Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 45
Retrofitting Steps

Hello students, welcome to the second lesson of this course on Retrofitting and Rehabilitation of Civil Infrastructure.

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In fact, the last lesson, we spoke about the different kinds of terminologies, the terms that we use, we also discussed about the steps that are required to be taken, for carrying out the retrofitting operation for any civil infrastructure project.

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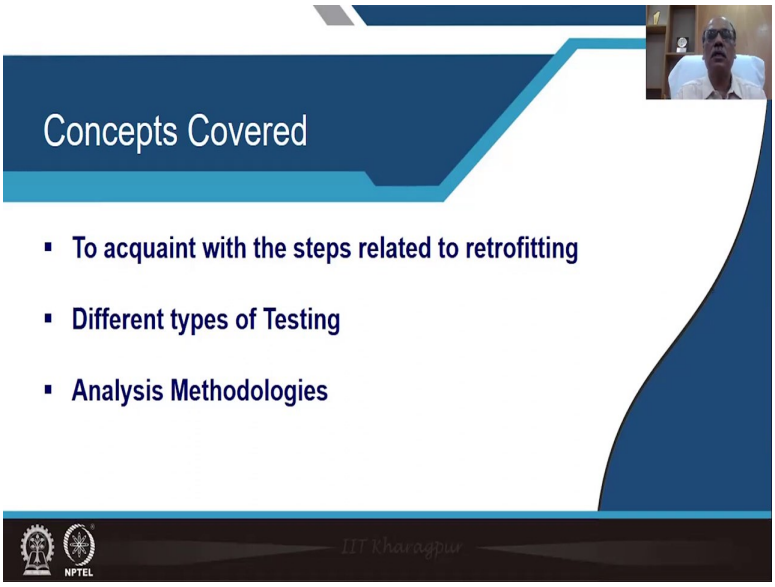

Now, in this particular lesson, we are going to talk about these steps in little greater detail, the steps that we have spoken about in the last lesson. We will see each one of them that how do we execute these steps, so, that we can arrive at the appropriate retrofitting measure for the structural systems. While doing so, we will look into the kinds of testing that are required to be done and also we will discuss about the analysis methodologies that we need to adopt to analyze the structural system in an appropriate manner to arrive at a conclusive decision.

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Well, just to recapitulate, what we did last time, in the last lesson. We spoke about the steps of retrofitting that in a generalized sense that we need to adopt for any structural system that

will be undergoing retrofitting operation. We need to review the existing construction documents, we need to carry out field investigations, we need to carry out the site visit and to the field investigations, we need to carry out certain exploratory investigations, we need to probe into it if needed, we can do little, destructive actions on the structural system to carry out the case that are needed.

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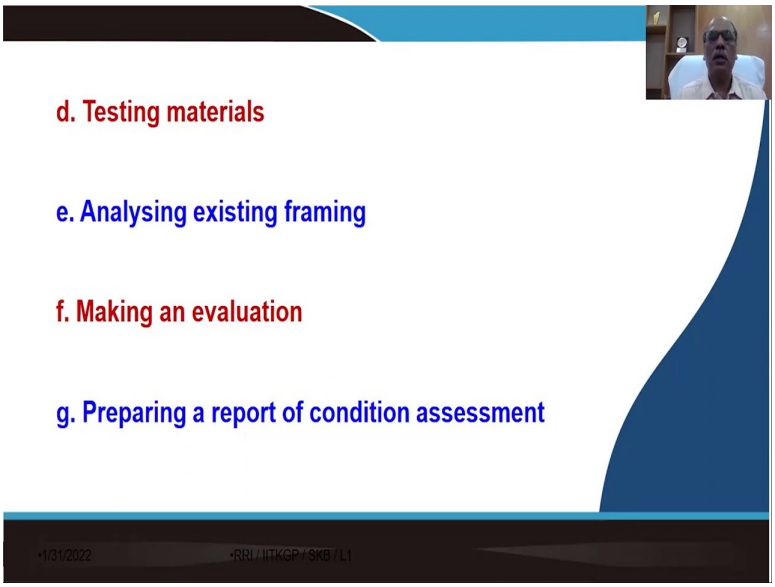

Then, during probing the materials that we collect, we try to test them in the laboratory. Alongside that, we also try to carry out the tests on the structure, so that we can get the correct information, we try to collect the data which we are going to analyze in an appropriate manner to come to a decision. In fact the next step which we say that analyzing existing framing, it talks about the kind of framework that has been adopted in the structural system and what are the kinds of loading that the structure was designed for? And what are the kinds of loading that the structure is undergoing at this point of time and try to analyze the system and make a comparison.

