Retrofitting and Rehabilitation of Civil Infrastructure
Professor Sriman K Bhattacharyya
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Lecture 44
Introduction

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Hello students welcome to the course on retrofitting and rehabilitation of civil infrastructure. Well, I am Professor S. K. Bhattacharya from the Department of Civil Engineering at IIT Kharagpur. If you have any doubts and if you want to reach me, you can contact me through my email address, which is given here as bsri@civil.iitkgp.ac.in.

Well this particular course is useful and important for the students or the practicing engineers, particularly having background in civil engineering, those who have done their graduation in civil engineering or practicing civil engineering, maintenance of structures, either civil engineering or any other allied areas in construction or other related fields, I think this course is going to be useful for them.

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To start with, we are going to talk about review and overview of the course. And many times, we do come across different terms when we talk about restoration, rehabilitation, retrofitting of structural systems. So, we will try to understand what is the meaning of these terms? Why do we need to retrofit a structural system what is the purpose, and then we will look into what are the steps that are necessary for retrofitting a structural system? So, we will try to cover these aspects in this particular lesson. And we will see more and more into it as we go along into this course.

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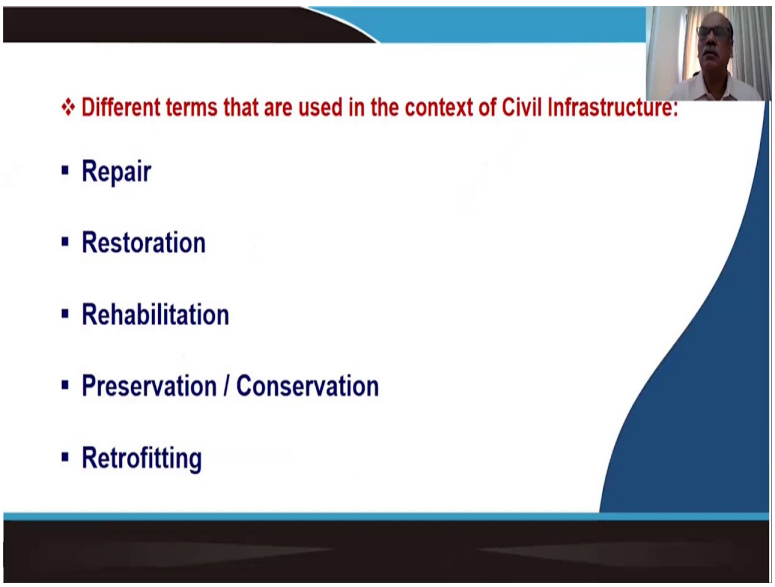

So, let me talk about some of the terms that we do come across in the context of retrofitting of civil infrastructure system. I am sure you must have heard of the term called repair. Repair

is a term that is very commonly used for repairing different kinds of systems. In civil infrastructure, when we find some kind of distresses, some kind of adverse situations or some elements which are not in order, which we like to bring them in order by going through some process which we call as a repairing process.

Let me give you an example, which we mostly use in our common day use. Let us say you have a wooden chair with four legs and with two arm rest. And let us say one of the arm rest is having some difficulties, either it has loosened up, because the connection between the horizontal and the vertical members have given away, so by fixing that in an appropriate manner, the job comes to an order.

So, by fixing that, what you have done is that, you have done some repairing of that chair. Similarly, in case of structural system, now, you might see some kind of cracks that are happening, which may not be a structural crack, may not be because of any structural distress as such but it could be kind of superficial crack, or in some places, let us say the plaster has peeled up. So, you like to address those kinds of defects in the system, and those we normally call as repair.

Very frequently we come across a term called restoration. We need to restore a system back to its action,that is the meaning of distress. Again, if I take the example of a chair, let us say that one of the legs of the chair has sheared off at a particular location. Now, naturally the chair cannot be used, because the leg has lost its strength in getting the load, but if we fix that shearing of that leg by suitable connections by employing maybe some external element to it on the existing system, the chair can be put back in action and it can be used.

