Retrofitting and Rehabilitation of Civil Infrastructure

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Lecture 54

Retrofitting Techniques For Structural Elements

Welcome to the third lecture of the module on Retrofitting of Reinforced Concrete Structural elements. And in the last two lectures, we have discussed on different aspects of the different kinds of distresses that we observe normally in reinforced concrete structural system and also we have tried to explain that.

What are the different kinds of investigations that are required to be done, different tests that are required to be done and then we need to interpret the test results in an appropriate manner, analyze the structural system to arrive at the proper diagnosis of the cause of the stresses. And then, you need to adopt suitable retrofitting measures.

So, that you get the proper actions or the structural element and we have discussed a few retrofitting techniques on structural elements. In fact, we have started with the column and we have discussed certain retrofitting measures for the columns. Also in the subsequent lecture, we have discussed certain retrofitting measures for beam elements as well.

So, we are going to talk about I mean, we said that we will be discussing about the beam elements. In this particular lecture, we will be talking about certain retrofitting techniques for the beam elements.

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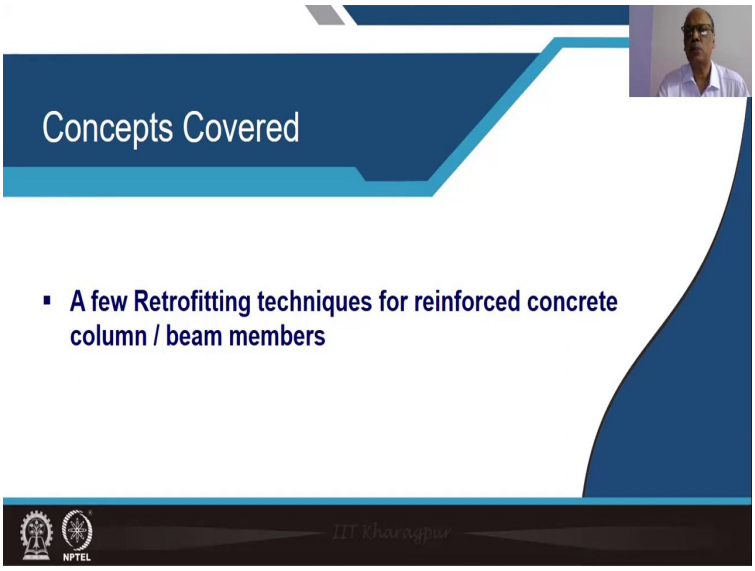

And, before we jump on to the retrofitting techniques for the beam element, I thought it will be appropriate to demonstrate to you some more techniques that we normally adopt for columns for the retrofitting of the columns. In my previous lecture, I have spoken about the jacketing techniques that can be adopted in reinforced concrete elements.

And those reinforced concrete elements if you have observed that we have taken rectangular shape, and we have stated that either using concrete or using steel as the material retrofitting material how we can create kind of confinement for the structural elements, so, that we get the proper actions or proper strengthening of those structural elements.

Now, in this particular lecture, we will be talking about the retrofitting techniques, first for the column some more jacketing techniques that we normally adopt, and then I will switch over to the beam members.

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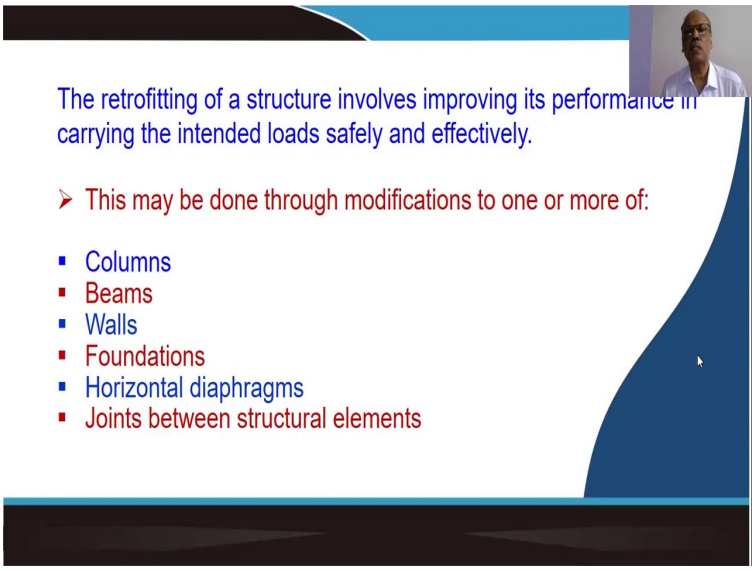

Again, as I have told you earlier, that we need to retrofit the structure in a manner which will involve improving the performance of the structural elements, structural member, so, that it can carry the load for which it is intended for. And we like to take up these elements we have spoken about columns.

