Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 50
A Few Retrofitting Techniques

Welcome, in this module, we are discussing about the retrofitting of masonry structural system.

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And in my previous lecture, I have discussed about certain aspects of retrofitting masonry structures, particularly I have shown you what are the different kinds of distresses that we normally see in case of masonry structures? And how to diagnose that, that is very important, as I said that, after you visually go for the visual inspection, go for different kinds of investigations, then you need to diagnose that what is the actual problem, what is the root cause of the problem, and then you try to apply certain retrofitting technique, so that the structures can be retrofitted in an appropriate manner.

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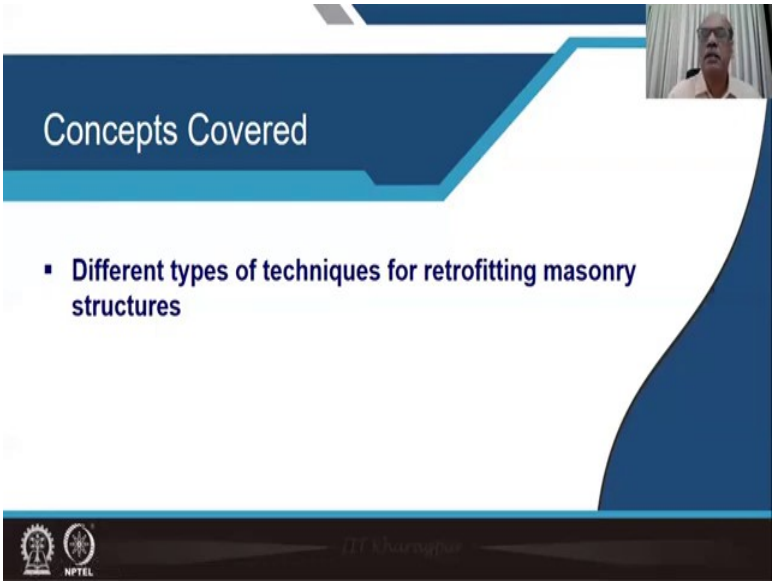

Now, we have discussed certain features of the retrofitting technique. And here today, what I intend is, that we wish to introduce to you some more types of techniques that are normally adopted for retrofitting masonry structure.

Now, one aspect I have to told you repeatedly, and once again, I wish to remind you, that two aspects had to be looked into. One is that, whatever you see in the structural system, in terms of distresses, they are basically the effects of some cause.

Now, unless the actual cause of these effects are identified, it will not be, possible to get rid of the problems, unless we can attack the root cause of the problem, unless we rectify the root cause of the problem, the effects in terms of distresses either cracking or, spoiling whatever we observed, those will continue to happen. If we do not address them properly, what it means is that you need to come up with proper diagnosis of the problem. That is number one.

Number two, what we are showing you over here is that certain techniques, certain standard techniques, which are used normally to retrofit masonry structural system. Now, for any problem, or any structures that you look into, it is not possible always to apply any unique solution for the problem. It has to be looked into in isolation for that particular system, we have to understand what are the difficulties that are associated with it? And what is the appropriate solution for that particular problem.

So, from amongst the techniques that you know, or what I am going to discuss with you, you can pick up appropriate technique, which is suitable to retrofit that particular system.

So, this has to be appreciated, this has to be understood very clearly, because many a times it is being asked that whether this retrofitting technique is better or the other one is better, when the question is, the retrofitting techniques are techniques, they are to be adopted, depending on the kind of problems that you are addressing. And each problem mind that they are unique by nature, you cannot generalize saying that because the building has cracked. And that is the reason the problem of this building and the problem of that building are identical.

And, that is why you applied the same solution, what has been applied in that, that should not be done. So, it has to be very carefully investigated. It has to be studied very carefully, come up with the appropriate diagnosis for that particular problem. And then apply the retrofitting measure, and that is what is the advice that has to be taken. And this is very, very important, when we look into the systems.

