block of material which has an area of cross section A that the material property is E the modulus of elasticity of this material is E.

Now, preliminary analysis tells us now, what is analysis? Analysis tells us that the compressive stress is P by A and the corresponding strain is sigma by E, so as far as the strain is concerned. We could write the strain as either sigma by E, which is written here or we can also write it as P upon a times E that is what our classical understanding of stress strain behavior; how the material deforms and what is the expected level of deformation and so on is.

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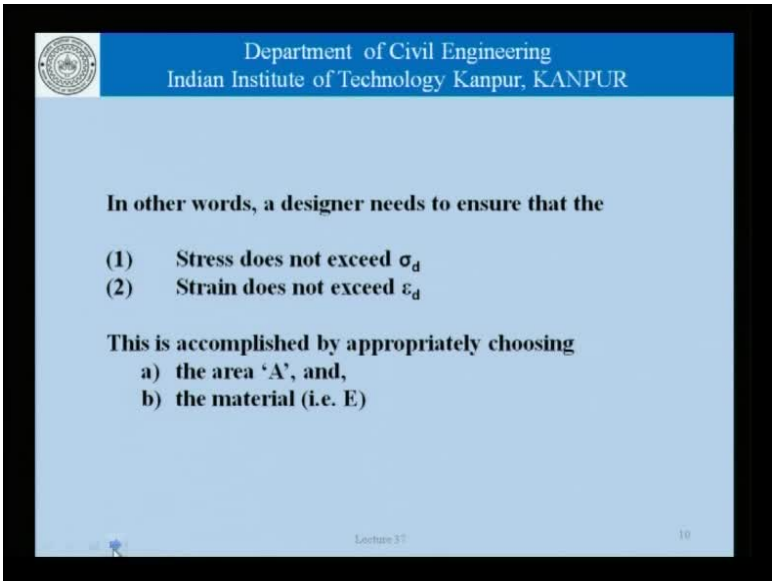

Now, what is the design? Correspondingly the design means, whether these values that is sigma that we get here or the epsilon or the strain that we get here, these are acceptable or not; in other words the designer needs to ensure that the stress does not exceed sigma d which is what we have determined earlier and the strain does not exceed epsilon d. How does it done?

This can be accomplished by appropriately choosing the area A and the material, that is the E. So, basically analysis is exercise, which tells us the response of the structure to a given load, when the material properties in the geometry of the member is known and

design is the exercise, where the geometry and the material properties of the member are determined for the same load with the provision or with this specifications that the response is acceptable. Surely there will be response surely there will be some deformation.

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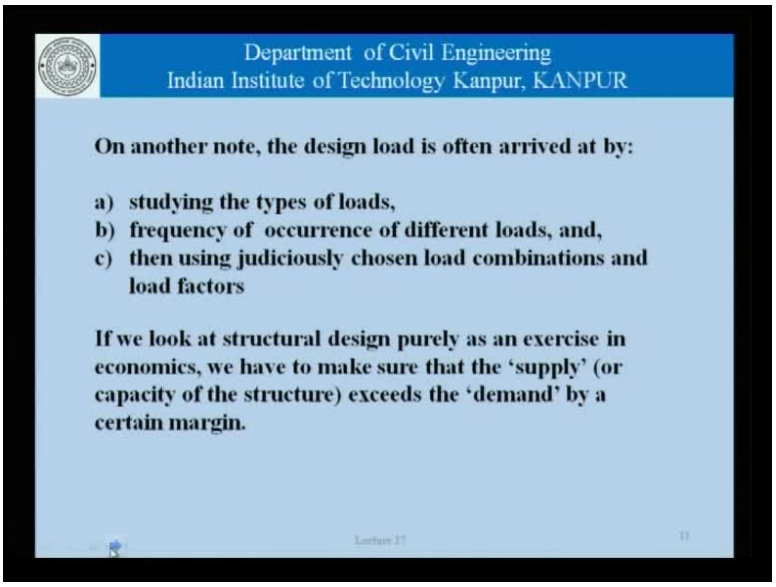

Now, whether the deformation or that response is within acceptable limits that is what is the design exercise, on another note, how do we arrive at a design load? This we get from studying the different types of load that the structure is likely to be subjected too. We have dead load, live loads, earthquake loads, wind loads, snow loads and so on and so forth; depending upon, where the structure is located; what is the past history of events in that region; what is the load that the structure is lightly to be subjected too and so on.

We also study the frequency of occurrence of the different loads. How frequently do earthquakes occur in a particular region? How frequently does it snow? How heavily does it snow and so on, and then using a judiciously chosen load combination and load factors. What we do is? Combine different loads, dead loads and live loads and earthquake loads could be one combination. Dead loads, wind loads, live loads it is another combination.

We may make an engineering decision that certain load combinations will not be accounted for, at the end of it, design is also an exercise in economics. We need the

structure, which is economic that is also married to the concept of importance of the structure. The impact that is failure has, if a structure is a high impact structure may be a nuclear power plant or a very critical bridge. We might like that structure to withstand even those forces which are likely to occur very very infrequently whereas, if it is a structure which is not critical, we may design for a lower level of loads or a different load combination.

Now, if we look at structural design purely as an exercise in economics. You have to make sure that the supply; that is the capacity of the structure exceeds the demand on the structure by a certain margin. What is a capacity of a structure or a structural member? It is the capacity or the load carrying capacity, if you want to talk in terms of structural design.

It is a load carrying capacity of that member and that depends on the geometry and the material properties. What is the demand on the structure? The demand on the structure is the load that acts on it; as we have discussed just before several loads or different loads would activation on it and as a designer, we come to a certain design load and for that design load we need to make sure that the structure has enough capacity.

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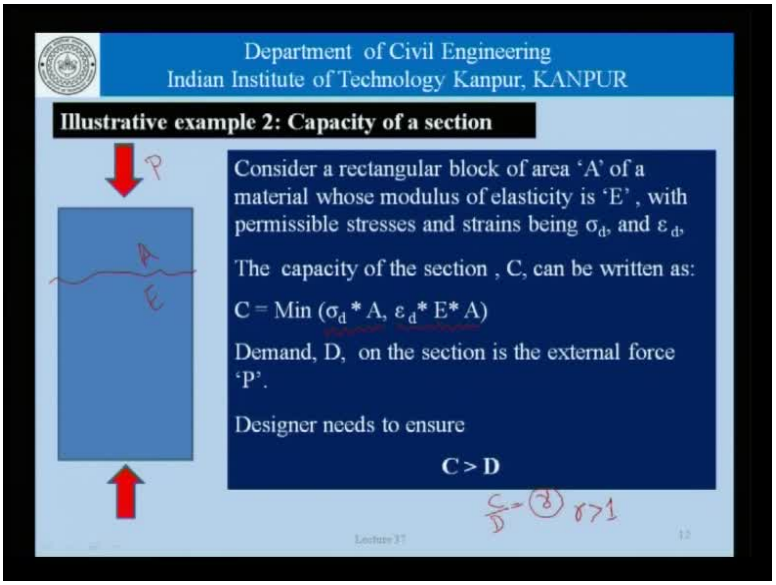

Now, this concept of enough capacity basically, means that the capacity that is a supply should exceed the demand by a certain margin. Going back to this example, that we had of a rectangular block with area A modulus of elasticity E and the permissible stresses

and strains be sigma d and epsilon d. The capacity of the section C, can be written as the minimum of sigma d times A epsilon times E times A. So, the lesson of the two governs the capacity.

So know, how the capacity is? The demand in the structure or the demand D on the section is the external force P which acts on it and that is the example that we had talked about earlier that there is the load P acting on it. This area is A the modulus of elasticity of this material is E and the demand D is therefore, a load that acts on the member and the designer needs to ensure that C is greater than D or the ratio C by D satisfies some criteria that we lay down. The capacity should be of factor gamma times the demand and this gamma should be greater than 1.