We will be talking about column little more, I will be switching over to beams and then in subsequent lecture, we will be talking about other structural members as well that what are the possible techniques that can be adopted. What are the prevalent techniques that are available with us and how we can make use of those techniques in the event is a necessary.

So, we are going to discuss on those aspects. So, that you get acquainted with the retrofitting techniques and you can apply depending on the situation depending on the particular structural system that you are going to retrofit depending on the kind of distresses the structural system has.

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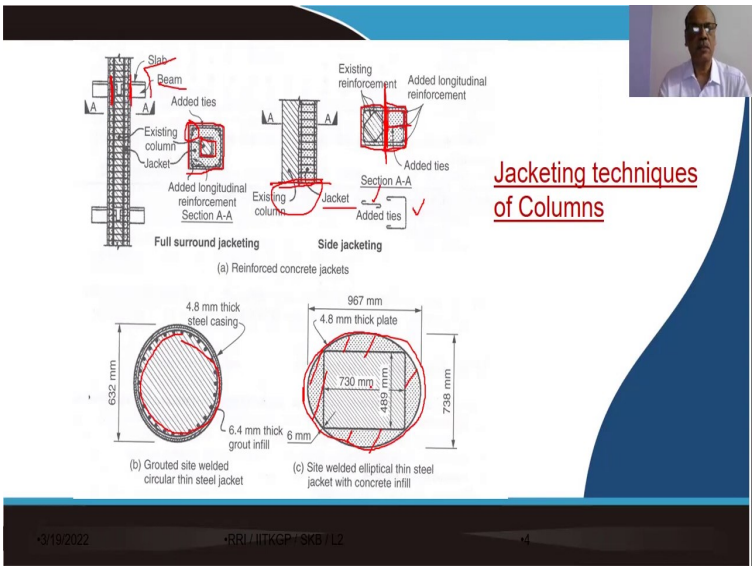

Now, I have spoken about the jacketing of column members earlier in my previous lecture, where I had shown that the concrete members, concrete columns of square or rectangular shapes if they are in distress, how they can be jacketed using either concrete as material or steel as material. And those we have looked into.

Now, here, we are going to talk about the jacketing of columns in some little more greater detail. Now, here, as you can see, in the first case, I have a square column, as you can see over here, this is the original column that I have, which is square in shape, and then we have applied a jacketing jacket all around the columns.

And, we have put additional members now, when you want to strengthen this column, naturally, you may have to enhance the size. And here the size of the columns have been enhanced, as you can see over here, this is the external periphery, these are the new level of concreting that we are going to give and there are reinforcements that have been added 3 on this, side 3 on this side.

And then to connect that we need to have that, ties. So, you will remember last time we were talking about the ties that we provide in such a way that you cannot provide the full tie over here because already a member is existing. So, it will be appropriate that if we can have U-shape, tie and splice on both sides, but here depending on the size of the columns, you may go for the close tie as well. And you can adopt that and then, you need to apply concreting additional concreting

in this, creating some kind of roughness on the existing surfaces, so that you create a bond between the old concrete and the new concrete.

So, this is a kind of a jacketing, where the entire column gets surrounded by additional concreting member that is being applied on this. Now, when you have the slabs and the beam as you see over here that you have Slab, you have Beam. So, the column is continuing now, to continue this either we have to create some kind of opening, but which is sometimes tedious job.

So, to make continuity, what we can do is that we can put some kind of a drilled hole in the slab and the beam and then continue the reinforcements that we are providing along this. And then those areas can be grouted with the cement slurry, so that we can create a continuity between the the upper layer and the lower layer.

So, that is how the jacketing of the continuous and of the jacketing can happen between the floors. Here, another kind of jacketing that has been done a, well, it is not jacketing in the true sense, which is not the existing column does not gets surrounded by the new concrete, but here the jacket has been provided on the side of the existing column.

See, as you can see over here in the plan that this is the existing column that we have, and on adjacent to that column, another member, I mean, we are adding new member adjacent to it, and we are creating some kind of a connectivity between the two. So, it is a kind of a side jacketing and, here we are adding the longitudinal bars along with the ties as you can see here that, you have a tie which is U-shape to encompass the column also in between we have one small tie, which is of this particular shape.