So, what in effect we have done? Is that we have restored the chair for its use. Similar kind of situation you can come across in the civil engineering structure, you might find that you know some parts of a structural system has shown sign of distress, which if you fix it locally, the old structural system becomes effective and can be used effectively to carry on the transport load.

So, if we take such kind of actions, we normally call that the restoration of the system has been done. Many times, you will be hearing that we talk about the term called rehabilitation., if we want to rehabilitate a system, you need to carry out the repair restoration action that we have spoken about, but it may so happen that you can rehabilitate its system by employing another element not necessarily from the same kind of system with which it exists.

Say, if I take the example of the chair again, let us say one of the legs of the four legs is broken, and if we want to make use of the chair, we can replace that leg with some supporting material, it could be some other material not necessarily from the similar kind of material with which the chair has been created, but the system can be brought back in action. So, similar thing we can do in structural system, we can rehabilitate a structure by employing suitable methodology, bringing in some other structural element with it and restore the whole system or rehabilitate the whole system so that the structure can be put in use.

So, that is the kind of action that we take, we call that as a rehabilitation of the structural system. Many times, we do hear, the terms called preservation or conservation of structural system, and these are particularly pertinent or usefully for the structures which are normally called as a heritage structure, the structures which are old, surviving for a longer period of time, but have shown several signs of distresses at different places.

Now, there are two ways of looking at it, we can preserve those kinds of heritage structure by suitably intervening in the system and it means that we can repair, we can restore, we can rehabilitate and preserve the system. Many times, you will find that the architectural communities, they will prefer that a system which was built with a material in the past, fabric of it, should be retained as it is without bringing in different kinds of materials in the system.

And if you want to do that, then it has to be retained in its form as it is without intervening much into the system. Either similar kinds of materials are available today which can be used or if the material is not available, we do not put any other foreign material to it. But we like to conserve the system as it is to the extent possible so that the heritage of the system can be ensured. And that is where we use the terms called preservation or the conservation of the system.

When we talk about retrofitting, retrofitting a structural system can be for different purposes. If a structure has shown the sign of distresses we can attend to it, we can intervene in the system, we can adopt the repair methodologies, the restoration methodologies, the rehabilitation methodologies, the methodologies that we have talked about in those cases. So, that the structure can be strengthened and can withstand the load for which this is designed or for which now we are trying to use it for the loading system that we intend.

Now, retrofitting thereby does not necessarily mean that we need to only carry out the rehabilitation when there is distress, retrofitting can be done in a structural system, even if it

is not distressed, but we want to upgrade the system. If we feel that the structure was designed for some loading, but eventually we want to go for higher loading in the system and then we try to check in that which are the elements which are going to be overstressed because of the additional loading and those elements we try to strengthen them by bringing in some other element into it, so that the structure can withstand more load.

So, retrofitting is a process which can be done or which is used in back either for strengthening or distress system or strengthening and existing system which is otherwise weak and to take more loads. Just to give you an example in this context infact the Indian standard code IS-456 is used for clean and reinforced concrete. In the earlier version of this code the minimum grade of concrete was stipulated as M-15, but, in the present code, the revised version, talks about the minimum grade of the structural concrete has to be M-20.

Now, the question that arises is that the structures which were designed and constructed based on the earlier code, wherein the minimum grade of concrete was M-15 for structural purposes, should those structures be demolished and not to be put in use? Or what are the actions that are needed for such systems? And that is where possibly the retrofitting comes in.

We need to look into that if we analyze those structural system from the present-day loading perspective and try to see that whether the structure can serve the purpose as per the requirement of the present codal-provisions then, what are the actions that we need to take, which are the elements that are required to strengthen, so that we can use them effectively for the loading that we are going to use today with the stipulations of the present orders provisions.

So, to do that, we may have to take certain actions, we may have to strengthen some of the structural elements in an appropriate manner. And if we do that, then we will say that, yes, we have retrofitted the structure to make it effective for the present-day loading system. And in fact, in this course, we will be talking about more of such things, that how structural systems can be retrofitted using appropriate methodology, using appropriate materials, using appropriate technology, so that the structures can be strengthened can be upgraded for proper uses of the system with appropriate loads.

