Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 48
Some Aspects of Seismic Retrofitting

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Welcome to the 5th lecture of the module, which is on overview. And you have seen so far, we have discussed several aspects on the steps that we need to take for carrying out the retrofitting operation. And in the previous lectures, we have spoken about different aspects and in this particular phase or in this particular lecture, I like to talk about some aspects of seismic retrofitting.

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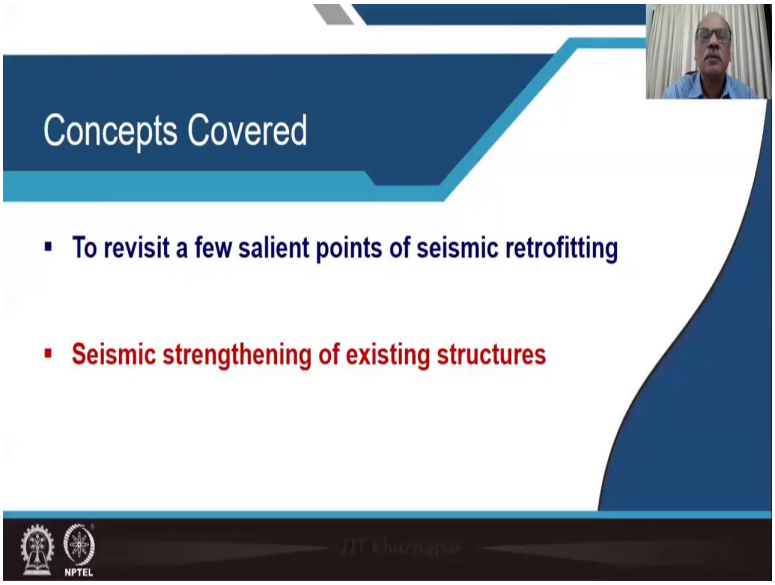

I expect that, once you go through this particular lecture, you will understand certain salient points that are required to be taken up for seismic retrofitting. And for the distinct structure, how do we strengthen them, so that they can resist the seismic effect in an appropriate manner?

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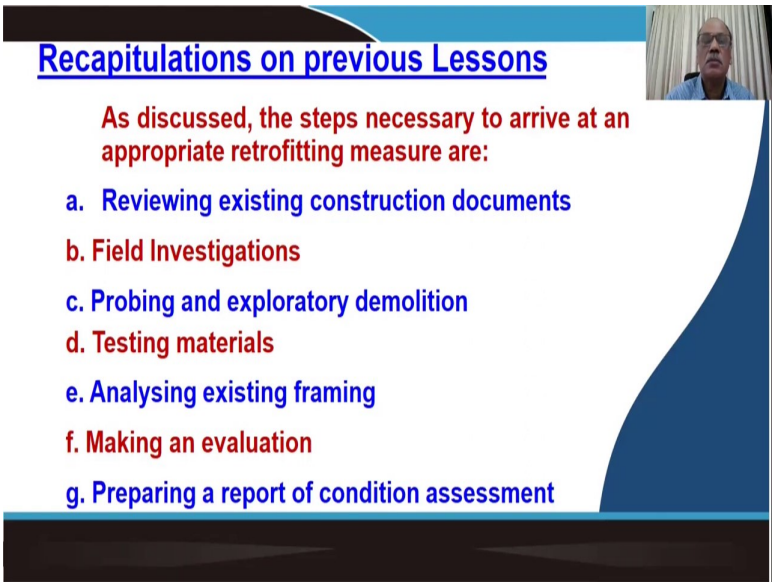

Now, the question that comes is what do we mean by seismic retrofitting? In fact, we have spoken about in the beginning, that the structures are exposed to different kinds of loading systems, including different kinds of environmental loading systems. So, we get different kinds of natural calamities and earthquake is one of such calamities in which the structures are exposed to. And thereby, because of earthquake we have seen in the past, that structures do undergo different kinds of distresses.

So, when we talk about seismic effect, it means the earthquake effect, for which the structures are affected. And if the structures are damaged or distressed, how do we take those structure into account to retrofit. Now, I am showing you this particular slide again which I have shown it you on earlier occasions as well and you must have noticed that we are looking into the different steps in stages in a detailed manner and the steps of retrofitting that are necessary in a systematic way and this we have spoken about again and again.