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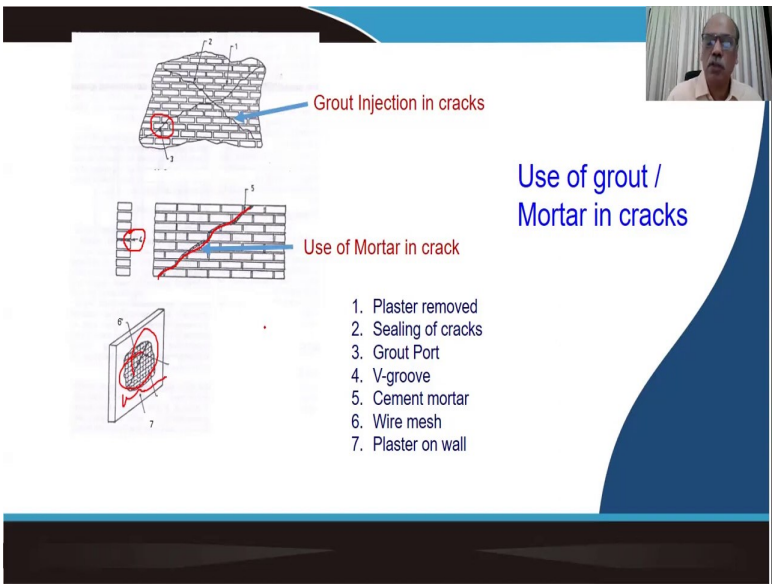

In my previous lecture, I had spoken to you about use of grouting material, or mortar, cements sand mortar, or I said that epoxy modified mortar, which can be used in the cracks. When you see the cracks as I was trying to tell you in my previous lecture, that the cracks can generate, because of the settlement of the foundation, cracks can generate because of unusual lateral loading that the system will be subjected to. So, there could be different kinds of actions that can happen, which can cause cracks in the masonry structure.

Now, if that happens, let us say, if there is settlement of the foundation, then alongside the repairing of the crack, you will have to also address the issues that are associated with the settlement of the foundation. That means, you may have to improve the ground, you may have to strengthen the system, so, that further settlement do not happen. And alongside that,

when you take care of the foundation settlement problem, alongside that you need to repair the crack, which has generated in the masonry wall, or masonry structural system.

So, you will have to know in an appropriate manner that how these cracks can be repaired. Now, if the cracks are finer, that means width is smaller, say in the range of around 3 to 5 millimetre. Possibly, you can fill up those cracks by injecting cement slurry grouting material or epoxy modified cement slurry grouting material.

And how that is done, I had explained to that earlier that the crack top part of the crack is try to seal and then at certain points we put the grouting port, through which we inject the grouting material so, that it penetrates the entire cracks and different points, to the appropriate points we try to put the grouting port, and through which we send the cement slurry grout material by a pressurized system. So, that the grout material penetrates through the crack and crack gets filled up.

So, in the process, the cracks get repaired and alongside that, if these cracks have been generated, because of the settlement of the foundation, if we can address that settlement problem also, then, your problem will get resolved, you will find that no further cracks will be generated in the system, and at the same time cracks also will get repaired by the grouting process.

If the crack width is larger, let us say you get in the range of 5 to 10 millimetre, then by grouting alone, it may not help. You may have to use the mortar. So, that because, it is a wider crack, it could be deep penetrated crack. So, we try to introduce mortar in the system, so, that the crack can get filled up and the two parts which were separated out because of the cracks, it gets connected by using this mortar, and this is what has been shown over here that you repair the cracks on this.

Now, here there are a few steps that we adopt, when we adopt this kind of repair technique onto the masonry surfaces, what we try to do is that, the top plaster on the masonry wall system, we remove it. So, we remove that is what here has been shown, that in from the wall the plaster has been removed, and this after removing the plaster what we do is that, we try to seal the cracks by cleaning it properly.

And then as you can see, here that the grouting port has been shown over here. So, likewise in appropriate place, we can put the grouting ports through which we try to pressurize the grouting material to go inside the cracks and fill up the cracks, or as it has been shown over

here when you have wider cracks. These cracks can be filled up by inserting mortar into it, this could be cement-sand mortar, or it could be epoxy modified mortar in this crack.

And for the each of penetration of mortar, or for the grouting material, the surface as you can see over here the surface is prepared a V-groove kind of a thing is created through which either you put the grouting port, or if the crack is wider, you can insert the mortar inside so that it gets filled.

After repairing the crack, because then you will have to apply plaster on this. And normally, what happens is since these two parts were separated out, and you have introduced some other material over here. To prevent the plaster from further cracking, which could be surfacial crack, or shrinkage kind of cracks, we put off a layer of fine wire mesh, or chicken wire mesh, we normally call it, we provide a layer of wire mess on the surface, and then we apply the plaster.