So, you have two additional ties those have been provided over here along with the longitudinal members, and this entire area is concreted and the bond which is getting created is along this surface, where, you have the existing concrete and the new concrete is added together. So, it is a kind of a side jacket, but one aspect has to be kept in mind that by doing so, you are basically increasing the base area of the column through which the load is going to be transferred.

So, if you do not have adequate space on the foundation to accommodate these additional elements, you may have to enhance the foundation as well to add to this. So, you will have to be

careful while doing this kind of jacketing additional element that is coming in to the adjacent into the existing one.

So, that the load transfer mechanism is appropriate and that does not, cause or invite additional stresses into the system that has to be looked in. Third thing is that here, another element has been brought in the member instead of concrete. We are brought in still as we did last time, you remember that for the square column we said that steel plates can be used as a box to confine.

So, like if you have a circular column, circular concrete column you can make use of steel plate and you can encase the existing column you can confine thereby the internal system is confined by the external plates that is being provided. So, between the plate and the existing concrete a layer of concreting can be done which we call as a micro concreting with small stone chips.

So, that so the small coarse aggregates I should say that you can provide and you can do the concreting in between the spaces of steel jacket and the concrete existing. Now, sometimes a rectangular column, if it is to be encased with this steel can be encased in this form as well it is an elliptical form.

Where you can form this elliptical shape with this steel plate and this elliptical shape then encompass the existing rectangular or square column and the spaces that are being created in between the steel jacket and the concrete member here you can provide the concrete you can add additional concrete to it.

So, that you can create a continuity between the external steel member and the internal member. So, this is also a form of jacketing which is normally adopted to strengthen the member, mind that our objective is to strengthen the existing member. So, we try to adopt that by different means, by bringing in different additional materials and see them in an appropriate manner by proper designing, so, that we get the additional strength into the system.

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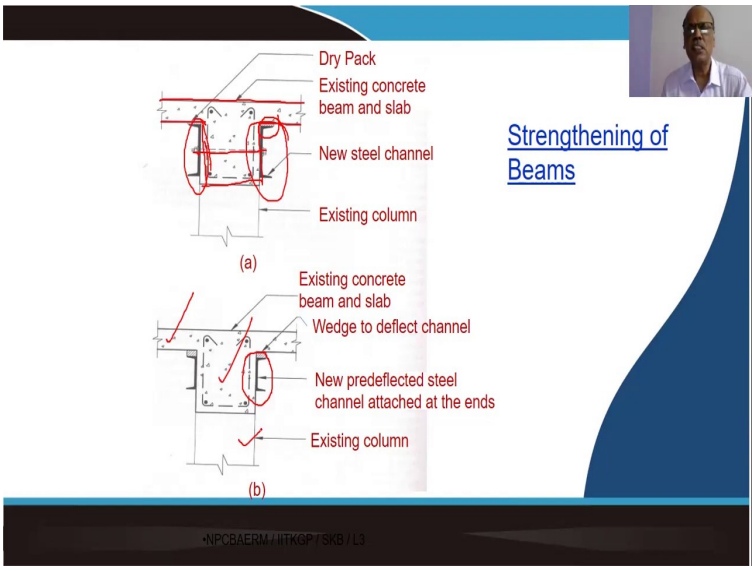

Well, while we talk about the strengthening of beams the reinforced concrete beams obviously, we are talking over here, in this particular case, as you can see here, this is the existing beam, it is a kind of a T-beam, let say it is a part of the slab and this is the beam member again, this is the slab. So, this existing slab beam system is strengthened by using steel channel members on either side as you can see here.

The steel channel members have been provided and the gap between the bottom of the slab and the channel is small element over here is given as a packing you will put a dry packing over here. So, that when the slab deflects, the deflection does not I mean the flexible material can take care of that compression at that place. Now, this channel in fact adds to the strength of the beam.

So, if the beam is to be strengthen then we can provide two channels on either side of the beam and connect them together here as you can see over here a bolt has been provided between through and through from one side to the other side and for doing so, all you will have to do is you will have to make a drill into the concrete beam.

And then take them bolt from one end to the other tighten it and then the gap that will be created in the beam we need to insert some amount of grouting material, so that we can create a bond and a continuity in the concrete structural element. So, this is a kind of a strengthening actions that can be adopted in a beam member.