And in the last lecture, we have discussed about the analysis method, namely the matrix method of structural analysis and I have explained to you that, how matrix method of structural analysis can be made use to analyze a structural frame in two-dimensional plane or different kinds of the loading systems that the structures is exposed to. Along with the

member property or the structural property that the structure has at present, which we can get the information through the measurements.

And as I have told you that there are several test procedures, which can be adopted into the structural system and looking into the structure by visual inspection and if we can identify some distresses and if we decide that yes, we need to carry out these kinds of tests. So, we carry out the tests, we gather the data and try to make use of those data in our analysis procedure. And thereby, we try to frame up that what kind of distresses the structure has undergone and based on that, we try to frame up that what should be the retrofitting measures that should be adopted?

And I have told you also that when we talk about retrofitting, we try to look into two scenarios, and what are those two scenarios? Scenario number 1 is that, the structures which look a little vulnerable, and if they get exposed to kind of natural calamities, which we are seeing here as an earthquake, there is a possibility that the structure may undergo damage now, so, those kinds of structures are vulnerable against earthquake.

Now, how do we know that? To know that we will assess, we will have to make an assessment. And if you remember that in the beginning, I had spoken about that, in earlier days when IS-456 was there prior to this reason and the suggested grade of concrete was M-15. But now, as per the revised code that suggested minimum grade of the structural concrete is M-20.

Now, the structures which were built with M-15 grade of concrete, which were designed as per the earthquake provisions, which were there in the previous code, which is because in the revised code, we changed the zones and all. So, the structures which were designed earlier, if they are required to be used in an appropriate manner in the present context, then what are the kinds, what are the deficiencies that we find in the structural system, and how do we strengthen them in such a way that it can carry the load as we need the present day?

So, this is one aspect that we are trying to look forward to, and the second aspect that we are trying to look forward to is in the event of any earthquake in a particular area, the structures do undergo damages and if the structures are damaged or distressed, then how do we retrofit them in an appropriate manner, so that those structures can be used again? So, these are the two aspects that we are trying to look forward to.

And when we are talking about seismic retrofitting, what do we mean is that, particularly with reference to the effect of earthquakes, what are the things that do happen? How do we identify that, how do we look into in those aspects and what are the spatial aspects that we need to look forward to when we are talking about the effect of earthquakes and the corresponding retrofitting measure? And that is what we intend to discuss in this particular lecture.

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So, when we are talking about seismic retrofitting, what we strategize our actions, and when we try to strategize our actions, what we say is that, in the event the earthquake has happened in a particular area, we need to quickly make a survey of the structures, whether they have undergone any distresses or damage and if it has got damaged, what kind of damages have happened in the structural system? So, we try to categories the different structural system, and then we say that, we need to immediately pay attention to those structures, so that they can be retrofitted in an appropriate manner and can be put to use without losing much time.

So, which are the structures that we need to look into, which are the facilities that we need to look into? First thing is that, post-earthquake emergency facilities. So, the facilities which give us supply, regular supply to run the daily life. So, those facilities are the emergency facilities and those must be touched immediately and should be, it should be intervened without losing any time.

Lifelines, there are some structural systems, I will show you the kinds of structures that we call as lifelines normally, and those lifeline structures are to be attended to without losing

much time, because otherwise the life will come to a halt. So, we need to look into those very carefully. Apart from those, once lifeline structures or the emergency facilities are undoubtedly the areas where we need to pay our attention to.

Apart from that, there are structures say which are unreinforced masonry structures, many dwelling houses the residential of buildings are made out of the brick masonry system and normally they are unreinforced. So, those do undergo a damage because of the earthquake, because they do not have much of lateral load resisting systems and as a result the cracks do generate, some part may fall down. So, we need to look into those structures and also, we need to attend to them in an appropriate manner.

Also, we need to look into the aspects of the cost as well. The structures which have undergone damage to a large extent, where your retrofitting will be expensive, those aspects, because arrangement for the finance also is one aspect that is to be looked into. So, what we do is that, we can group structures, the structures where with less investment, we can repair or retrofit them immediately.