So, if we do that, then at least the plaster will be able to bear along with this wire mesh, which is reinforced with the wire mesh, can withstand some amount of temperature variation, or any kind of variation due to the shrinkage. So, there by, no further cracks will be generated on the surface, and this is what has been demonstrated over here, that on this surface you can have the layer of wire mesh, and then the surface is plastered, this part, part 7 in this is a plaster surface that you see over here.

So, this is how this particular technique, retrofitting technique is adopted, when we try to repair let us say because of the settlement of the foundation, or even if I am repairing because, when the wall has cracked because of the lateral loading. So, this is one technique that is normally adopted for strengthening or repairing the wall.

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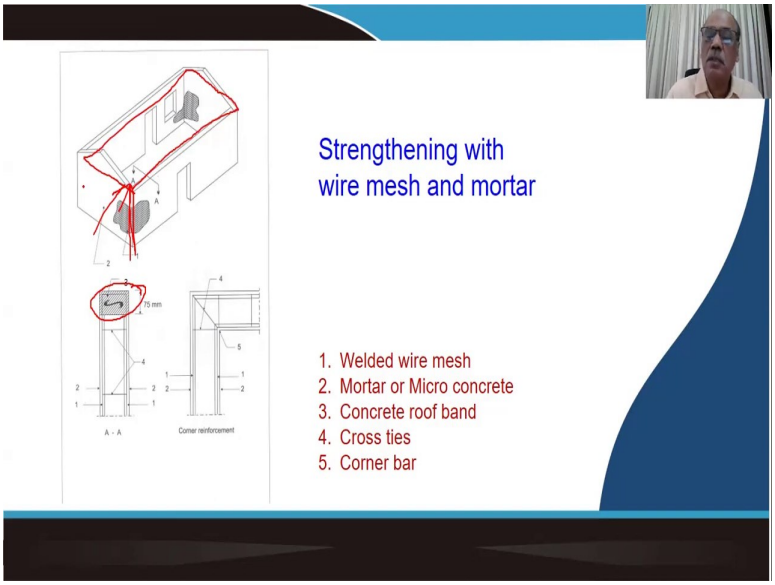

Sometimes what happens, you will observe the corner of the walls, where you have two walls connecting. Particularly, when such kind of masonry buildings are subjected to the lateral loads, these junctions show the sign of distresses. So, if there are signs of distresses along this wall, we try to repair the corners and strengthen the corner. So that, you get a better performance from this.

Now, when such kind of thing happens, let us say the lateral force is acting on this system from this side to the same. So, when that happens, this wall will undergo movement and as a result, it will try to separate out from this cross wall.

Now, in such cases, what we try to do is that, we try to repair these in an appropriate manner. So, that it can be strengthened and if it is not provided with some systems, if we want to upgrade the existing system, then we try to introduce some element, so that the building can be retrofitted in an appropriate manner to carry further loading.

So, here what has been shown over here, in line with the previous one as stated that, at this corner, if the cracks are finer, we can remove, open up the area, provide wire mesh at this corner, and then connect these wire mesh in an appropriate manner with the walls, and then plaster, apply a layer of mortar, rich mortar, or sometimes we introduce the micro concreting, you remember? When I was talking about the material, I had stated that, with finer chips, we can introduce concrete, which we call as a micro concrete. And we can introduce micro concrete in this system as well.

Also, if the system is not provided with a strengthening element, like I want to talk about it as it has been shown over here in this section A-A, you see at the top we like to introduce a reinforced concrete band. So, all along this periphery, if we introduce the band, then it will become stronger, it will strengthen. So, if it has not already been introduced, this can be introduced to strengthen or safeguard the building against some lateral loading.

So, this is what has been talked about over here, that in this place as we have stated in the previous scheme, that after applying the wire mesh, we try to provide a layer of plaster, mortar, or micro concreting and the surface is plastered again. Likewise, if you get some corner, the corners if they are reinforced, we try to avoid some kind of ties, so that it can give you better strength and make it stronger.

Now, also I will show you in a few minutes that we try to strengthen these walls by inserting certain kind of materials into. Sometimes, we try to bind all four walls together by providing a metallic strip all along, all four once and connected at one point, and tighten them.

So, in the process what happens the whole thing gets a confinement, and the building is tied up by that strap, which we call as a strapping, or sometimes we introduce steel bars in terms of a pins, so that the longer walls and the cross walls they are connected together, which we call as a pinning, I will show you in a minute that these are the kinds of retrofitting also can be adopted.