You see this is another kind of detailing that is adopted for strengthening the beam member here also on the sides of the beam the channels have been provided or these channels are primarily added towards the end of the beam. And also we try to give these beams as a, we add one element over here, which is the wedge element which can deflect this flexible, this channel member is flexible to certain extent and can undergo substantial deformation or deflection when it is being load being added at the top and this wedge, it takes care of that deflection and that deflection gets transmitted into the channel.

So, and this channel is provided towards over the end of the beam it is not in the previous case this channel was continuous over the entire length of the beam or in this particular case the channel is provided towards for the end primarily to take care of the shearing actions that the members will be subjected to.

So, here we need to strengthen the beam by adding additional steel material. So, the scheme that you see over here, this is the slab, this is the beam and this is the column which is continuing on the column the beam gets connected and that is how the beam can be strengthen. So, this is one scheme that we normally adopt for strengthening the beams.

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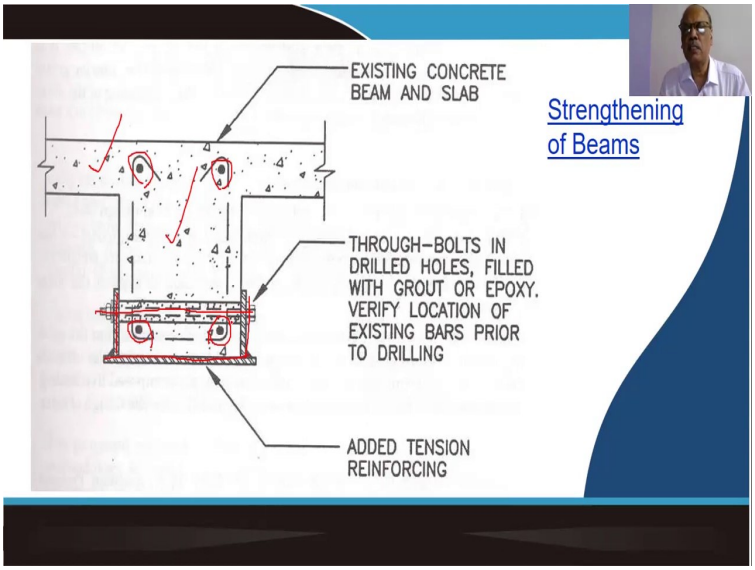

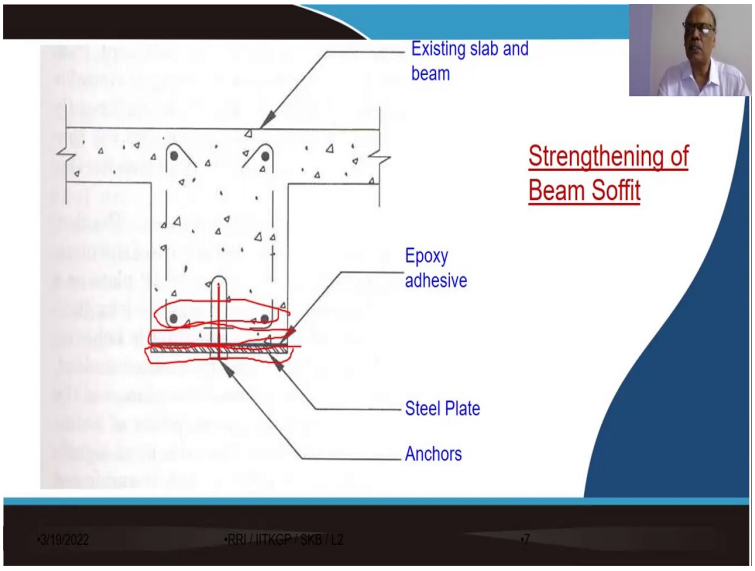

There is another scheme which is adopted over here, as you can see that the bottom fiber the tension zone has been further strengthened by adding a plate at the bottom of the socket of the beam and to have a continuity of this plate, this plate has to be held in position and to hold the plate in position two side plates have been provided, one on this side, on this side and these side plates are getting connected with the bolts.

So, it is again get through and through bolt which is to be inserted by creating some kind of hole into the concrete we make a drill and then we take the bolt through the drill hole, but after the bolt has been put in place, the hole has to be filled up with the grout, the cement slurry grout or modified with the epoxy.

So, that you get a continuity in the concrete structural element and create a connectivity between the bolt and the concrete and by doing so, the entirethis steel casing that has been provided will be in place and we will be able to take the load. So, again this is the existing concrete slab, this is the existing concrete beam, these are the reinforcing bars in the compression zone and this is the reinforcing bar in the tension zone.