So, basically we have to ensure that the capacity may be 1.1 times gamma that is 10 percent more than 1.1 times D that is 10 percent more than the demand or 20 times more than the demand and so on; depending on various things such as the importance of the structure and so on.

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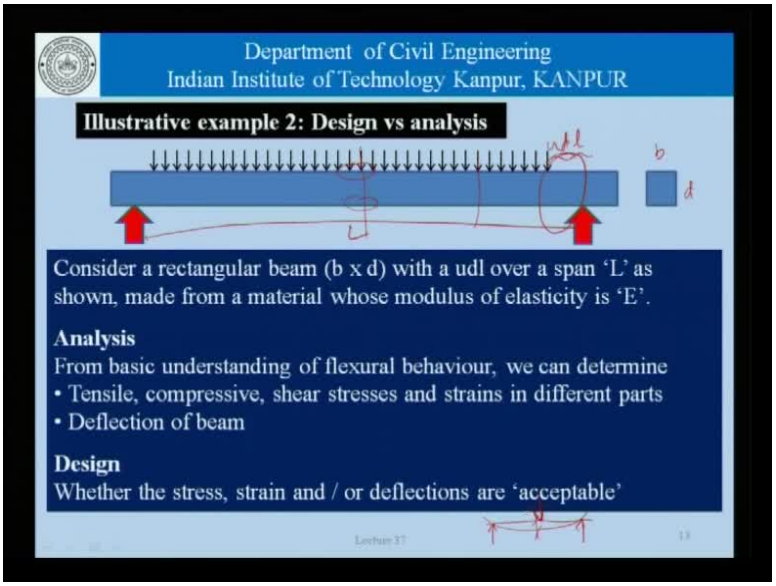

So, let us consider another example. Here is an example of a simply supported beam measuring d by d, that is the cross section of the beam and it has a uniformly distributed load over this span L. Assuming that the modulus of elasticity of the beam is E. The analysis means that from the flexural behaviour of the beams. We determine the tensile, compressive, shear stresses and strains in the different parts of the beam. We know that

we can draw the bending moment diagram for a beam under different loading conditions, and this is the simplest of them and from those bending moment diagrams, we can get the stresses and strains in the different parts of the beam. We can get them in the bottom fiber, we can get them at the top fiber, we can get them in the center of the beam a certain distance away from the beam. We can talk about what is the stresses near the support and soon and so forth that is the analysis.

We can talk in terms of deflection of the beam, we know that a beam, which is subjected to certain loads deforms and this deflection is something which we can calculate from our understanding a flexural behavior of beams. Now, what is the design? The design exercise really means, whether the stresses strains and our deflections are acceptable. We have specifications, which tell us that the deflection of a simply supported beam, which is maximum let us say the mid span should not exceed L by 325 or l by 450 and so on.

Where those numbers come form is a different story, but it is important to understand that the designer needs to satisfy the criteria that are laid down in the design specifications. We must also remember that the design specifications are not time independent; they are time dependent that is the specifications change over a period of time. A code published today, may permit a certain amount of deflection and that gets revised when the code is published 10 years later and these things the designer understands and the problem arises for structures which were built for a different set of specifications.

Now, what is the relevance of this very simple discussion from the point of view of maintenance of structures? When do we really need to repair, rehabilitate, retrofit or strengthen a structure? What is the difference between these terms that is the term such as repair, rehabilitate, retrofit, strengthen, reinforce and so on. We often hear these terms, and now what is the real difference between these terms and whether they are simply synonymous.

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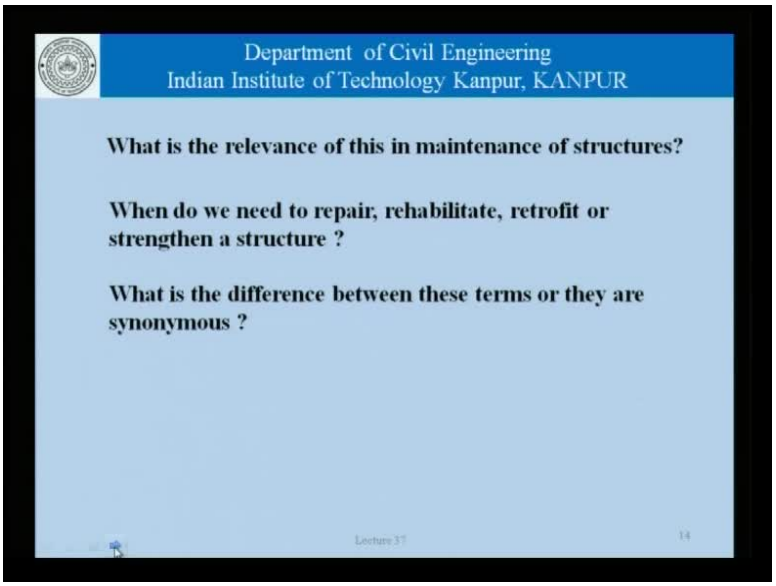

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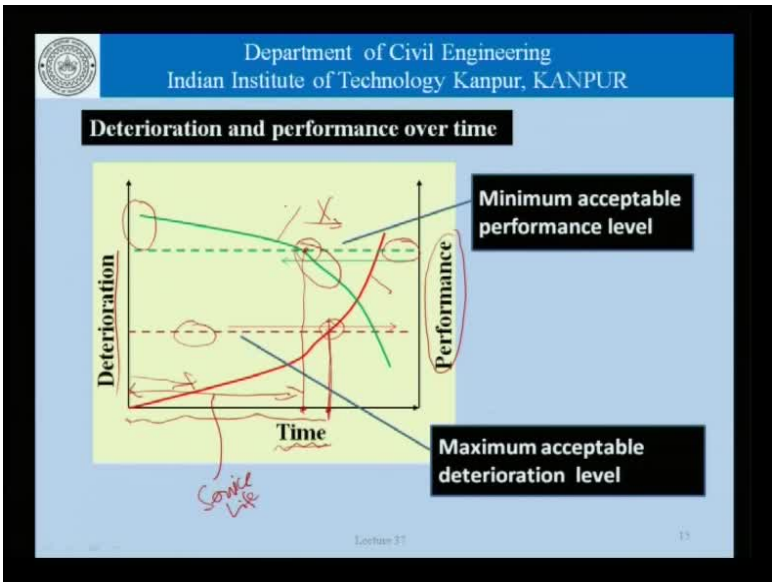

Now, in order to understand that, and now getting started with the framework, now beginning to answer these questions, what is the importance of understanding these simple concepts from the point of view of maintenance of concrete structures? Let us look at this graph, this graph really shows the variation of deterioration with time and this red line here is the line that shows deterioration time dependence.

Similarly, the green line here shows the performance versus time. So, we see that as the structure is in service for longer and longer periods of time. The deterioration tends to

increase and at the same time the performance tends to reduce the structure becomes less and less performing. Now, this dotted line here shows the minimum acceptable level of performance similarly, this dotted line here, shows the maximum acceptable level of deterioration in a structure. Now given the fact that over a period of time the performance deteriorates, initially we have to have the performance which is slightly higher than the minimum acceptable level.

Now, from this graph, what do we surmise or can we make a comment on the service life of the structure well as far as a deterioration is concerned, this line here or this time span here is the time span that the structure is the strength serviceable from the point of view of deterioration levels. It is only a this point that the level of deterioration in the structure is exceeding the critical level that is the maximum acceptable deterioration level.

Whereas from a performance point of view that times reach somewhere here, beyond this point the structure is not serviceable from the point of view of performance, because at this point the performance has fallen below the minimum acceptable level and therefore, the service life of the structure will be lesser of these two times and that is this time, so this time becomes our service life.

So, if somehow we knew, how are the deterioration changes over time or how the performance changes over time to begin with then we would try to ensure that during the service life of the structure the performance does not go below the minimum acceptable level or the deterioration does not exceed the maximum acceptable level.