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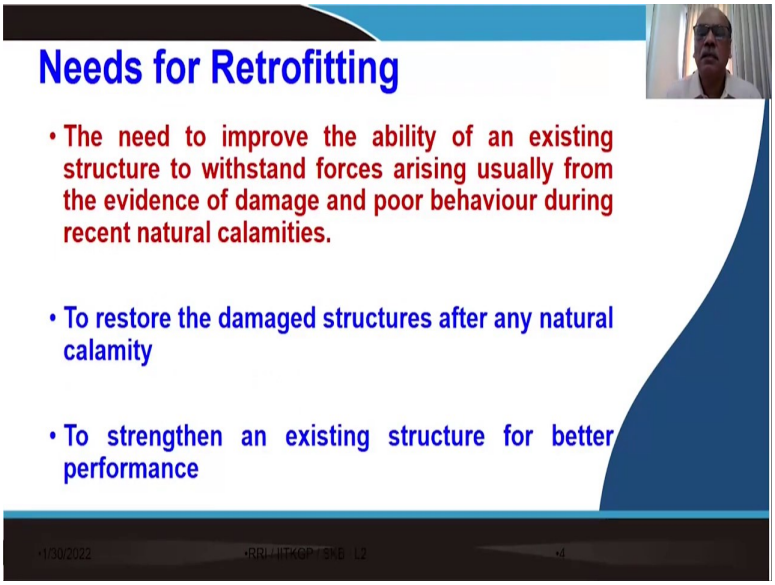

Thereby, the question that come that, what are the needs for the retrofitting or where we tried to adopt it to fitting in the system? The need to improve the ability of an existing structure to withstand forces arising usually from the evidence of damage. As I said that, if you find some amount of distress, damage in the system, you try to repair that damage in a manner where the structure becomes fit to carry the load.

Or, sometimes you will find that because of natural calamities which occur very frequently, see in terms of earthquake or cyclones or flood, for several reasons, the structure can undergo distress and each structures undergo distresses for such reasons, then once the calamity is over, you need to look into the structural system, you need to understand that distresses and you need to go for retrofitting, so that the structural system becomes usable the way we need.

Also, as I said that, to strengthen an existing structure to carry more load, as per the present-day requirement, we may need to intervene and thereby, we need to strengthen some of the structural elements so that the structure is made usable. And that is where the need for retrofitting comes in.

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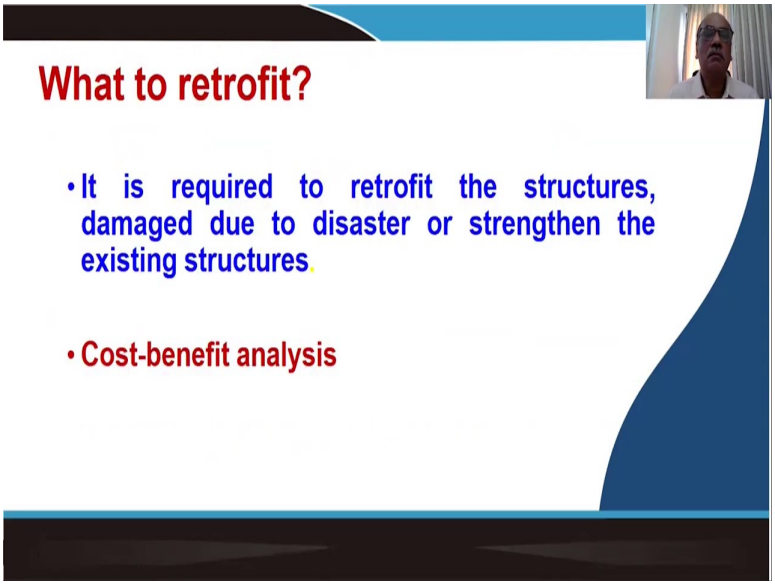

Now, the question that comes is that how to adopt the retrofitting measures, and which are the structures that we can retrofit? Looking into the structural system, if you find that distresses have happened to such an extent that you need to take a decision, that are you going to retrofit the structure or you are going to demolish and reconstruct?