Alongside that we try to get the test results. So, combining these we are trying to make an evaluation. We need to understand the health of the structure, what was originally done here what was meant for carrying the load, what kinds of loads and the capability of the structural system. Which are these, what is the present status, what is the current status of the structure? What are the kinds of loads that it can carry at this point of time, if we apply the load as we had envisaged in the beginning, whether we are getting any over stresses at any point.

So we like to investigate Pro and come up and make an evaluation. Based on this evaluation. What we do is that we try to take a decision that whether retrofitting is required to be done. If retrofitting is required be adopted, what is going to be the cost involvement for such retrofitting? And as I had told you last time, if you remember that you know we take a decision whether we are going for retrofitting operation for the structural system, or we are going to demolish and deconstruct.

So, when we decide that yes, based on this preliminary investigation, we need to carry out the retrofitting. Parallely we need to understand what is the cost involvement in such retrofitting works. And thereby we take a decision. And then we finally prepare a report based on all these studies and give our recommendation. So, this is the first I would say the major step that is required to be taken up for retrofitting any structural system.

And if we decide to retrofit these structural system and then we need to look into in greater detail that what are the kinds of retrofitting measures those can be adopted to bring the structure back to its normal loading capabilities. So, that is what we will be discussing in this particular course, as we will go along. But right now, let me look into each of these steps that we have spoken about.

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In for arriving at a decision that whether the retrofitting is to be done or not. So, the first step, as I said that is reviewing the existing construction documents. Now, if you were told that well look this particular structure is in distress and please look into it, examine it and tell me that whether we need to go attributing or not. So, first thing that we try to look forward to is

that what are the documents, designed documents available for the structure, the next we need to look for, whether there are design calculations or what was the basis based on which the designs were carried out, what are the drawings, we normally call as build drawings.

The drawing initially are prepared for a structure, but during the course of execution, certain changes do happen. Now, finally, the drawing which is preserved are the drawings which was, are the drawings which were incorporated with those changes that were made during the construction stages, which we call normally as built drawing. The drawing which have been, which can be referred to as constructed of that structural part. So, we need to look for the drawings and that is very important.

And if there are any other information like time to time what happens is during maintenance of the structure, some kind of intervention do happen, which many a times may not be recorded in the drawings, but there could be some documents, which can say, yes, after so, many years of construction of this particular structure, some interventions had happened, either some additions were done or some repair works are done, certain kind of informations of that time, if they are available, that will certainly be beneficial.

So, we try to gather the data, we try to gather the information related to the existing structure, and there is the first step because if we have these documents, mind that, we will get large number of informations from this. Particularly, for reinforced concrete structural system, it will tell us, what are the kinds of reinforcements that have been used, how many numbers of reinforcements have been used in a particular element, what is the diameter of the bars.

So, all these detail informations can be extracted from the drawings, which is difficult otherwise. So, this step is very, very important. But, many a times what happens when we go for retrofitting an existing structure, we find that availability of drawing is really a question mark. Many a times we do not get it, and if we do not get it, then our job becomes a little difficult, then, if we have the drawings with us.

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We will talk about if we do not get drawings, what do we do subsequently?. Assuming that we have some set of drawings as-built drawings, we know, what are the things that have happened in the structural system and how the structures have been constructed? What are the materials have been used? What are the arrangements that have gone in into the structural system that we can establish from the drawings.

Second thing that we need to do is, we need to carry out the site visit, we need to carry out field investigation we would like to see in situ, how the structure is and that is a very important step, going to the site the structure has to be investigated. Primarily this is a visual investigation, you need to inspect each and every part of the structure, try to identify whether there are any distresses in the structural system. If there are distresses what are the kinds of distresses which are visible externally.

And we try to relate these distresses with the kinds of activities that can happen, certain distresses could be the result of something else. Now, again, if I compare that with the case of a human being, normally we say that, the person has fever. Now, fever is not actually a disease, it is the manifestation of some disease that has happened within some disturbances which has undergone inside.