Now, one aspect has to be kept in mind in such cases that when you, since you are drilling holes and taking the bolt through and through, through the beam element, the location of these bars, existing bars are to be decided before you carry out the drilling operation. So, that the bars do not come in the path of the hole otherwise the bars will get disturbed by the hole.

So, it has to be ascertained where through the position of the bars and then accordingly you have to decide that where we will be drilling the hole. So, if you drill the hole through this beam, then you can take the bolt through and through and in the process the beam soffit can be strengthened that, because of the flexural action, the bottom fiber will be under tension.

So, tensile stresses will be existing at the bottom fiber or by adding steel. Now, naturally you are enhancing the carrying capacity of the beam member, if that entire system, the two systems the existing concrete along with these additional steel, if they work in unison, then it is expected that this member is going to carry more load than in the previous.

So, in the process you are basically strengthening the beam you are basically enhancing the carrying capacity of the beam. So, this is a technique that can be adopted to strengthen the beam. This is another scheme which is being described over here, what is being done is that if you find that beam is not able to carry the load or it is lacking its carrying capacity.

Then you can enhance it by increasing, by providing some plates in the tension zone, the tension zone is provide the plate, the plate, steel plate will be able to carry the tensile stress basically in the reinforced concrete what happens if your tensile stress is large the bottom part of the concrete will crack, it will not be able to take that load and eventually you try to transfer the stress in the steel region in the reinforcing steel.

Now, by adding steel plate over here, what you are essentially doing is you are trying to transfer the tensile stress into this steel plate. Now, how are you going to place the steel plate at the bottom of the concrete beam soffit. Now, to connect the plate the two actions can be taken one is that you provide some kind of adhesive between the beam soffit and the steel plate and thereby the steel plate will get attached to the beam soffit.

So, this is one action. The other action is that along the length of the member at intervals at certain locations you provide the steel bolts or the anchors, which will hold the plate in position and we will create a bond between the existing concrete and the steel plate. So, by doing these two actions.

So, you can provide epoxy adhesive to connect the steel plate along with the concrete and in addition to that, we can provide the anchors along the length of the beam, so, that the plates can

be connected with the existing system and thereby you will get additional carrying capacity of the member.

So, the beam can be strengthened and is expected to carry more load than what it was getting earlier. Now, many a times what happens in a beam, the steel plates can run from one end to the other end or also depending on the amount of strengthening that you need for that beam, you may provide the plate at the central zone of the beam.

It need not be for the entire length of the beam, but for the central zone, where you find that bending stresses is exceeding the capacity of the existing beam, you can provide a plate and you can achieve the purpose as well.

So, you need to decide depending on the situation where you need to add a plate whether it is for the entire beam, or from one end to the other or you like to add beam only in the central zone where, by adding that plate you can achieve the capacity and thereby you can strengthen the beam. So, you need to take a decision accordingly and decide that how it is coming. So, this is another technique which can be adopted to strengthen the beam.

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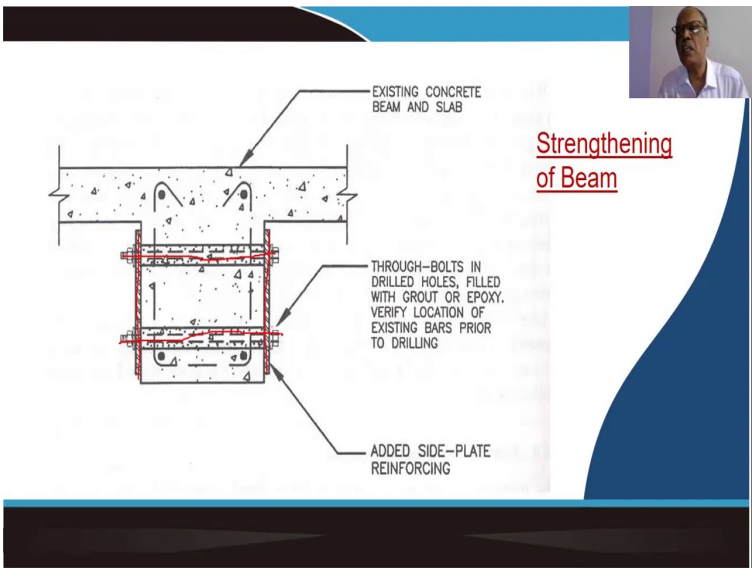

Well, this is another strengthening technique for beam. And in this place as you can see here that we have provided plates on the sides, in the previous cases or in the first occasion, we have side plates for small depths and then that was connected with the bottom plate, in the second case it

was just a bottom plate which was connected. Now, in this particular case, we are providing side plates, but side plates over the entire depth of the beam, you see the side plate that is being provided is over the entire, almost what the entire depth of the beam.