So, we identify those structures that which can be with little intervention can be put to use. So, we say the buildings which are less expensive to retrofit should be targeted immediately, so that they can be retrofitted and people can be rehabilitated in those places as quickly as possible. Then the kinds of structures where large number of people are accommodated. So, vulnerable buildings with many people, the places where large number of people are committed. So, those structures if they are attended too, then again, it can be put to use and many people can get comfort.

And then, we look into the heritage properties, which are distressed and damage, in fact, for heritage properties, as I said in the beginning, if you remember that we need to maintain different protocols, sometimes some of the heritage structures we like to preserve in a manner the way it was constructed, that is without changing any material, we need to conserve them in appropriate manner.

So, we need to look into the heritage structures in an appropriate manner and come up with the retrofitting strategies that are required to be done and then we look into the balance systems whatever are available. So, this is just a thumb rule that, what is the order in which we need to look into carry out the seismic retrofitting for the structures and systems.

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Now, as I was saying that first thing that you need to attend to is the emergency facilities or the lifelines, the lifeline structural systems or lifelines system are those which are categorized in this like, water supply system. In a locality, if the water supply is not restored, if the water is not supplied, then there will be chaotic situation, because people will not get drinking water. So, the water supply system must be restored without losing much time.

The supply of gases, cooking gases, people should get properly otherwise that will create again a problem for people. Electricity supply, because today, we are so much dependent on the electricity, if electricity is not restored immediately, then there will be hue and cry. So, many times what happens due to earthquake the electric poles get uprooted, the electrical lines get disarrayed and it becomes a huge chaos.

So, you need to immediately look into that and do some kind of retrofit, so that electricity supply can be restored without losing much time. The sewerage system is very important, because you need to make the washrooms, the toilet areas functional, and accordingly you will have to see whether there are any damages in this sewerage system or not, if there are damages, they must be attended too.

Stormwater drainage, it is important, because in case it rains, then the areas gets waterlogged. The drainage systems should be made free from debris and other things so that the water can flow through. Telecommunications, the communication tower and all is to be if in case they are damaged need to be restored immediately.

The transportation systems, the road network should be made proper, because many times what happens you will find that there are culverts which might get damaged, broken. Roads, because of the subsident sometimes it generates cracks. So, the road network has to be made good without losing much time.

And then the different kinds of other services that are used in a building to be restored. So, these are basically the lifeline structures on which we need to pay our attention to retrofit them in an appropriate manner so that the life goes on smoothly without much of difficulty.

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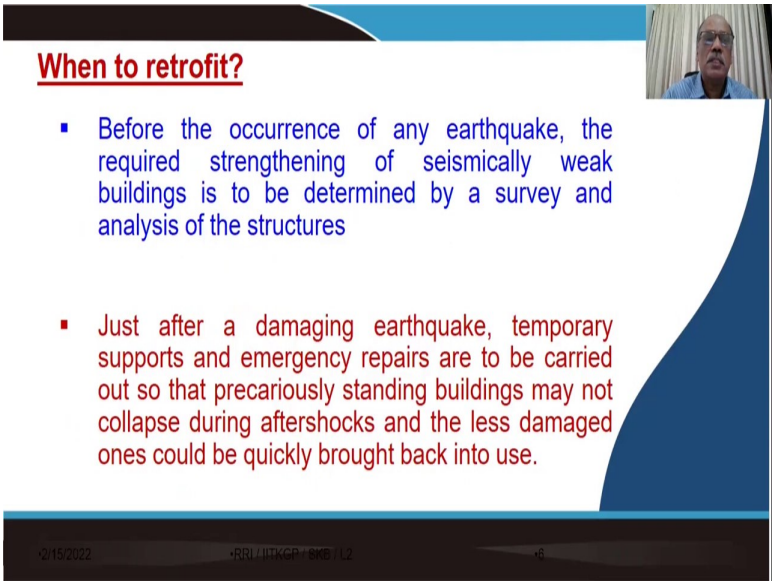

So, the question that counts that when to adopt the retrofit measures and what to retrofit? And as I told you earlier also, that when earthquake happens in an area, because it is you cannot predict beforehand and as a result of all neither you get warning for such earthquakes. Now, when earthquake happens, the structures do undergo damages if they are not designed properly to resist the earthquake of that kind of a magnitude.