And that is where I think your role is important, you need to assess, you need to analyze that if you have to, say for example, there is a natural calamity for which some of the structures have undergone severe distress and you are called to examine the structure and give your input that what is to be done for the structural system. Are you going to retrofit it, rehabilitate it, or you want to demolish it and reconstruct?

Now, to do that, you need to do or carry out a systematic study based on which you can say, yes, this structure can be retrofitted in this manner, or else you say that, well, this structure has gone to such a damaged state that is very difficult to retrofit and in the process it requires demolition. Now, when we say it is difficult to retrofit, what I mean is, see that way, nothing is impossible to do it, but question that comes is at what cost?

Now, if you try to retrofit a structural system, for which you have to spend huge amount of money, which is as good as going for the new construction, then the question comes that, is it wise to go for retrofitting structural system, or we should reconstruct? And that is where you need to carry out the cost benefit analysis. That means, if after assessing, you find that if we have to retrofit the structure, the cost involvement for retrofitting such structural system is

going to be x and if that x happens to be more than about 60 percent of the cost of the new construction, then it will be wiser to go for new construction rather than retrofit.

Then the point is that when you are going to retrofit a structural system, certainly you are going to strengthen the structural system, you are going to upgrade the structural system, but any intervention, and this has to be kept in mind, any intervention that we do in a structural system, certainly it cannot be made as good as a new structure. Certain amount of inbuilt stresses gets generated which we call residual stress, which always we cannot remove and as a result, the retrofitted structure cannot be considered as good as a new constructed structure.

So, from that particular perspective, from that standpoint, you need to look into it pragmatically and see that if the cost of retrofitting action for the structural system is expected to be more than about 60 percent the cost of the new construction, then is better to suggest that go for new construction, demolish the structure, rebuild, rather than going for the retrofit. But, if it is otherwise, then possibly it will be prudent to go for retrofitting and upgrade the structural system, so that the structures can be put in action.

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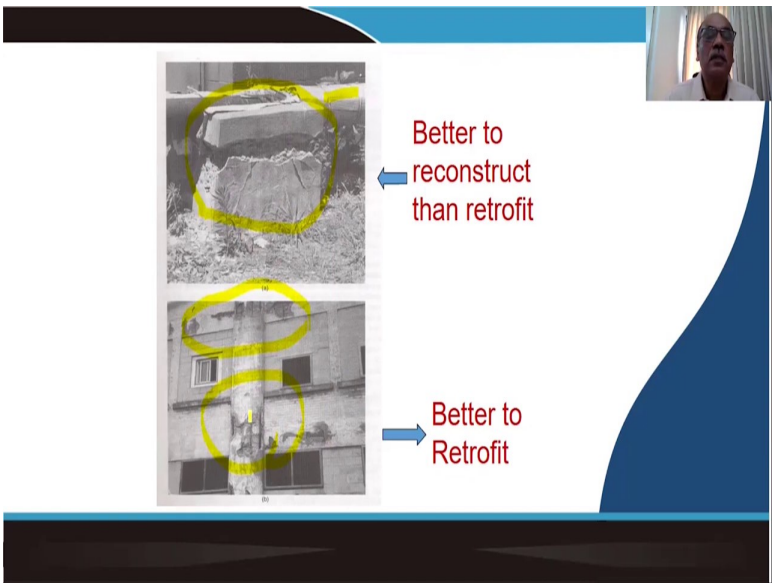

Now, here I have given you two examples, you can see that. See this is the structure, it is a support, is a kind of a supporting system for the pipeline, which is going along this. Now, you see here this support has undergone some kind of distress, and the distress is such that two parts have been actually separated out, you can see this, this top part has been separated from the system and it has gone up.