Now, by providing these side plates on the beam, now, these plates are to be retained in position now to keep this place in position what is needed is that we again put a bolt from one end to the other. So, that these plates can be connected together and can be held in position. So, the bolts are provided and these bolts are provided along the length at suitable interval again that has to be calculated based on the design aspects, we need to decide about the diameter of the bolt and the spacing that we need.

And by doing so, what you are doing is that you are providing two additional plates, also the thickness of the plate has to be decided depending on the kind of actions that you are trying to resist, the shearing actions or the flexural actions. So, but one important thing is that when you go for these kinds of schemes, mind that you need to drill holes through which you will be taking the bolt from one end to the other.

Now, for taking, for providing the drill hole you will have to ascertain that where the reinforcing bars are there in the existing system. So, that the bolts can be drilled away from the existing bars and then after you complete this operation, the holes are to be filled up with the cement slurry grout or epoxy modified grout so that you create a continuity in the structural system and also you create a bond between the bolt and the concrete system.

By doing this now, the additional plates are attached to the beam sides and thereby you can expect to strengthen the beam. So, there are these certain kinds of a techniques that you add plates on the sides, you add plates at the bottom, you try to create some kind of a confinement, you provide plates in the part of the beam, you provide plate in the entire length of the beam.

But when you do so, it has to be connected in an appropriate manner either by adding adhesive but mind that by just adding adhesive is not good enough because the strength of the adhesive and strength of the steel plates are not identical. So, if you are adding a steel plate with a concrete through adhesive only then the purpose may not be served. So, you may have to add additional anchors along with that adhesives so that you get the purpose for which you are doing this. So, this is again another scheme which can be adopted.

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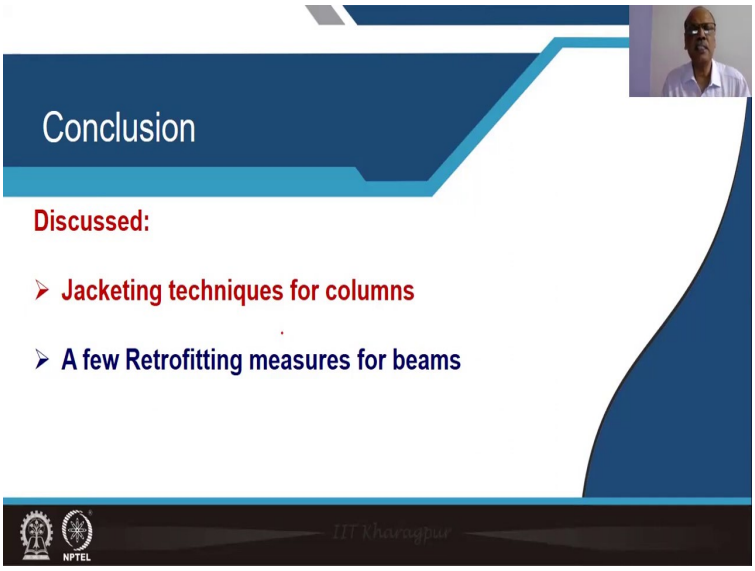

So, all now what I can say is that for the columns and the beams, now, I have tried to explain that what are the kinds of retrofitting techniques that are available are commonly applied. But what I have tried to tell you again and again, is that retrofitting schemes or techniques that I am showing over here are representative, it does not mean this is the only technique that is available, but these are some of the techniques which can be adopted.

You can think of some other innovative techniques, which can be adopted and you can come up with your own technique and can apply, but mind that whatever you do, whatever elements you bring in either using concrete or steel or any other material, it has to be designed in an appropriate manner to arrive at the properties of the material, to arrive at the sectional configuration of the material it must.

And also creating connectivity between the two, creating a bond between the two, so that the load can be transferred in an appropriate manner. So, these are some of the retrofitting techniques that we normally adopt in different structural elements. And as I go along, I will be discussing again in the subsequent lectures, some more techniques that can be adopted for different other structural members.

Thank you very much. Thanks for your attention. And, we will be looking into some more of these kinds of techniques, in the subsequent lectures, where we will talk about that how these retrofitting can be adopted in different structural systems. Thank you. Thank you very much.