But apart from that, in a particular area, as I said that, if you look into the new code on earthquake 1893, you will find that, these provisions have been changed from the earlier code. So, when the provisions have been changed, it means the existing structures are to be re-evaluated with the provisions of the clauses that are given in the new or the revised code.

Now, based on that, you will have to find out whether the structure, existing structure is safe against the earthquake forces that are expected in that particular zone, because of the past experience, whatever we had. Now, if you find that a building structure is not capable of

resisting the earthquakes as it is expected, based on what is guided in the revised code, then you need to take action on those buildings.

So, we call those buildings as seismically weak buildings, that means, those buildings are not capable of resisting the earthquake forces as per the present stipulations in the code, and in the event this much magnitude the earthquake happens in a particular area. So, if you identify some buildings, which are seismically weak, then what you need to do is that, you need to strengthen them, you need to retrofit in an appropriate manner, so that it becomes strong to resist the earthquake of that magnitude in that area.

So, there you need to adopt the kind of a retrofitting and for that you have to know that what is the seismic demand of that particular area? What is the demand from the structural elements that they have to resist earthquake of this magnitude, then what are the properties this will process? And those properties if they do not have, how do we strengthen them, how do we intervene in that element, so that it becomes those provisions can be taken care of in an appropriate manner?

And that is what has to be done, and that is what it says that strengthening of seismically weak buildings is to be determined by a survey and analysis of the structure. So, you need to carry out the visual inspection, you will have to carry out different tests to ascertain the present properties of the materials of the structure, you will have to carry out test to ascertain the present strength of the structure and based on those data, you need to carry out the analysis and assess the vulnerability of that building that the elements how weak they are in comparison to the requirement.

So, if you can assess that, then those elements can be strengthened by using suitable measures, which we will be discussing as we go along, you can strengthen them and then can the building can be made stronger, and we can say yes, in the event of earthquake, this will be of this kind of magnitude, it will be able to survive, it will be able to resist that kind of earthquake.

So, this is one part of it, as I was telling you earlier. And second thing is that just after a damaging earthquake, the temporary supports and emergency repairs that we carried out, so that precariously standing buildings may not collapse during aftershocks, and the less damaged ones could be quickly brought back into use. So, what it means is that intervention

is necessary immediately after any earthquake event, there are certain buildings which might have undergone distresses.

So, you will have to look into the distress's, actions are required to be taken immediately, so that they do not collapse. As I was saying that the emergency facilities, the lifeline structures, those are to be looked into the first instance, then also parallelly unreinforced masonry structures or the buildings where you need less interventions in those places immediately actions are required to be done, so that the structures could be kept in a position. And with little intervention and you can bring it back to its normal use. So, this is how you need to act on, this is how you need to retrofit the structural system to save, to make it safe against seismic action.

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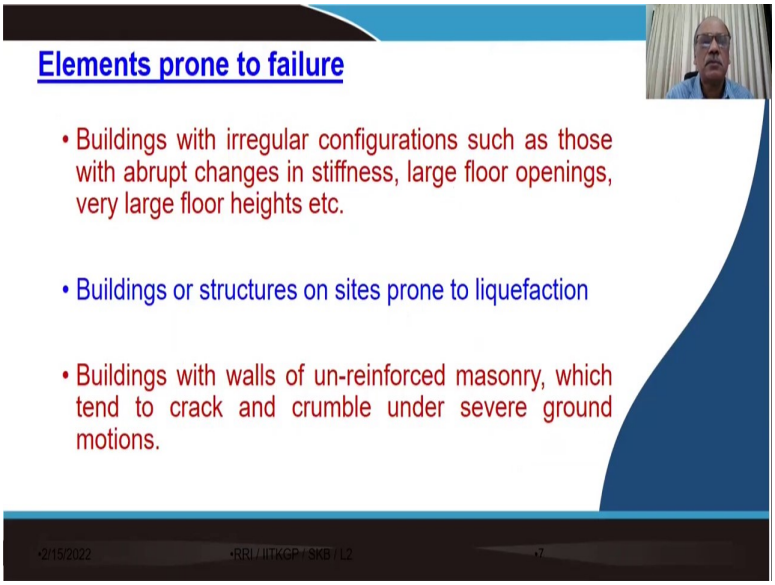

So, just to give you an idea that what kinds of buildings which are seismically weak or where there is a possibility that those structures might undergo damage when they are subjected to earthquake forces. Now, it has been observed from the experience of the past earthquake that buildings with irregular configurations, such as where there is a change, now, the building structure is going with the larger size and then there is a sudden change in the stiffness.