Now, in such cases, if we want to retrofit this supporting pedestal. The cost for this is going to be substantially high. Possibly in such cases it will be prudent that we demolish this system and reconstruct and that will be easier and costly. In contrast to that if you look into this particular building system where you see that some part of it has undergone distresses in the columns, in the wall, the beam, and if this distresses if we look into it, this certainly can be repaired, can be strengthened, can be upgraded to take care of the additional loads.

And in such cases the cost that is going to be incurred in the system is not going to be that prohibitively high when you compare with the new customers. So, if I make a comparison between the two systems, just to give you an example, I would suggest that yes, for such system, where the cost is going to be high the system, by retrofitting we are not going to get much, we discard it and reconstruct it. Whereas for such systems, for such building structural system, where we find that, we can apply certain repair methodology, we can bring in some additional element and strengthen the structural system, we can retrofit the system.

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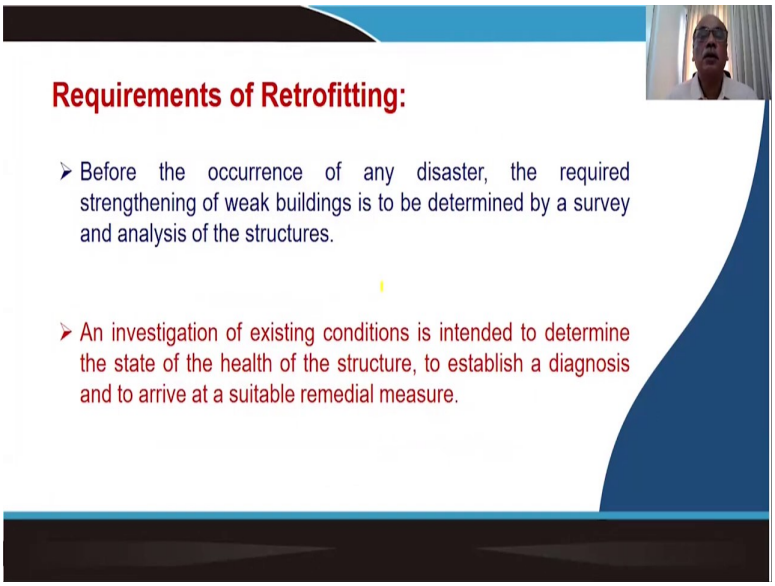

Thereby, what are the requirements of retrofitting? Normally, we try to do some kind of maintenance activities on the structural system, periodically we try to look into and thereby what we say is that, time to time we are strengthening it. So, before any disaster happens, before any natural calamity happens, if there is some weakness in the buildings, it will be better to strengthen them and this has to be done by careful survey, analyzing the system and understand them.

Now, if we have to do that, because when we say that the building is weak, now, how do we know that the building is weak? So, what is needed is, we need to understand or investigate the existing condition, so that we can try to understand how is the health of the structure and that is where the term called health monitoring comes in.

We take any structural system, we try to investigate this present status, present condition and if we find that yes, there are certain weaknesses in the system in terms of desired load carrying capacity, then we will go for certain methodologies, certain steps by which we can adopt the retrofitting. So, all we need to do is that, we need to diagnose a system, again, can be compared like the health monitoring of a human being.

When you have some difficulties, go to a doctor, doctor checks certain aspects, from external aspects on your physical systems, and then subsequently they do prescribe certain tests to be carried out. So, for us, for building, for structures we carry out the similar kind of thing, if we have to diagnose that, yes, there are certain difficulties in the structural system, we need to carry out certain investigations and try to understand how the present state of the structure is and what are the kinds of interventions that are necessary, so that we can adopt those interventions in an appropriate manner and we can adopt the retrofitting measure in the structural system.