So, here I have showed the technique that we have learned in the previous slide, where I have spoken about the putting a layer of wire mesh and then the plaster, so that you get a stronger system. So, similar kind of arrangement can be done in case of strengthening of the corner joints in a building, which have rather susceptible along with providing a roof pan, so that the system becomes stronger.

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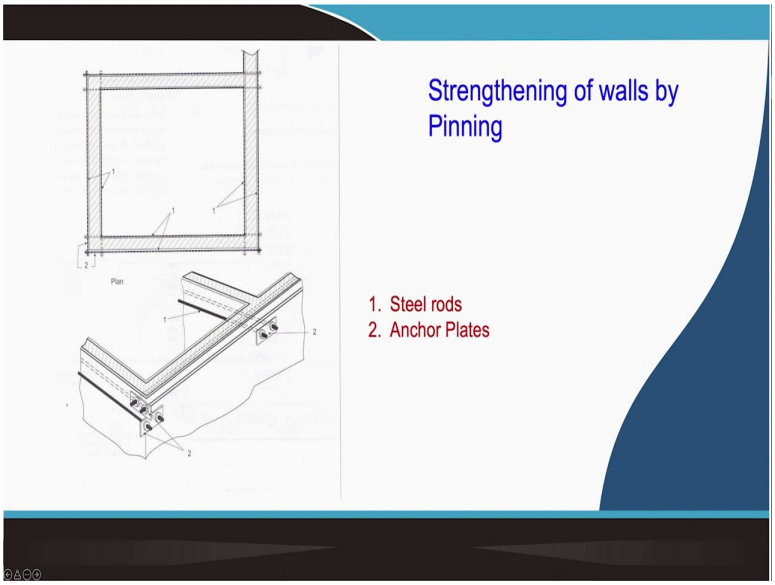

Now, as I was telling you that when you have this cross walls are creating, you have a wall along this, and these corners are showing a sign of distresses, corners are showing the sign of distresses, what we can do is that to combine the cross wall and the long wall in an appropriate manner, we can provide the pins here as you can see that we have provided the bars or the rods, which you call as a pin, which is running from one end to the other. And as you can see over here, the beam is passing through a plate, which you normally call as anchor plate, and in this anchor plate also there is a knot across this pin.

So, by tightening this knot, you can apply some amount of prestressing force, this is a kind of prestressing force that you are applying along the length of this bar. And thereby, the bar will hold these two elements together by a compressive force. So, what we try to do is that we try to apply these kind of bars as you can see over here, we have applied here, we have applied here, we have applied in the cross direction as well.

So, on all directions, we try to provide the bars, which are acting as a pin, and tying the two walls together. So, in the process, the idea is that we try to connect the two walls in an appropriate manner, so that this whole building can be strengthened. So, this is what we call as pinning.

Now, as I was saying that apart from these also, I can put steel plate, say wider steel plate, which can run through all four sides, it comes here, comes applied over here, applied over here, and then applied over here, and then connected, it can be connected at one point, or it can be connected at two points. And then, they are tightened again by using bolt, so that this

strap gives a tightening effect on the wall, core wall system, which we normally call as strapping.

So, either you can use pinning, or you can use strapping by which the whole system, the whole masonry system can be combined together, all walls can be unified to act together. And these strapping can be done along the length of the building at different heights, you can put one at the lintel level, another at the roof level.

So, depending on the kinds of distresses you have, depending on the kind of confined, kind of bonding unit, we decide that at how many places you can apply these kinds of strapping, and in the process, the whole system is unified to act in unison. So, this is the idea with which the pinning, or the strapping, is and it is quite common that is applied in case of masonry system.