So, this is placed in the junction between the change in the stiffness is a vulnerable part or you have floors with large openings, where because of the lateral loads, there could be concentration of stresses, again, you can expect some damages can happen. So, in such cases we need to be careful. So, if in an earthquake prone zone, if you are looking into a structure, you should pay your attention to these aspects to see that, whether they are taken care of in an

appropriate manner, whether they are strengthened in an appropriate manner and if not, you need to apply a proper retrofit, so that the structure becomes stronger.

Then from the site properties point of view, that if the structures are placed on a place or a site where the site is prone to liquefaction, then of course, you need to take certain safeguards, so that at the event of liquefaction of the site, building does not collapse. How do you prevent, how do you do the strengthening of the soil, so, that, ground preparation can be done, so, the ground improvement can be done, so, that the buildings are safe?

Buildings with walls of unreinforced masonry. I was telling you earlier that unreinforced masonry buildings, when they are subjected to lateral loads, we do see that there are cracks which are generated in the wall because the joints between the two bricks, you have a mortar, mortar is a weaker part through which the cracks generate and you can propagate or sometimes because of the settlement of the wall you find that the cracks or sometimes some part of the walls collapse because it may not have proper lateral resting of the strength. So, these are some of the elements which we observed, they are prone to the effect of the earthquake.

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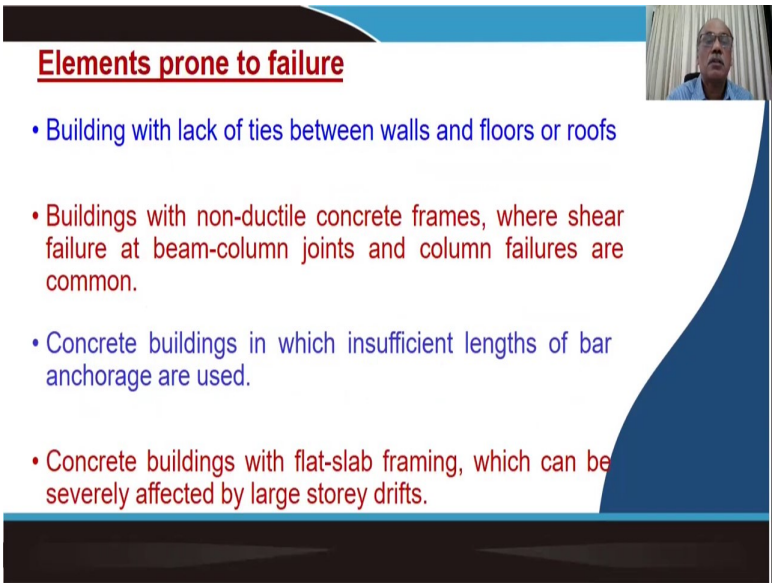

Buildings with lack of ties between walls and floors or roofs many times it will happen. I will show you some of the examples where you have set for walls on which you have a truss system as a roofing and if they are not interconnected properly, then there is a possibility that the roof can get separated out from the whole building system itself. Buildings with non-ductile concrete frames where shear failure at new column joints, joints failure occurs.

So, if the we talk, when we talk about the seismic aspects of the concrete frame, we normally say that, it should be buildings with non-ductile those structural elements will be ductile enough it means that under lateral loads, it should undergo a large movement, before it really collapses, it should undergo large displacement.

So, ductility should be there, but for the concrete element to achieve ductility we need to detail the reinforcements in an appropriate manner, so that we can achieve the ductility. We will discuss some of the aspects later time when we will discuss about the retrofitting measures because of the seismic effect.