So, likewise, if you see a crack in a building, it does not mean that, just like that, that crack has happened, there has to be something behind this. So, we need to understand that, why that

crack has happened in that particular place, what could be the basic reason, what is the root cause for such cracks to have appeared?

Now, many a times what happens, if you see a crack, you repair the crack, but then you find that another crack has appeared after some time next to that crack. So, what that means is that you have not addressed the root cause of the problem. So, what is important is that, we need to understand that, what are the kinds of distresses that have happened, and that is what is done during the field investigations stuff.

We try to understand that, if we have noticed certain kinds of distresses, then what are the tests that we can adopt, we suggest that the kinds of tests that are required to be done for that particular structure, whether we need to, if it is a reinforced concreting, whether we need to extract force from the concrete elements and test it for its strength, whether if the drawings are not available and if we do not know the foundation system, whether we need to dig.

Our soil adjust into the structure and try to find out what is the kind of foundation system has been adopted, so, many aspects evolve, when the site visit is done, or the field investigations are carried. So, we try to understand that what are the kinds of distresses the structures have undergone and try to come up with, right what are the kinds of tests that can be adopted for this structural system to take a conclusive decision.

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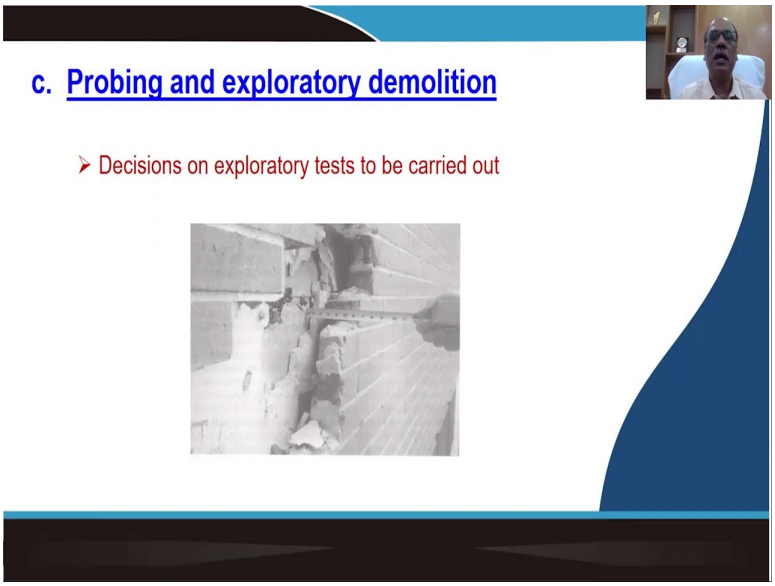

Thirdly, as we said that we need to have, probing or exploratory demolition these are necessary for the tests to be carried out as I said, that if we want that well, the earth adjacent

to the building is to be excavated to see what is the kind of foundation that has been adopted, so, that is a kind of a exploratory work that we need to do or if we want that well, this wall thickness we find that is varying at different places, can we make a small, destructive work in that and try to see how the walls are, whether the wall is a solid wall or there is some cavity within the wall.

These kind of things can be done with small interventions in the structural system. So, if we need to probe something, we need to decide that well, whether we should go for this kind of exploratory work, destructive work to measure certain parameters to come up with some benefits. So, this part is again very important to collect the information for the structural system.

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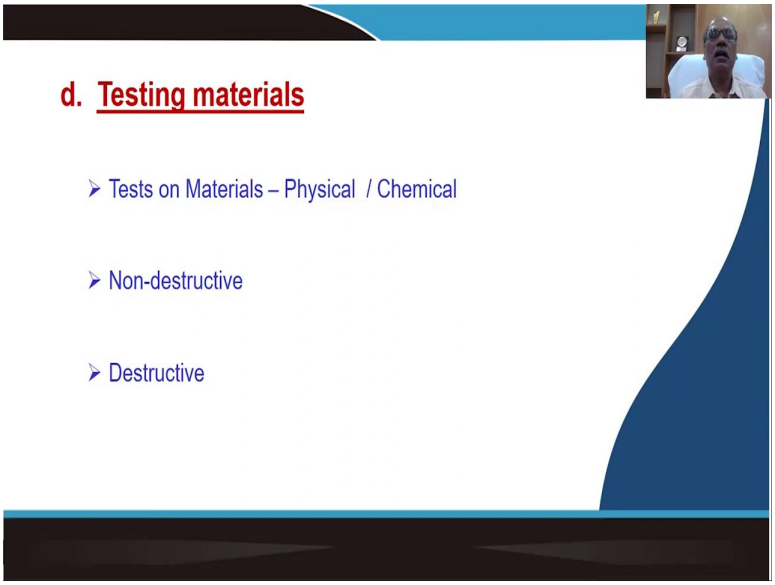