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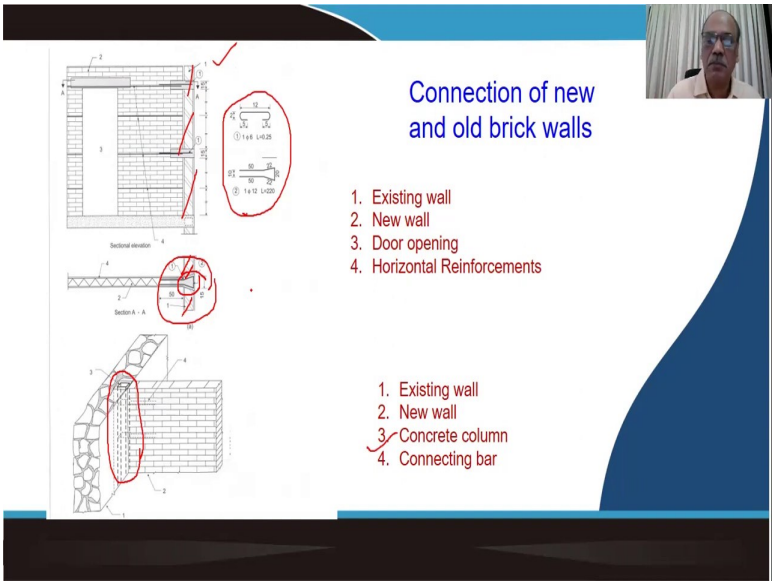

Many a times, what happens that, you have some existing wall, and in that you need to create, or add additional walling system into it. Now, if you do that, then the connection between the old wall, and the new wall is a challenge, and we need to do that in a way so that do not get a differential movement between the two system, and at the same time, the whole system should act in unison, and you should get the appropriate result. So, this is what has been shown over here that, we say that number 1 is this is what is the existing wall. So, this is the existing wall system that we see over here.

So, this is the existing wall. Now to this, this number 2 is being added which is the new wall. So, if we are adding this new wall, then what will be the connection between this existing wall and the new wall system, and this is what has been shown over here, this is the plan

view of this. So, as you can see, this is the existing wall, and this new wall which has come in, is connected at different layer with some kind of steel pin, as the details are shown over here as you can see that we have added steel pin in this particular form, or also we have added the hooks to connect these steel pins at intervals.

So, at this corner, this junction between the two wall system, we try to introduce a reinforced concrete element which we call as a column unit, this is the number 3, that is written over here is a concrete column. So, this concrete column is provided at the junction between these two walls, between the existing wall, and the new wall. And at this junction between these to have interconnection between the two, we provide the pin connections, of the pins at different intervals.

Now, this is a scheme that helps on over here now, actually, when you try to apply this particular scheme in the system, then mind that, you need to design the system in an appropriate manner, and when we try to say the design the system by that what we mean? We mean that the sizing that you will be doing are adequate, adequate to carry the loads and in terms of stresses, you will have to see that the system does not undergo any displacement, or other any settlement, which can cause the separation between the two walls.

And two, if you try to understand the kind of settlement that can happen, and eventually found that how much force will get generated at the interface that is to be estimated, and accordingly you need to decide about what is the diameter of the bar that you need to provide to give an interconnection between the old system and the new system.

So, mind that, once you conceive a particular technique, you need to design each and every element, so, that those elements can carry the expected load from outside in an appropriate manner, and the retrofitted system should be able to withstand and it should be durable. So, these aspects are to be thought of very carefully to be detailed meticulously, and then only it can be executed to get the desired result.

So, these aspects should be, so what I am trying to show you is kind of a technique that can be thought of, in fact, people can come up with several innovative ideas from the concepts that I am talking about here, or from the knowledge of your reinforced concrete structural or masonry structure.

You can think of certain methodologies in these directions, that how do we modify these come up with certain things, and apply them in an appropriate manner with proper design, so,

that the system comes robust, and it can withstand the desired forces, and this is what should be the objective of applying the retrofitting technique into the structural system.

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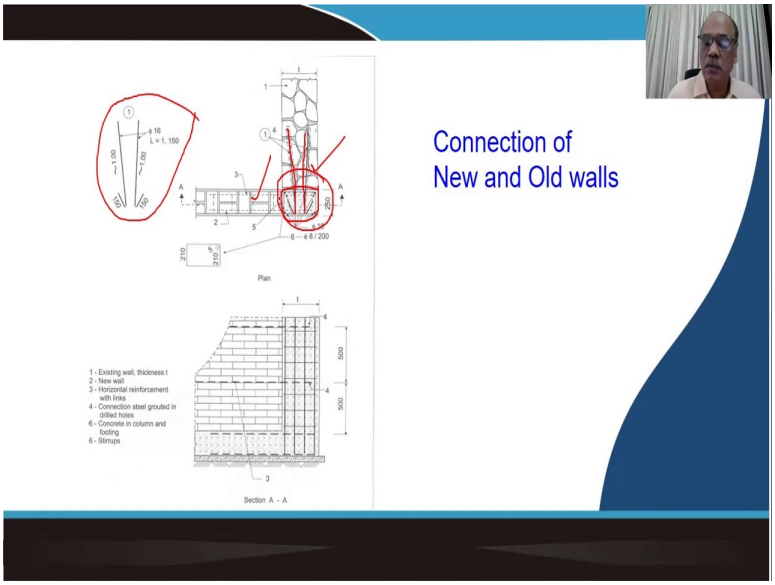