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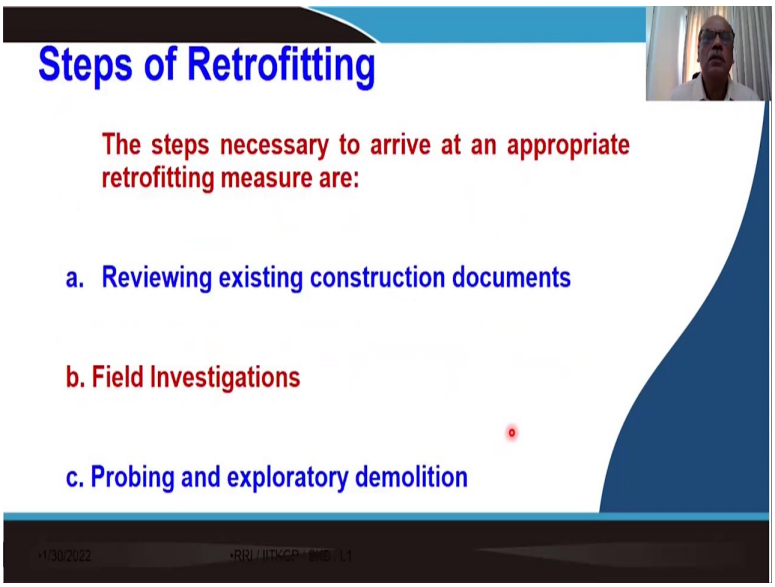

Now, to carry out this retrofitting, normally, there are a few steps that we need to go through. What we need is, we need to look into the documents that are available, when we look into a an existing structure, there is a building, or a bridge or any other civil engineering structures

that we are talking about, we try to find out that what are the existing documents that we have. At first the main existing document that we try to forward to is the drawings, the drawings with which the structure was constructed.

This is the first thing that we should do that if the drawings are available, then if it is good, then you can look into it that what are the kinds of systems that were adopted? And that we will talk about the basic things of the whole structural system. But unfortunately, many times the structures when we try to see which have undergone distresses, and if we try to look for the existing documents, the drawings, we do not get that and that is where difficulty comes in.

Because when we are trying to say that the structure has undergone distresses, has undergone damage, what are you mean is that, damage is nothing but is the difference between two states that means, the how the structure was in its original state, and what are the changes that have happened over a period of time, because of certain actions on the structure? What are the differences, what are the changes that have undergone? If we can assist that, then we can see that what are the kinds of deterioration that have happened, what extent it has happened, and then we can identify, yes, some amount of damages to the system.

Now, to establish those we have to proceed very systematically, we need to go and look into the structure which we call as a field investigation, we carry out visual survey, we try to look into the different aspects, the different distresses that the structure has undergone and then from our basic knowledge, we try to correlate that this distress can be called related with this particular actions.

So, based on field investigations, we try to carry out certain investigations and come up with some conclusions. We need to carry out some amount of probing for which we may have to demolish some part of it, to understand the behavior, to understand the properties of the materials that have gone in into the structural system. So, we need to carry out investigations, we need to carry out probing and exploratory demolition. And I use the term demolition it could be locally for some material we want to extract for chemical analysis for physical analysis.

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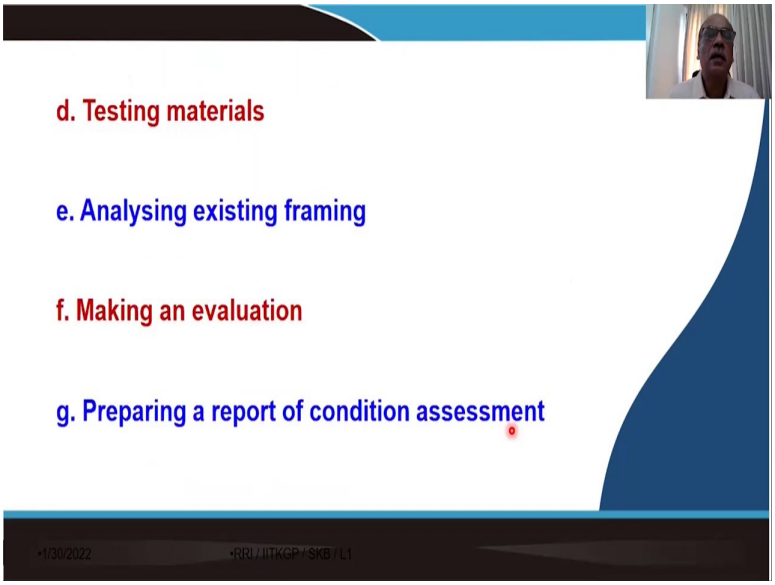