Then concrete buildings in which insufficient lengths of bar anchorage are used. When your anchorage system in the bar is not adequate, then there is a possibility that the building might show distresses. Then concrete buildings with flat-slab framing which can be severely affected by large storey drifts. Flat-slab is a slab system where you do not have the beam as such the slab is directly resting on the column system and such kind of elements are vulnerable against earthquake forces.

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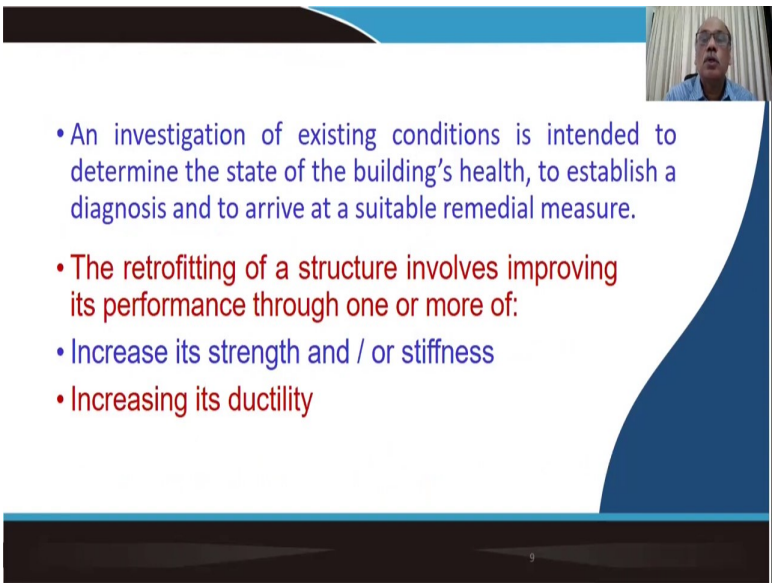

So, what is intended is that investigation of existing conditions is intended to determine the state of the building's health, to establish a diagnosis and to arrive at a suitable remedial measure. And this is what is our objective and this is what I am saying again and again, that we need to investigate the existing conditions of the building by suitable means, by different means either through visual inspection or through application of different kinds of tests,

making use of the test results by analyzing, we try to estimate or assess the present health of the building.

And once we can make a proper assessment of the building, then we say, well, this building has undergone distresses because of this-this actions and these are the remedial measures are to be adopted, and we implement that, so that the building becomes safe. So, particularly, when we are talking about retrofitting a structure against seismic action or to prevent the earthquake forces, we say we like to improve its strength or the stiffness of the structural element, and at the same time, we need to increase its ductility as well.

So, that members are ductile enough, they can undergo large displacement when they are subjected to large lateral load and as a result do not collapse without giving much, I mean, it does not collapse immediate.

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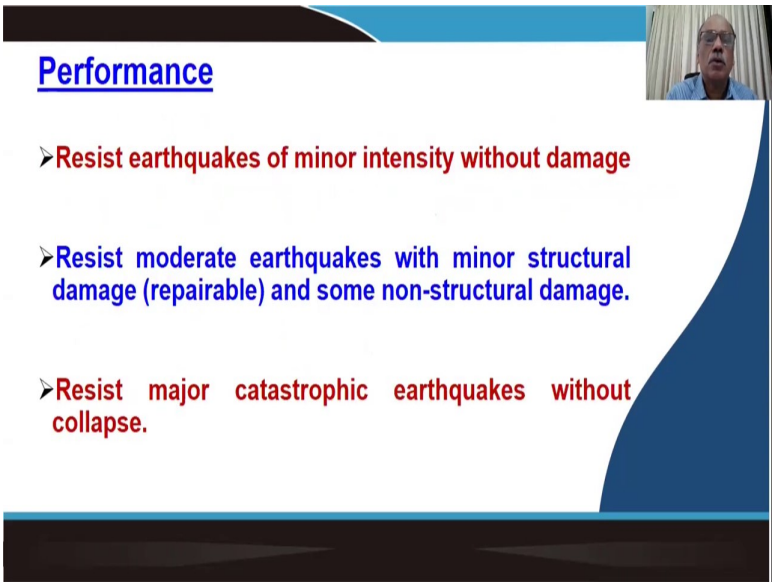

So, what do we expect normally as a performance when we do carry out the seismic design, whether it is a new building, which are designed for the seismic effect, or the building, existing buildings, which are retrofitted or the damaged buildings which are retrofitted? We normally try to adopt these retrofitting measures, the seismic retrofitting measure and there we try to achieve certain performance of those buildings.