This is another detailing that have been shown over here, is that you have again, two walling system, and existing wall, and the new wall that is being introduced. In the previous case, the new wall was getting introduced in between the existing wall. Here, the new wall is getting introduced into at the side of the existing one, and while doing so, how these two are interconnected together? So that these two units act as one unit, and that is the object.

So, here as you can see that alongside this, this is a random rubbing stone masonry wall, and to that a masonry system is getting added, and again these are two dissimilar materials, there is a possibility that depending on the time of construction, that could be there is a possibility of differential movement or settlement, and because of that, there could be generation of cracks at the interface.

Now, two erase that, if we can estimate that what is the kind of settlement that is expected on the new wall, so, at the interface between the existing wall and the new wall at this place, we try to safeguard this in an appropriate manner. Now, what has been done is, at this location we have tried to introduce one reinforced concrete system is a column, you see with the reinforcements, lateral reinforcements and longitudinal reinforcements, and these columns have been tie in with the existing wall through these set of reinforcements, and the detailing of the reinforcement as it is shown over here.

Now, this will try to prevent the shearing action at these two interface. Also, in the even some amount of tensile forces get generated, because of the separation, the beams will be able to withstand that, or the rods that we provide should be able to withstand. So, we try to provide reinforcing bars along with this column member, so that these two systems can be connected to each other. And thereby we can get the system which is unique, combining the two systems together, but mind that, as simply I said that here of course it is shown on that 16 millimetre diameter bar.

But now, what is the diameter of the bar that you need, what is the length of the bar that is to be inserted within the wall has to be designed, based on the assessment of the load that you expect, from the load that it will be carrying from the settlement that the foundation might undergo, you should be able to assess that how much shearing action can happen at the interface, how much tensile stress can get generated at the interface, from which we will have to calculate the diameter of the bar, the length of the bar.

And thereby, you can create a system finally, we should be able to withstand as expected loading on that. Now, if the actual loading on the system exceeds the expected loading for which we have design, then there could be distresses, but you will have to assess what are the loads that the member can be subjected to, and how these can be safeguarded by considering this kind of a system.

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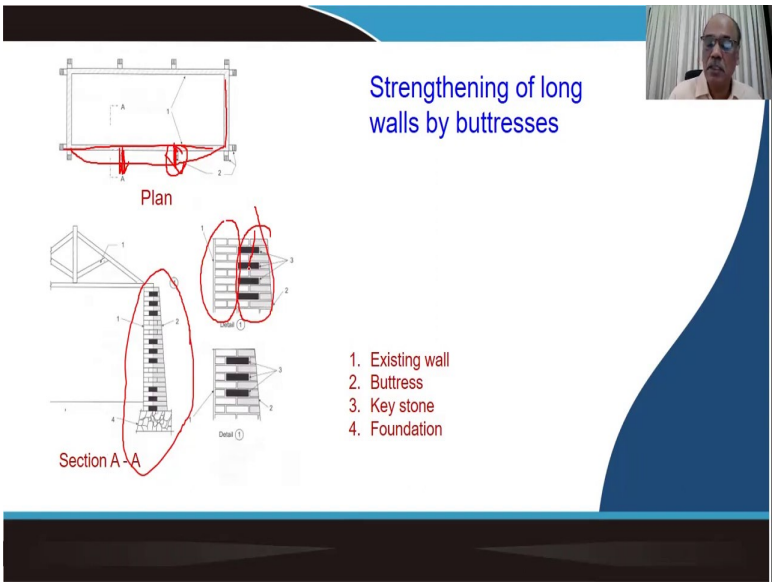

So, another case that we come across many a times,that you have a building in which one wall is long one in comparison to the others cross wall. Now, if this happens, this will have a tendency to kind of underway buckling, because it is a long wall. So, when it is subjected to

some kind of compressive force kind of system, then the wall will have a tendency to move towards outside. Now, if that kind of thing happens, then what happens is the existing column members are further strengthened by adding another layer of walling system into it, and you see the wall on the column that was existing, that is now further enhanced by adding this.