Now, this is the concept which is very important from the point of view of maintenance. We have to understand that maintenance really means action that is taken while the structure is in operation to better understand, to present status as far as the deterioration as far as the performance is concerned, and then we try to intervene and try to alter the nature of the deterioration time or the performance time graphs.

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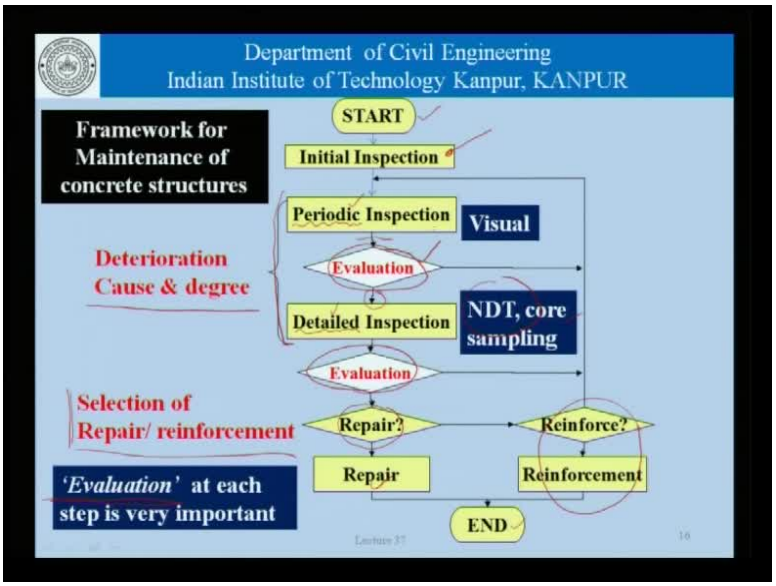

Now, if we continue with this discussion, here is the framework for maintenance of concrete structures, we start that is at the start, we have the structure has been built and put into service, so we have a initial inspection to determine, whether the structure has been built as per drawings as per the as per the specifications, whether there are any blemishes in the structure to begin with and so on.

After certain point in time, we have periodic inspection which could be visual, which could have certain simple tools been used and so on. From this inspection, we need to carry out an evaluation. Evaluation is a judgment that an engineer or a user exercises based on the input data that he has from the periodic inspection.

The decision could be to go for a detailed inspection or it could be to simply reinforce the structure or take some action as far as detailed inspection is concerned, the detailed inspection could include nondestructive testing, core sampling and so on, and gain an evaluation needs to be made; in terms of what is the action that is required to be taken, it could be repair, it could be reinforcement and so on and so forth.

Once we decide to repair, we need to be carry out the repair and the chapter closes, till such time as we go back to the start, because the repaired structure or for that matter the reinforced structure is as good as a new structure in a certain sense, we need to start with an initial inspection as to carry out. So, as to understand whether the repair work or the reinforcement work has been carried out with diligence as far as specifications, and we

have achieved whatever we wanted to achieve and if that has been done, once again the process starts and we have periodic inspection detailed inspection and so on.

Now, in this pat here, we need to understand issues related to the causes and degree of deterioration which means we must have an understanding of the deterioration mechanisms that are operating, it could could it could be corrosion of reinforcement it could be alkali aggregate reaction it could be fatigue and so on and so forth.

So, this part here in order to be able to carry out periodic and derailed inspections, we must understand the mechanisms of deterioration and also the relevant nondestructive testing tools, and the limitations of the data that is available to us at the end of the testing as far as the repair and reinforcement of structures is concerned, we need to carry out a survey and find out what is the best method that we can use, what is the most appropriate material that can be used, what kind of equipment that need to be used and so on

Having said that we must remember that evaluation is a very very important step at the end of each if these processes that we have underlined here there is an evaluation step at the end of the periodic inspection, there is in evaluation at the end of the detailed inspection and so on. So, evaluation is basically the process of exercising once judgment in terms of what is the further action required, all test methods give us certain results and it requires judgment to decide, what is the next step that is to be taken.

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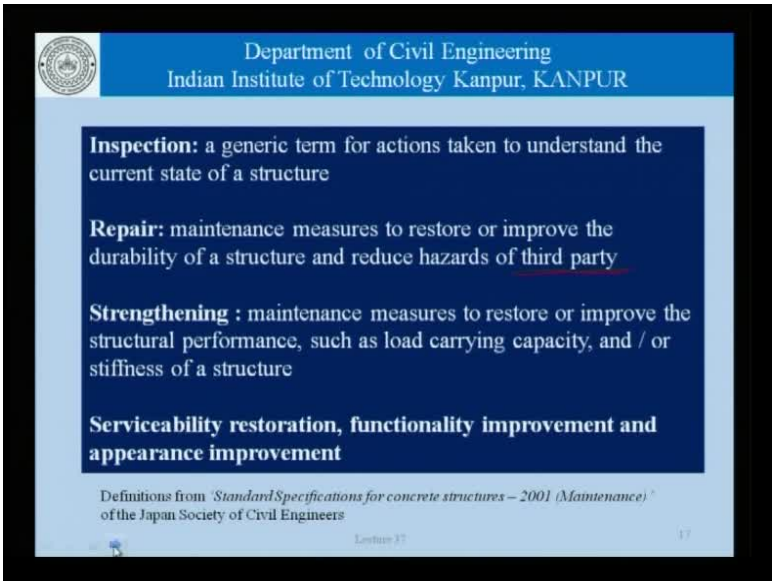

Now, if you look at more rigorous definition of some of these terms the inspection could be defined as a generic term for actions taking to understand the current state of a structure, those actions could be simply visually inspecting the structure or carrying out a Schmidt hammer test, an ultrasonic pulse velocity test, it could be carrying out a load test, it could be carrying out a infrared thermal energy.

Repair is a term which could be used for maintenance measures to restore or improve the durability of a structure in reduced hazards to third party. Now this third party hazard is something very very important that the owner of a civil engineering infrastructure project or a concrete infrastructure project must keep in mind, if we have a concrete bridge which has certain cracks and due to some reason, loads are otherwise a chunk of concrete was to fall and hurt a passerby. Now that is something which is very very serious and we must take all measures as part of our maintenance strategy for that particular structure to ensure that that simply does not ever happen.

Strengthening in contrast is a maintenance measure to restore or improve the structural performance such as the load carrying capacity and all the stiffness of a structure and so on. Serviceability restoration, functionality improvement appearance improvement and so on are also measures that are taken as part of the maintenance strategy for a given structure.

We must remember that concrete structures not only have the function of carrying load but, also have an esthetic function that is the concrete structure should be pleasing to the eye excessive cracks discoloration appearance of rust strains and so on is something which is esthetically unappealing, and maintenance actually will be required to restore esthetics appearance improvement.

Now, these definitions have been taken from the standard specifications for concrete structures of 2001 to maintenance part of the Japan society of civil engineers. Now this document is perhaps affords of its kind argument which lays down, the basic framework for maintenance of concrete structure.

From the point of view of a professional institution document different users the railways the roadways they have their own manuals and standards for maintenance. Now this document tries to provide a guidance or a framework for developing such documents across the globe or across the table for all kinds of concrete structures.