This step is important we call it as Testing of materials. Now, there are a few aspects into it. One is during probing or the exploratory demolition stage, we try to extract some amount of materials from the existing structural system. Now, the material of construction could be mason, it could be brick masonry, stone masonry, it could be reinforced concrete, it could be steel, it could be combinations of these materials.

So, we try to extract the materials for which we want to know the properties, if we are going for the analysis. In fact, we will have to go for the analysis of the structural system, and for that we need the material properties and that properties should be the present properties of the existing structural system. So, we need to establish those properties for which we need to extract some material and we need to carry out the tests.

The tests in the laboratory can be done either physical test or chemical test depending on the requirement. And for that we have to extract certain materials from the existing structural system. Also, alongside these on the structure itself, we do carry out certain tests to understand the status of different types of elements. It could be non destructive test or it could be destructive test and again we take decisions depending on based on the documents that are available based on the field study and understanding that what are the kinds of distances we have, we suggest that well, let us have some non-destructive tests.

And there are a series of non-destructive tests that are available, which we will discuss when you will go for specific structural systems and we will see that the number of tests or the types of tests do vary from system to system, but, in a generalized sense, there are a number of non-destructive tests that are available.

When we say non-destructive tests it means that we do not like to penetrate the structural system in any way and or demolish or remove some part of, so, these are non-invasive kind of testing system and from external services, we try to gather the data by adopting certain gadgets on it. There are other kinds of tests which are destructive in nature, when we say destructive it means, a small part of the structural system may be taken out from the structural system, and those can be taken to the laboratory for testing.

So, some type of destructive tests are also suggested, depending on the requirement and to come up with certain decisions, we may have to go for certain destructive tests as well. So, our testing part is very important and both in terms of material to establish the material properties as well as to establish the structural system, that how the system is whether all the elements are in good state or certain time sometimes we try to get certain qualitative data from the structural system.

How the structure really is, whether it is strong, whether the strength of the concrete is adequate to carry the load, certain qualitative parameter also we like to gather which helps us in taking a decision and as I said that, we can take combinations of non-destructive and destructive tests and based on these tests, we try to come up with a decision on what is to be done or the structural system.

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Our next step is extremely important, we talk about the analysis of the structural system, for this as I said that, if you have the drawings, it becomes easier, do you know what are the kinds of framing system that has undergone into the entire structures, if you do not have the drawings based on the field investigation, you will have to understand that what is the kind of framing system that the structure has and you need to analyze this existing frame system with the kinds of loading that it is subjected to.

Now, at this stage, you have aspects to look into, when you try to analyze a structural system, any analysis methodology that you adopt needs, the properties of the material that are required to be adopted, now knowing the kind of material that has been used for construction, you certainly can get the material data, but those data are basically as expected.

Or maybe when the structural system is new, you expect that the kind of properties will be applicable for the system. So, considering those property of the materials that have been used, you can analyze the system, which will give you as a benchmark solution, based on the analysis, you calculate, what is the amount of movement, what is the shear force, how much is the displacement that can happen, but that is your benchmark values.

Next, what you need to do is, you need to carry out analysis for the framing system or the structural system that exists with the properties that are existing at this point of time. And these properties of the materials we have already established or you have determined based

on the previous steps, you have carried out the tests. So, you know what is the existing property of the material that has been used for construction and also you will be knowing present kind of a loading in the beginning when you had analyzed the structural system you had designed ,you had constructed at that point of time.

Suddenly loading system was taken into account, but today when you are analyzing the system, whether you are taking the similar kind of loading or you are going for more load than what you had anticipated or you have changed the loading pattern that is required to be looked into. So, based on the present loading system and also kind of environmental loading, that the structure will be subjected to with the existing material properties, you need to re-analyze the system.