What we say is that, the retrofitting measures or the actions should be such that it can resist after the actions have been taken on the building in an appropriate manner, it should be able to resist earthquake courses of minor intensity or earthquakes of minor intensity or magnitude

without undergoing any damage to the system. So, that kind of retrofitting measure or actions are to be taken in the building.

But you mind that, that when you were trying to adopt these retrofitting measures on the vulnerable building, people might argue well, this building has withstood for such a long time and it did not face any earthquake at all, well, in another 20 years down the line, it is not going to face anything.

Because, when you try to do retrofitting naturally, you are going to invest money, and people many times are not ready to invest money in order to upgrade it or strengthen it further. So, we try to take some kind of a compromising measure, we take certain kinds of risk, which are based on performance.

So, well, we say that well, if the earthquake intensity is of minor type, it should be able to withstand without showing any distress, and for this the expenses are going to be like this, but if we say that well, for some cases, if the structural importance of the structure is set, we say well, the structure should be retrofitted or designed in such a manner that it can resist moderate earthquakes with minor structural damage, which can be repaired after the event of the earthquake and you can expect some kind of non-structural damage, let us say, a part of the pillar wall has gone up, which can be repaired or damaged, I mean, after the earthquake event.

And called for very important structures, we say it can resist major catastrophic earthquake without collapse. So, some kind of performance criteria we try to define and accordingly we normally not design retrofitted building.

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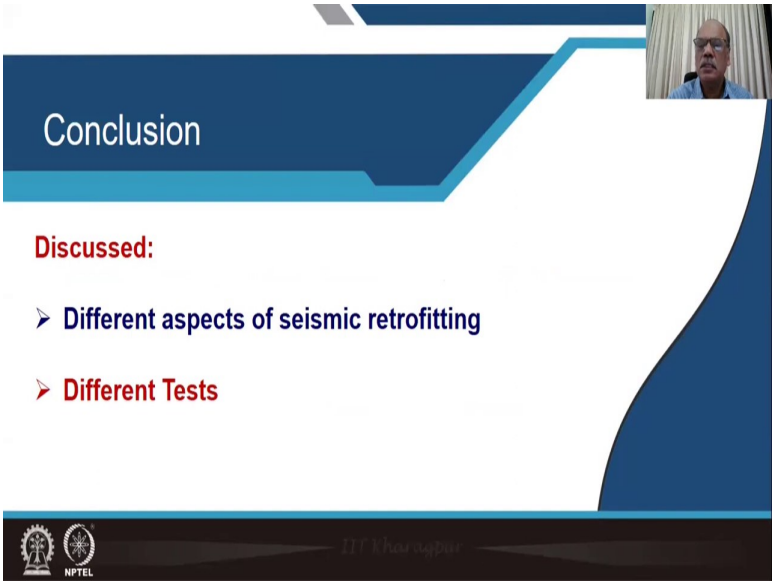

So, in general what I wanted to tell you in this lecture is that, I wanted to tell you some aspects of the seismic retrofitting, the concept or the ideas with which we do carry out retrofitting, and we are emphasizing with the particular term called seismic retrofitting, because the retrofitting actions which are required either for the post-earthquake damage scenario, or for the structures which are vulnerable against earthquake, we need to upgrade or strengthen them in an appropriate manner and retrofit so that the structures become usable.

And of course, we talked about the tests that we need to carry out and the corresponding strength gaining that is needed in the particular structural system, that is what we were talking about in this.

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So, that is all for this particular lecture, we will come back again. So, if you look into this part, this module, we have talked about the 5 different aspects in this lecture module, lecture lessons. And you have seen that how to go about through the steps to arrive at a particular retrofitting measure for a given structure and what are the steps that we need to adopt.

Now, we will try to go for the other modules where we will see in a particular reference that for a given structure says masonry structures or a concrete structure or steel structure, what are the kinds of distresses that we do come across? And how do we retrofit them in an appropriate manner, so that the structures can be strengthened and can be put to use without causing much of a problem? Thank you. Thank you very much.