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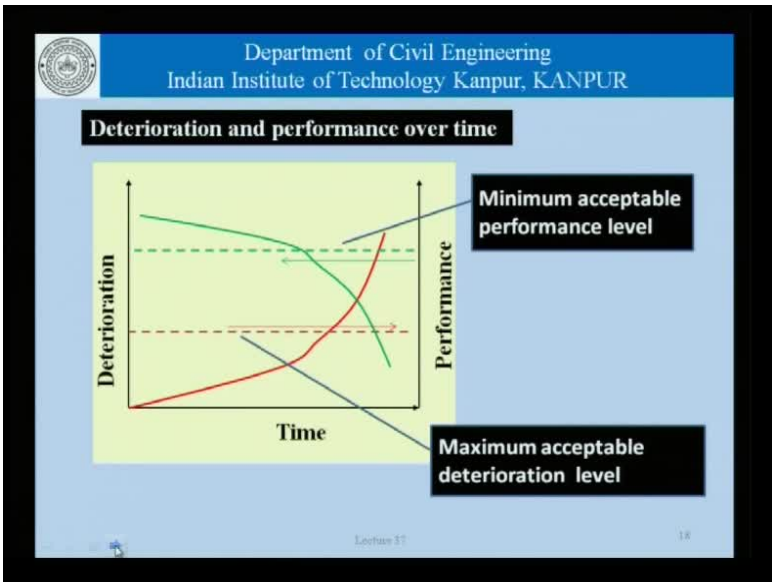

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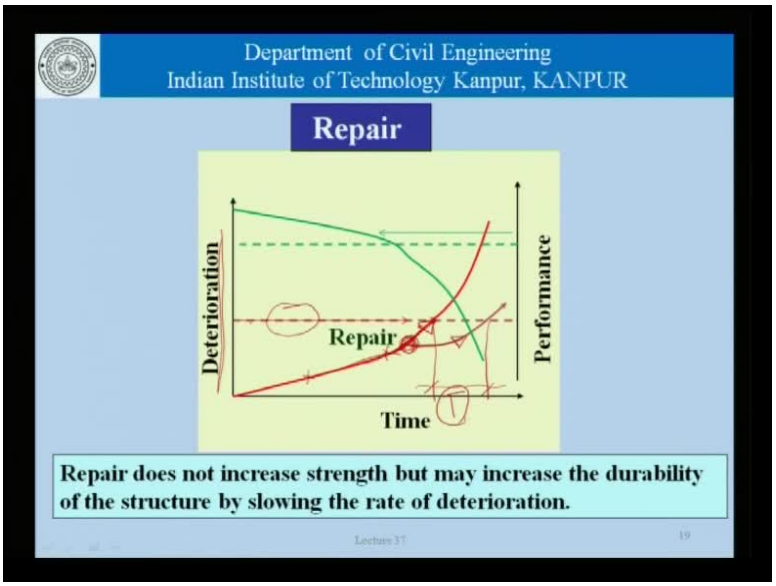

Now, if we look at this graph once again, that is the deterioration and performance changes over time, the minimum acceptable level of performance and the maximum acceptable level of deterioration. We try to understand the concept of repair from this graph, when we repair a structure at this point that is when we realized that the structure needs corrective action, if we do not take corrective action, we do not have much time left before the maximum permissible level of deterioration is reached. We take corrective action here and that is a repair action and what this repair action does is just change the

slope of this deterioration time graph which was heading this way it changes it into this line here and we have been able to extent the service life of the structure by this time.

So, this is the philosophical or the conceptual implication of a repair action will all this sounds very simply but, on the field it is not easy to implement, for the simple reason that How do we classify deterioration? How do we quantify deterioration? What is the parameter that we will follow as part of the initial inspection, periodic inspection, the detailed inspections and so on to say that well the structure has deteriorated from this point to this point and from this point to another and so on, and that is why it is a conceptual framework it is not an engineering framework.

An engineering framework would mean that upon the structure that we are talking about whether it is a marine structure, whether it is a structure in the cold climate, we define appropriate deterioration parameters and we try to follow those parameters, we measure them periodically and find out how they are changing.

Not only that we also need to find out what is the maximum acceptable level of that particular parameter that will call for corrective action or before that value is reached the structure should be repaired. It is much like the action that adopted takes when we go to him saying that we are not feeling well based on certain tests, the doctor decides whether a certain medicine is required what will be the dosage and so on

So, that decision is based on certain parameters which are measurable and the interpretation of those parameters is what the doctor carries out and that is the evaluation process. Those parameters can be monitored periodically and that is what we mean when we say that a structure should be inspected periodically, and if required a detailed inspection should be carried out and then we need to intervene by way of a repair action or a reinforcement action. So, what repair does is not necessarily increases the strength but, increases the durability that is the time that the structure would take or the time taken before the critical level of deterioration reached by slowing down the rate of deterioration.

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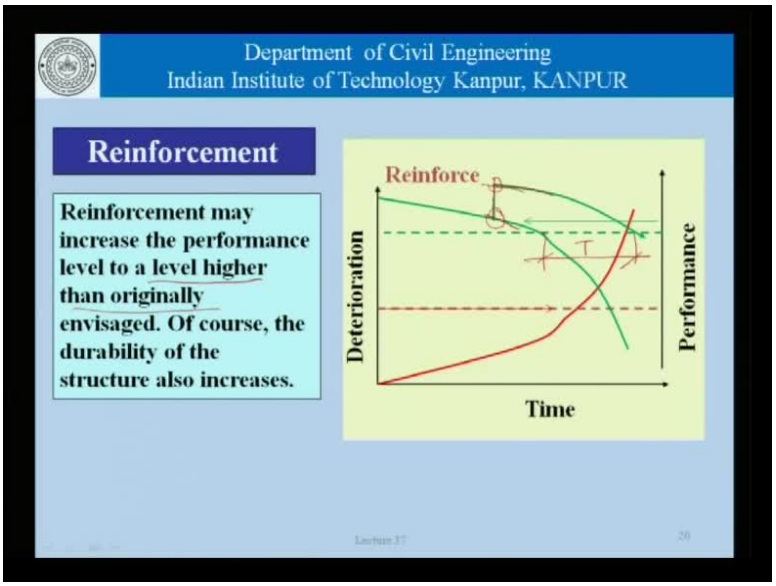

Now, what is the reinforcement action? Reinforcement action means increasing the level of performance to a level which could be higher than the originally envisaged level and of course, the durability of the structure also increases. Now this is explained here that if we decide to take reinforcement action at this point in time, because of our action the performance level has increased and not only it has increased may be the slope it which it was deteriorating has also been rectified.

So, what we get is an additional time which is involved here that becomes the improvement in terms of the durability or in an extension of the likely service life of the structure. Now this discussion on levels higher than originally envisaged and so on, arise from different reasons. Now what are the causes for repair and or reinforcement action?

So, if we go back to our example that we had of a simply supported beam with the u d l why would we need to repair or reinforce this simple beam, one could be an increase in the load level, it is not very uncommon in civil engineering structures which are in service for several tends of years that the load level increases.

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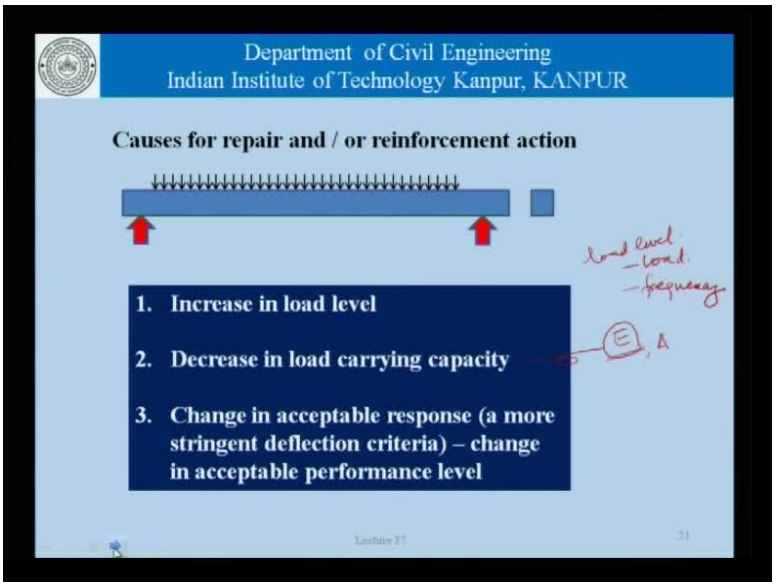

This load level could be in terms of the load itself for example, the excel load for trucks or for wagons in train increases and that happens, because of an improvement in the in the automobile or the wagon sector, it is a mechanical engineering development. What happens is that now, we have trucks available which can carry more load or it could happen in terms of frequency of application in a certain section a railway line, only one good strains of were passed in a day but, because of development increase in population and so on and so forth, the frequency of load application is much higher at the end of it. It is an increase in the load level. So, if the load level increases, the demand have increased from the discussion that we had earlier trying to relate the concept of structural design to the concept of economics in terms of demand and supply.