And if there are distresses in the structural system, it is expected that the response of this analysis is going to differ from the analysis results that we had obtained earlier based on the perfect properties of the material. So, these difference between the two analysis method or the analysis of the system, we try to find out that what are the differences that are happening and what those differences mean, how do we attribute those difference to what kind of problems that the structural system has.

So, this step is very, very important here you need to understand that, why certain difference is coming in the analysis result because of what reasons, and if we can identify that if we say well, we are finding that let us say the displacement of a particular point or the framing system at a particular point is differing by this much of percentage from the original deflection.

So, what that means is that certain parameters or certain system has gone wrong because of that, there is a change that is present. Now, you need to address that issue, you need to correct that particular part of the structural system so, that the displacement can be controlled and can be brought back to its original strength.

And that is where you need to understand that how are you going to adopt an appropriate retrofitting measure, so, that the strengthening of the system can be done, and the displacement parameter can be controlled. So, I spoke about displacement, but there are other parameters also, which are required to be looked into, and thus the reason this analysis stage is very, very important, and I presume that those who are attending this course, you are conversant with the different analysis methodologies.

We adopt normally the structural system that we are talking about, these are all three dimensional in nature, but then for the sake of analysis, we tried to transform them into dimensional system, two dimensional framework. So, you can go for matrix method of structural analysis or you can adopt finite element analysis to come up with, the output results that you expect.

So, you can discretize the member appropriately, apply the loading system and the member properties you will get because, you know the sectional parameters and all. And if you have the drawings, all the details that are available, if you do not have the drawings, then we know you need to carry out measurement at site based on which you will have to arrive at the properties.

And then you can carry out an analysis of the system by adopting any of these methods. In fact, at this stage, I am not going into the details of the analysis methodologies. And I presume, that you have the sufficient background and the knowledge of these kinds of analysis, those are adopted or analyzing in previous system.

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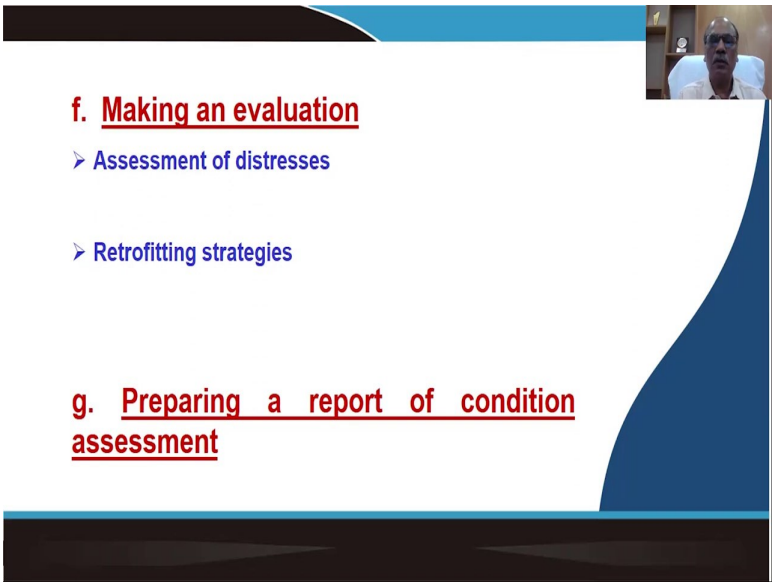

I said that, you need to carry out an evaluation, you need to assess the kind of distresses that have happened, based on your field investigations, probing investigations and the tests, so, based on all these, the collection of your visual observation, your observation of the distresses, testing the properties of the materials in the laboratory carrying out the test could be destructive, non destructive type and based on all these assessments you need to understand that what has gone wrong in the structural system.

As I said that the distresses is basically the manifestation of certain kinds of defects that have happened outside, certain kinds of weaknesses that have gone in the structural system, which are showing these kind of distresses. So, you will have to assess that part of it, what is the root cause of the problem for which such distresses is happening in the structural system.

So, if we can identify that, if we can identify the root causes of the problem, say for example, if you have seen a crack in the wall and the cracking in the wall is kind of an inclined crack, and then you start looking into that, whether that wall has any settlement or not, if there is a settlement and actually the, you expect that kind of incline cracks to come or let us say if we have a beam, and in the beam you find that at the bottom is there are vertical cracks in the web.