And then we need to carry out certain testing, then after carrying out the field testing, after collecting the material, we come back to the laboratory, we try to test certain materials to understand the present characteristics, present properties of the materials. Also, while carrying out the field investigations along with the documents, we try to understand what is the kind of structural system that has been adopted in the structure?

So, with that system and with that loading we try to analyze it, we try to adopt different analysis methodology to understand that what are the kinds of stresses that are getting generated because of the loading. And from the field measurement, we try to understand we want to correlate between the analysis and the testing. And then we try to make an evaluation that this is the existing status, it is the expected status and what is the difference between the expected status and the existing status.

If I find that there is a difference, there is deterioration, substantial deterioration, then the question that comes that we need to strengthen it, we need to retrofit it. But, how do we retrofit it, that is a question, that we look into for different elements, for different material, for different conditions, we have different types of systems we need to adopt, will go into those details, we will look into it.

But first thing is that, these steps we will have to carry out to come up with an inference that whether we need to carry out the retrofitting of the system and if it is to be carried out, how it is to be carried out? So, we prepared a report for the assessment of the condition of the structure, how the condition is at present.

And if there are distresses or deterioration in the system, then how are we going to retrofit it? What are the retrofitting measures that can be adopted, and how those retrofitting can be done? So, that the structure can be brought back to its original state, so that it can carry the load or which the structure has been designed.

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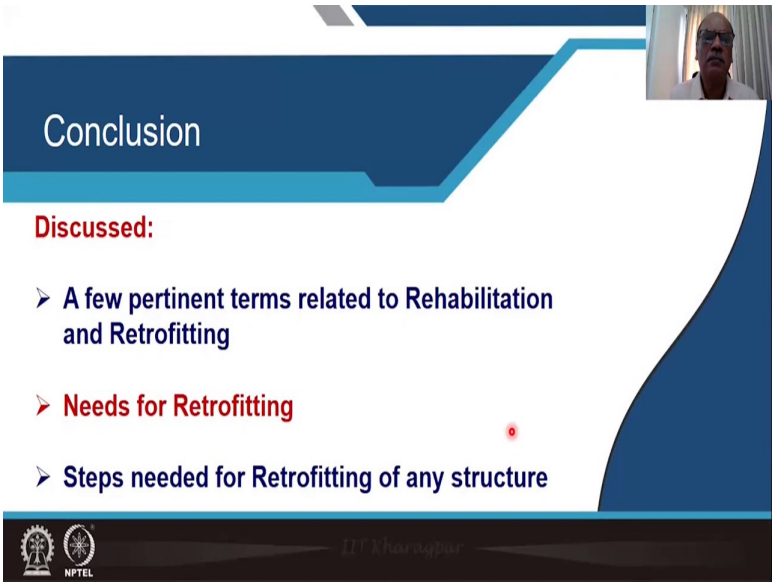

So, in this particular lesson, what I intended to do is that, I wanted you to get acquainted with the few terms which we normally use in connection with rehabilitation or retrofitting and what are the needs for retrofitting, why do we need to carry out retrofitting in structural system, and certain basic steps that are needed for retrofitting any structure.

Now, what I intend to do is that we need to go into the details for each of these steps, and the details of the steps that we have spoken about. And to understand that how do we adopt these steps to examine or investigate an existing structural system to come up with the retrofitting measures that are required to be adopted? And the steps that we need to take for retrofitting a structural system. And this is what we intend to continue in the next lesson.

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Thank you. And we are going to discuss again these steps in greater details in the next lesson. Thank you very much.