What has happened in this case is the demand has increased. We expect the structure to be able to perform under higher loads. It could also happened at the load carrying capacity of the structure has gone down, there is a decrease in the load carrying capacity and what does this mean, this means a change in the E, if we go back to our previous example, it could mean a change in the A part of the structure, part of that member has deteriorated weathered away corroded and so on and so forth.

Change in E means the material has undergone certain changes, because of which it has become less stiff, it deforms more under a certain action of load and so on and so forth or there could also be a change in the acceptable response. There could be a more stringent

deflection criteria and that really says that we have changed the acceptable performance level, may be the load level remains the same , may be the material is the same but, if we change the maximum permissible deflection we all know that the beam has to be now differently designed.

So, for all these reasons or a combination of these reasons beams, columns and any other structural member from concrete needs repair or reinforcement during its service life. What the another thing I would like to mention here is that when we are now talking about repair and reinforcement in this context. It is very clear that it is not simply a matter of patching up, it is not something like saying that we see some deterioration and do some action. So, that the manifestation or the visible sign of the deterioration is somehow taken care of.

It is like saying that we brush it under the carpet; we cannot and should not brush away signs of distress and deterioration in concrete structures under the carpet. It is nothing wrong concrete deteriorates and we need to take structural action. The designer has to be involved at each stage and decide what kind of action needs to be taken. The material engineer needs to be involved at all stages during the maintenance operation to decide what kind of material is being used, what kind of tests are been carried out for the material that is being used and so on.

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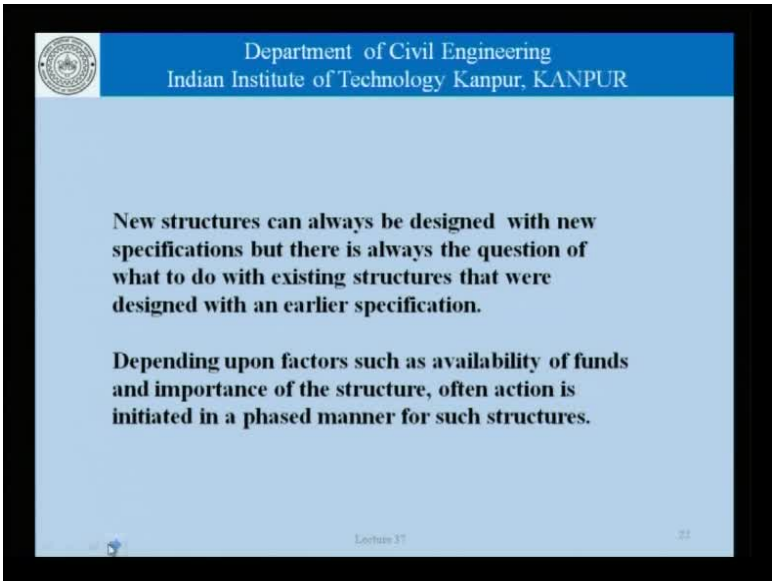

Now, new structures can always be designed with new specifications but, there is always the question of what to do with existing structures that were designed with an earlier specification. A structure which was designed with the certain specification may continue to perform as design but, due to changes in specification that response or that performance becomes unacceptable.

Now, whereas, the new structures can be designed to take care of that what do we do with the existing structures and that is a major challenge for all engineers, because, they are charged with because, they are charged with the responsibility of not only creating new structures or new infrastructure but, also maintaining the existing one.

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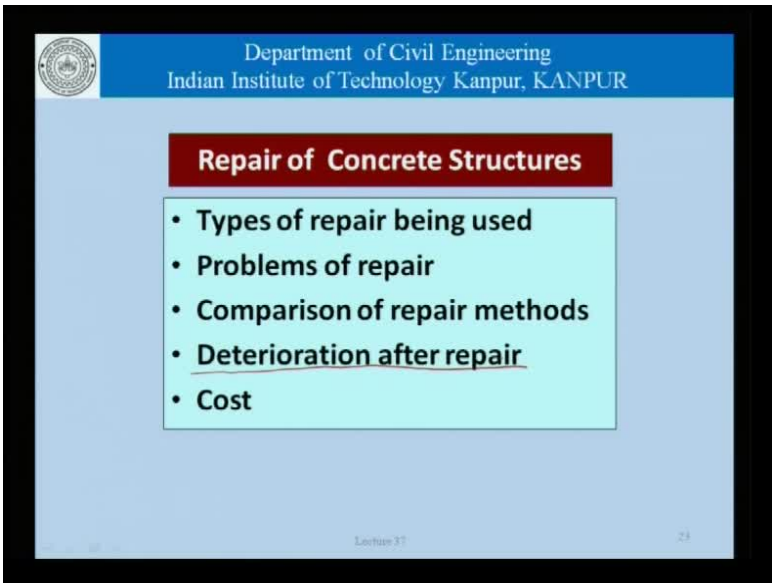

Now, depending upon the and for that depending upon factors such as the availability of funds and the importance of the structures of an action is initiated in a phased manner for these structures. Now let us talk about some of the considerations that we have in mind when we carry out the repair of concrete, when we carry out the repair of concrete structures, we need to understand what is the type of repair being used, what are the problems associated with repair of these structures, we need to have tools available to be able to compare repair methods, we need to understand the deterioration after repair. There would be a method which would give us immediate relief but, not be very durable and of course, finally, we need to be bothered about the cost involved.

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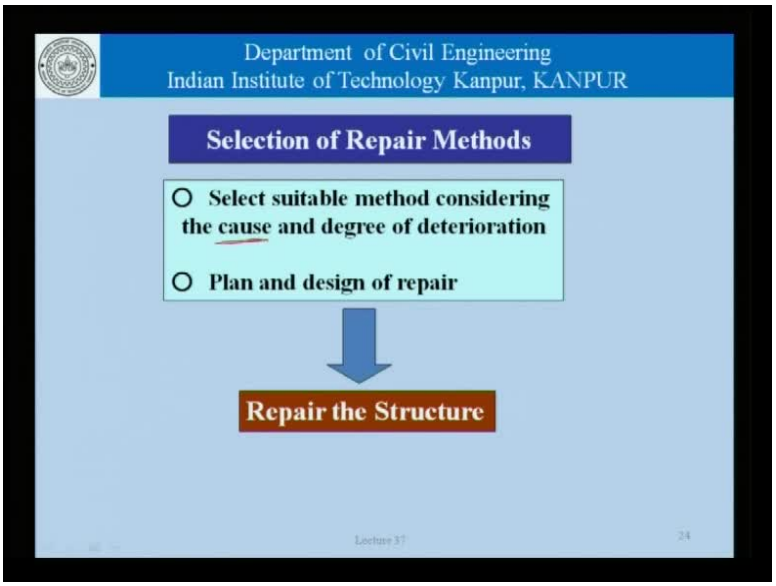

As far as selection of repair methods is concerned, we need to select the suitable method considering the cause and degree of deterioration, and then plan and design the repair process. The repair method needs to be very carefully chosen to address the cost unless we understand the cost and choose the repair method accordingly the repair method is likely to fail, and that is why we must understand the cause of deterioration mechanism of deterioration that has operated on that structure.