Now, if you test a simply supported beam with two point loading, you will find that, between the loads, the moment is prevalent and that is no shear, cracks do generate in terms of vertical cracks. So, what it means is that if you have vertical cracks there the moment is the dominant parameter and because of excessive moment those cracks up generated. So, you based on certain data that you have already you try to extend those knowledge to understand that why those distances arrive.

So, if you get to know these distresses, then it becomes easier or if the root cause of this problem, it becomes easier to identify the kind of retrofitting that you are willing to adopt, if you say that well, the walls have cracked because of the settlement of the wall, then what you need to do is that you need to adopt a methodology by which the settlement of the wall can be arrested, if you can do that, if you can strengthen that, then you after that, if you repair the crack, it is expected that no further crack is generated, if there is no settlement.

So, likewise, you need to take into account that what are the kinds of distresses happening and what are the connected root cause for them and address those root causes in an appropriate manner. So, that the structure becomes correct, it can be strengthened in an appropriate manner it can carry the load. So, that is where, you need to adopt certain strategy that how are you going to retrofit the structural system, which are the elements that to be retrofitted, how those are going to be retrofitted?

What are the correcting measures that you will be adopting, those of course, are the further assessment on that. So, at this stage, based on all these aspects that we have done through these steps, we try to prepare a report that yes, this is how we have gone into, we have

collected the documents, we have carried out the field studies, we have carried out ,we have collected materials, we have tested them, we have analyzed the structural system, and then by evaluating all these, we find that the structure has distresses of these kinds and these distresses have happened because of these kinds of problems in the structural system.

And we need to safeguard the structures against such actions by adopting this means, and this is how this is to be done. So, this gives us a complete reporting of the investigation of the structural system. Once we do that, once we know this and once we have identified the causes of the problem and subsequent to this is, we need to think there are larger number of solution methodologies are available for tackling problems of different kinds, which we will be discussing as we will go along or different kinds of structures system that how do we adopt those methodologies now, so, that the structure can be corrected and can be retrofitted in an appropriate manner.

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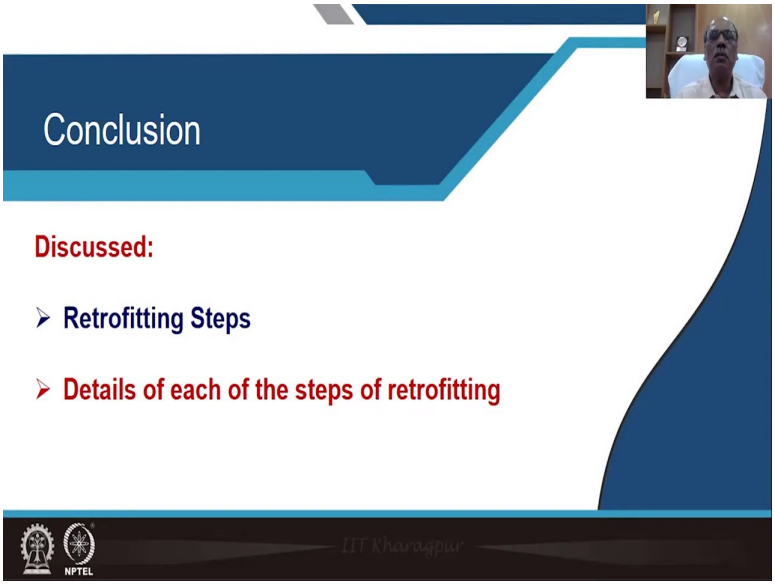

So, basically, in this particular lesson, what I had intended to, is to discuss about the steps that we need to adopt and these are very important mind that, that steps that we need to go through systematically to diagnose the problem in the structural system. And if we decide that yes retrofitting is to be done, then what are the kinds of retrofitting measures that can be taken and so, that, that can be adopted in the structural system subsequent.

So, what I am going to do next is that we are going to talk about the what are the kinds of retrofitting measures those are existing for different kinds of system, how they can be adopted, and they can be adopted effective.

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So thank you for this particular lesson. And, again, we will come back and we will discuss more on this as you go along into the course. So, thank you very much. And, and well, we look forward to the next lesson.