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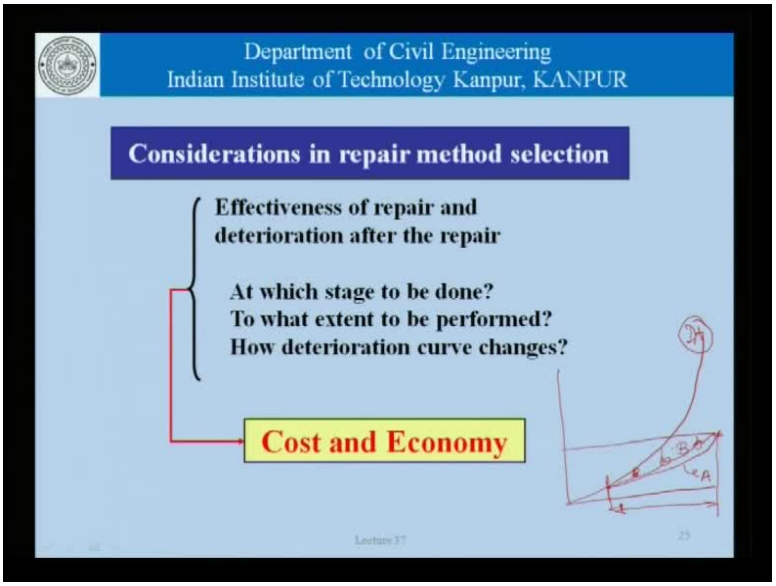

Continuing with this discussion we need to also figure out the effectiveness of repair and deterioration after the repair. We need to answer questions such as at what stage it should be done, to what extent it should be done and how the deterioration curve changes, that is the deterioration rate post repair that will really give us, how much additional service life we are able to add to that structure.

In this context there could be two questions, one is given up method of repair how much is the service life that it adds the question could be turned around and said that well the user wants an extension of service life by say 10 years or 20 years, what should be the repair method that is adopted at this point in time.

If we look at the deterioration time graph for a particular structure here, an option could be if e are intervening at this point in time that we take a repair method A such that we are able to extent the service life by this amount. There could be another option B which is less effective but, requires periodic intervention and that decision whether one should go with A or B is basic or could be governed by cost and economic considerations.

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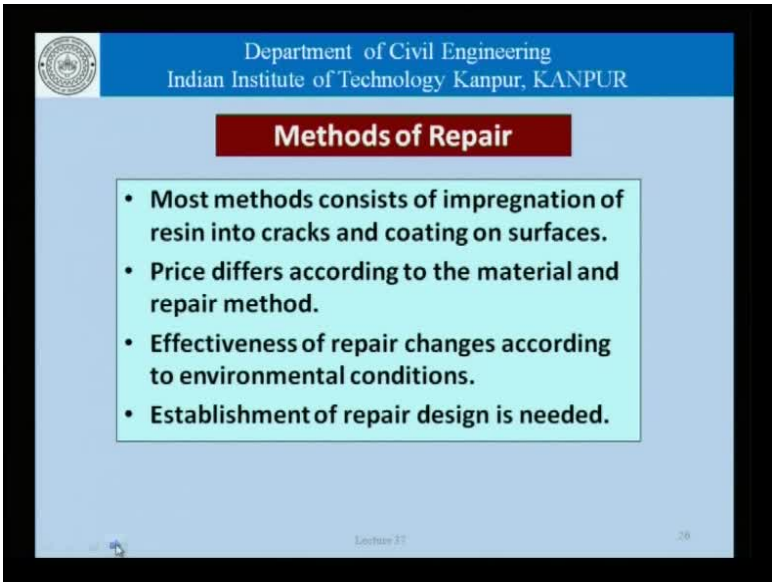

Now, as far as the methods of repair are concerned most methods, consists of impregnation of resins into cracks and coatings of surfaces as far as concrete is concerned most deterioration manifest in the form of appearance of cracks of some nature or the other and therefore, the and therefore, repair action is basically impregnation of resins into these cracks, and then applying coatings on the surface.

These coatings are applied because of several reasons one of them being that we do impregnation of cracks, the structure starts to look aesthetically very unappealing and of course, the economics depends very closely to the material and the repair method, and the effectiveness of repair changes according to environmental conditions, a particular repair method that works very well in dry climates may not work at all, if the climate was wet and therefore, we need to establish certain concepts in repaired design.

What is the kind of repair material to be chosen? What is the method that you should be used? How should it be tested and so on? These are concepts that we need to build into a area of repaired design. Repair cannot be done adhoc on the filled with very little knowledge on the part of engineer and simply based on the literature, which are repaired material manufacturer supplies.

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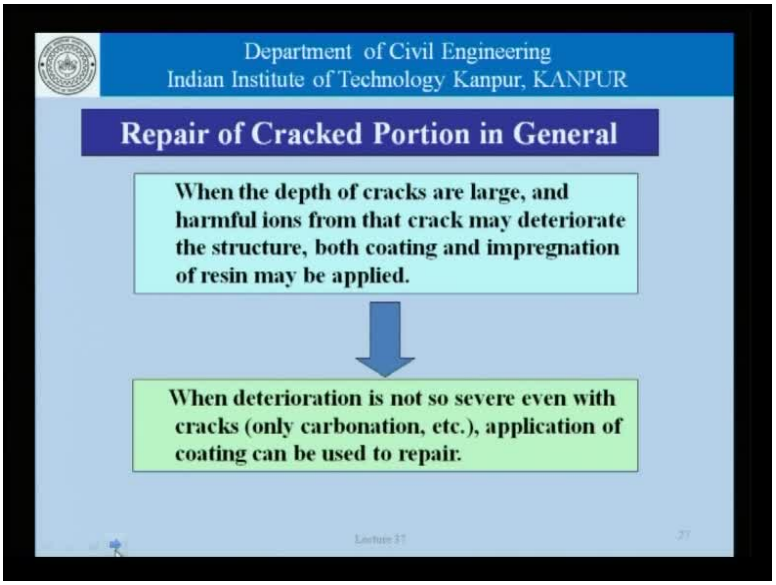

If we talk about repair of crack portions in general, if the depth of cracks is large and is harmful from the point of view of corrosion and so on. We may choose both costing and impregnation and if the deterioration is not so severe, it just cracks on the surface not very deep, we may choose to apply only the coatings on the surface but, these two coatings now need to be different qualitatively as we shall see.

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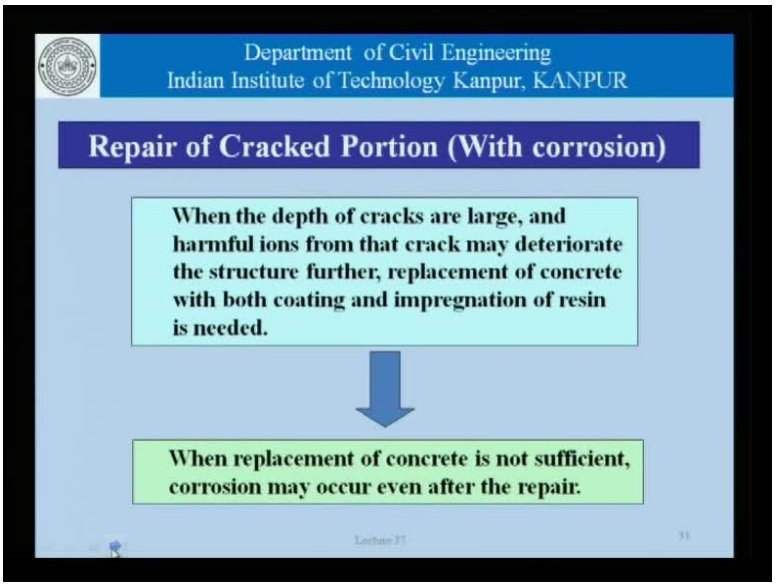

In the case of coatings being applied without impregnation of resins into cracks, the coating must possess enough plasticity or enough deformability. We must also remember the coatings may form cracks in the coating due to deterioration of the coating or fatigue load and so on. When we are carrying out a impregnation of cracks and application of coatings, We must also keep in mind the possibility that the impregnation of resins into the cracks is not complete and parts of the cracks are still left out, resin does not reach the crack fully.

Now, why does that happen it could happen, because of the fineness of the crack, because of the fact that the resin does not chosen carefully enough, the method that was applied to try to push the resin to the cracks was not appropriate, the quality control at the time of repair was not adequate and so on, and all these things effect the post repair performance of that structure.

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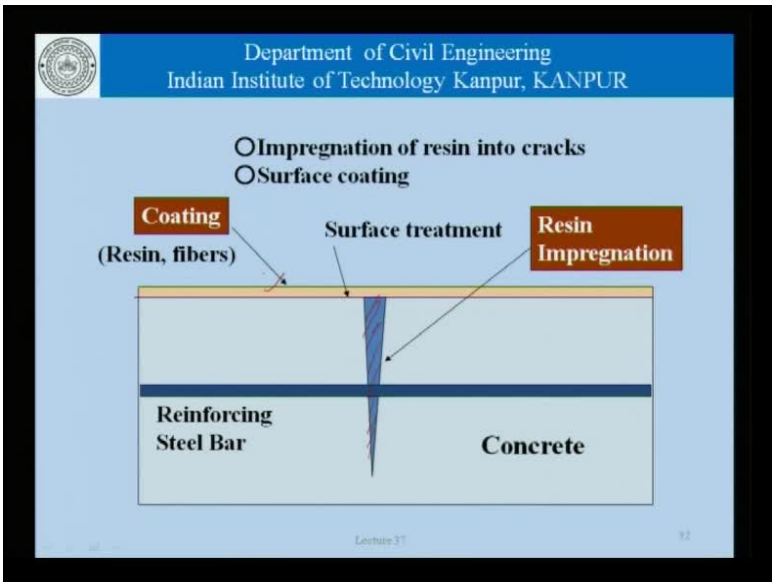

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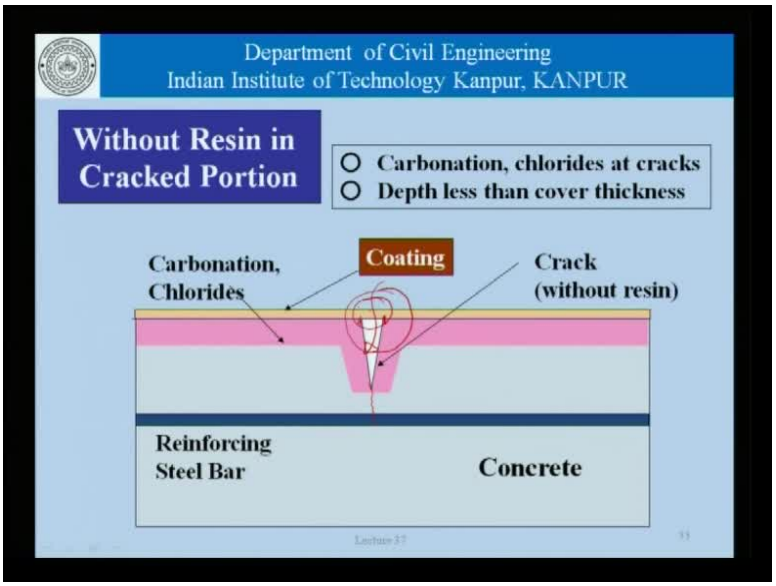

As far as corrosion related repairs is concerned and corrosion is indeed one of the most important and frequently seen mechanisms of deterioration and concrete structures, if the repair is not proper, we would always see corrosion occurring once again even after the repair works. So, if you look at some of the schematic representations of the kind of discussion that we had, we will have a crack which is formed here and this is a complete impregnation of the crack with the resin and find the application of a surface coating which could be resins resins reinforced with fiber and so on. In the case when we are not trying to do impregnation of cracks, we said that in certain cases when the cracks are not

very deep, we may not like to do impregnation specifically and only just do the surface coating.

Now, if you do only the surface coating what we shall remember is what is happening here, because of this width of the crack, this coating must have enough deformability to remain as a intact cover over the crack, and prevent material from going inside and that is what it designed for even when the structure is under load. So, these cracks have the tendency to grow and as they grow it is likely that this coating will fail and if the coating fails then the whole idea of repairing the structure is defeated and that is what we are addressing when we are talking about post repair performance of the structure the deterioration rates after the repaired process.

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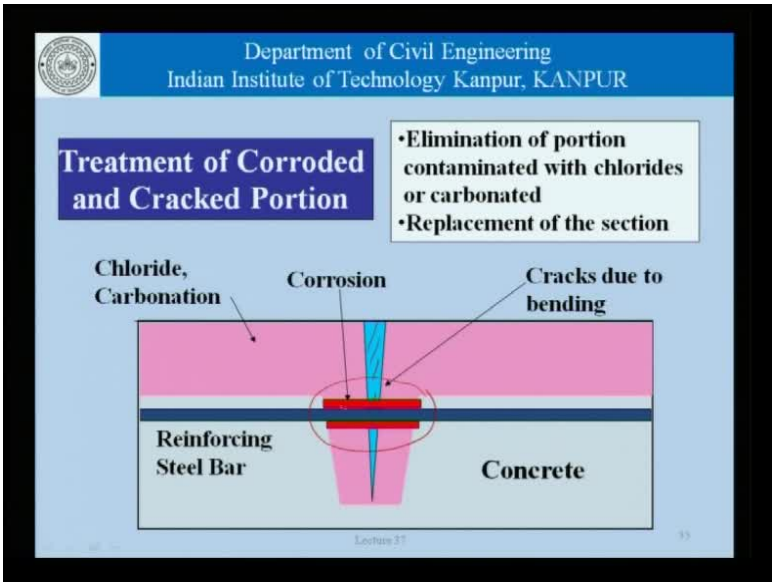

Now, this here is a representation of treatment of corroded and cracked portions in a concrete structure, corrosion being a most common cancer as far as concrete structures is concerned, if this is the portion of reinforcement which shows corrosion in the neighborhood of a crack what we would like to do is to eliminate portions contaminated with chlorides or portions which are carbonated and then replace the material there with something else as shown in this section.

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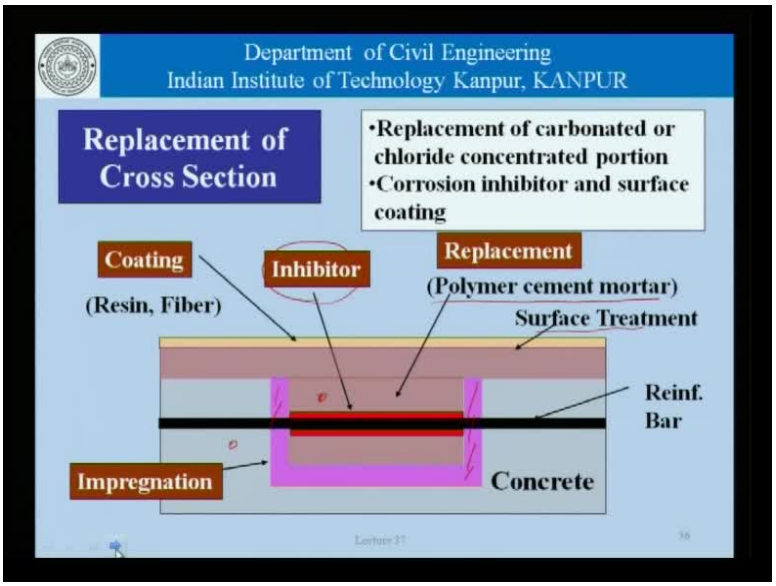

Instead of just trying to impregnate the cracks let the corrosion be, where it is and applying a surface coating, we are not going to get any benefit because the corrosion, root cause of corrosion is still is not addressed, what we really need to do? We need to remove all the contaminated portion around the crack, open the structure applying inhibitor on the reinforcing bars. So, that the corrosion can be effectively controlled and then try to replace the section with polymer cement mortar or any other material apply a surface treatment try to close this gap between the new material and the old material with the certain suitable material and then, and only then we can be show that the post repair performance of the structure will be good.

As far as application of resins on the surface is concerned, we must remember that the resins could be susceptible to ultra violet rays and therefore, we must keep in mind their deterioration over a period of time , when they are subjected to sunlight this has another example of a bad replacement versus a good replacement.

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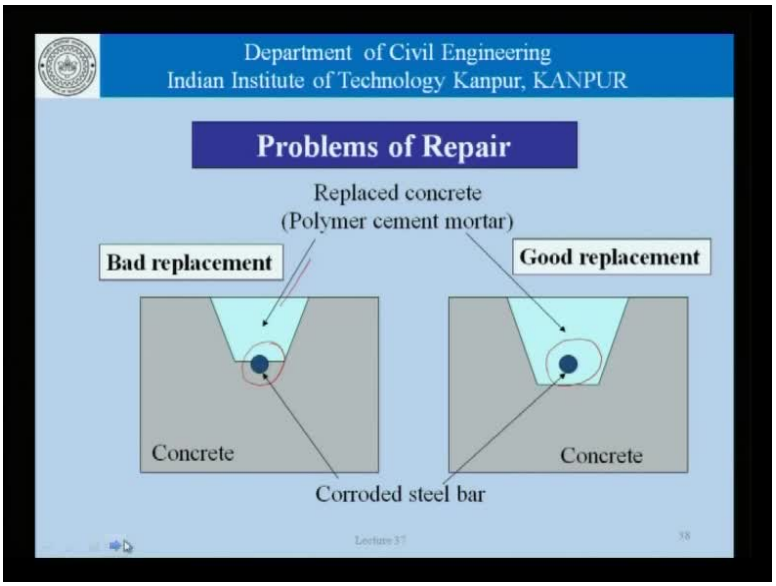

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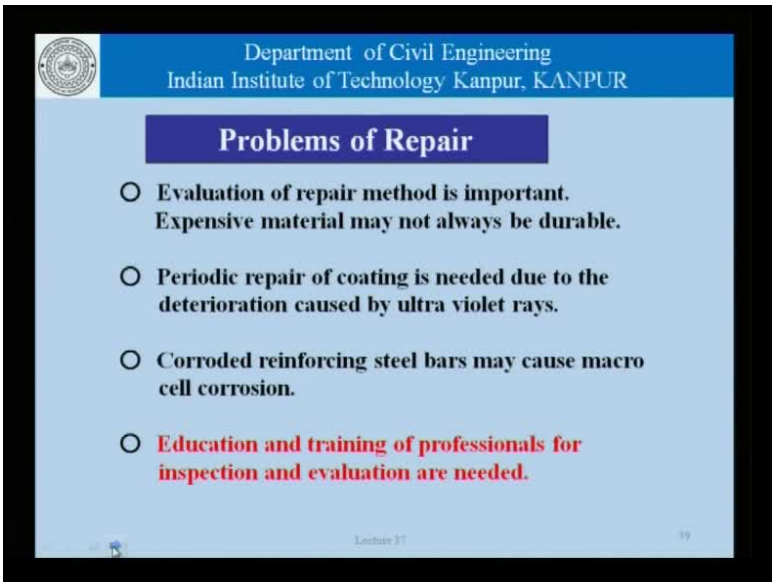

Where in this case the corroded reinforcement has not been fully exposed and no matter much polymer cement mortar, any other replace or any other repair material is placed here. It is unlikely that the structure is going to perform as required or as expected. It will happen only if all around this reinforcing bar, all around the corroded portion of the reinforcing bar concrete has been taken out and replaced with polymer cement mortar or the repair material of choice when it comes to problems as far as repair is concerned, we need to evaluate the repair material and the method.

Expensive materials does not necessarily mean that it is durable in all environments. Periodic repair of coatings is needed due to the deterioration that may be caused by a ultra violet rays. Corroded reinforcement steel bars may cause macro cell corrosions and education and training of professionals for inspection and evaluation is something which is very very important, and part of the objective of this discussion that we have had in this module of lectures has been to create an awareness among concrete engineers towards issues such as this that we must understand mechanism, we must understand mechanisms of material deterioration, How they are evaluated? How they are monitored what kind of repair should be used, whether the repair is going to be effective and so on?

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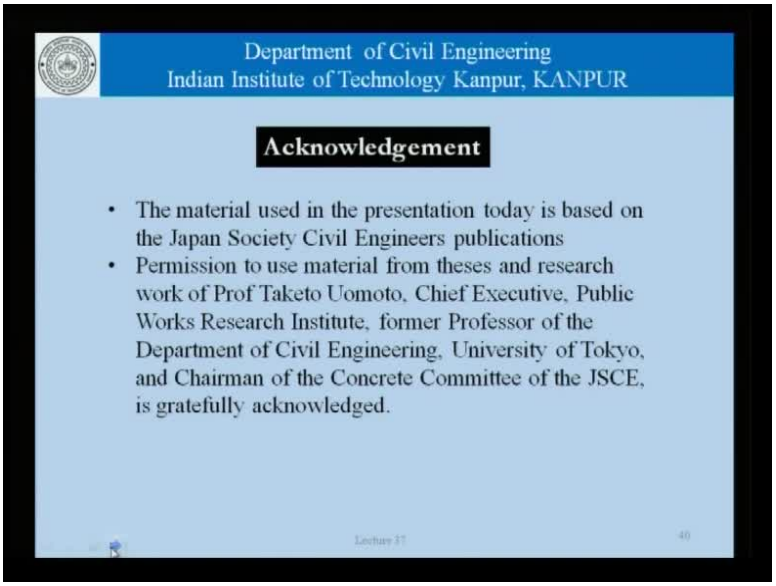

I must acknowledge the material that I have used today is based on the publications of the j s c e and I have the permission to use material from the thesis and research from professor Uomoto of the public works department and formally they professor at the university of Tokyo and before, we close we will have some homework, we could study the repair materials available for concrete structures that is something which we are not going to do in this discussion, we could try to classify some of the maintenance work that you see around during concrete structures into repair or reinforcement in the framework that we have discussed today, whether you feel that that particular maintenance action will be only in terms of delaying the deterioration process or slowing down the deterioration process or whether it has any structural merit.

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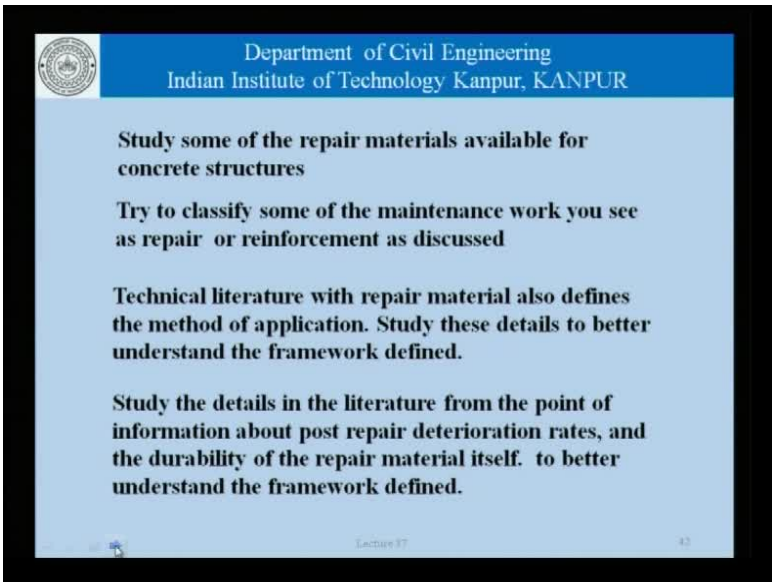

Technical literature with repair material also defines the method of applications, we could study these details to better understand the framework defined in terms of a combination of the material and the method, study the details in the literature from the point of view about post repair deterioration rates, and the durability of the repair material itself to better understand the framework defined.So, we have tried to put together today a conceptual framework ,we address repair and reinforcement of concrete structures within the framework of different iteration processes, and identifying or relating the maintenance operations to these processes and with this we come to a close for the discussion today.

Thank you.