So, we call this as a kind of a buttressing system that we provide. So, existing wall and the new wall, they are connected together by some kind of a connection, and these we call normally as a keystone. Along the length, along the width you provide these stones.

So, that this at the interface, it carries the requisites here that is coming over there, and thereby the two systems become unique, and you have these are nothing but in a long thin wall, you are adding some kind of stiffening supports, these members act as kind of a stiffener in the wall, and thereby, the buckling of the wall can be prevented, and this buttresses in the existing members, the masonry members are further strengthened by adding these key stones into it. So, this is another technique, sometimes we do adopt to strengthen the existing system, or the existing masonry system.

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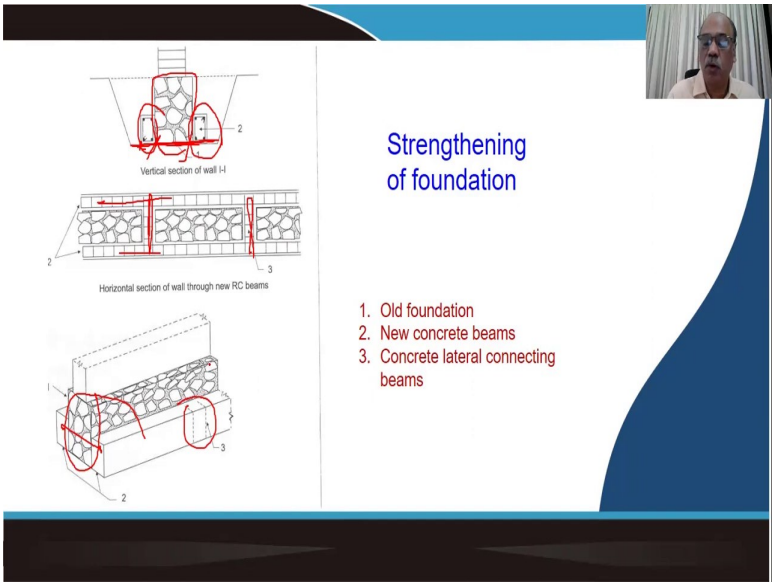

Now, when we try to add wall, or we try to add more load to the walling system, the foundation we have provided, sometimes it is required to be strengthen. So, if we want to strengthen the foundation system, all that we need is that, you need to widen the width, so, that the load can be distributed over larger area, thereby the bearing pressure that you get on the surface is relatively less. Now, to do that, a scheme has been shown over here, let us say you have an existing foundation system, which is like this, and to this, we are trying to add some concrete element on either side of this.

So, this is a stone masonry, random rock with masonry foundation, and at the founding level on the top of the soil where the foundation is resting, on either side, we are trying to introduce two reinforced concrete beam member, and these two reinforced concrete beam members on either side that has been provided this obviously gives you a wider base, earlier your base which was from this point to this point. Now, your base width becomes this point to this point, thereby your stresses below this gets reduced.

Now, of course your load also has increased and you try to keep the pressure within the bearing pressure of the soil. Now, to have effectiveness of these additional beams that have been provided on either side of it, we try to provide some kind of connectivity between them. So, we provide the cross ties, or cross beam in these two beam system. So, that this is the reinforced concrete system which are additionally being provided, the two sides beams along with the cross beam, which is combining the existing stonemasonry foundation system, so that you get a stronger system to carry the load.

And this is what is the view which is on completion will look like this, that you have two units of the reinforced concrete on this side, and this side. And they are connected at this level by the ties which are combining these two system together, and in the process the existing foundation system is getting confined or strengthen, so that you get a better load carrying, or load transferring mechanism.

So, the foundation system also can withstand them for that of course, you need to open up the soil on either side of the foundation, reach to the founding level and carry out, but mind that when you will be carrying out this operation, we will have to take enough safeguards to protect the structure so that it remains safe during the construction operation.

So, appropriate measures are to be taken to support the system, excavate the soil, reach to the founding level, create additional member alongside the existing member, tie them in an appropriate manner, and mind that nothing is at all, the beam members that have being provided, and the connectivity that is being provided, they are also required to be designed depending on the kind of load that you are trying to transport, the kind of connectivity, kind of bond that you are trying to achieve between the existing system and the new system.

So, all these aspects are to be considered in unison. So that you get a system which is, I mean this system should be able to hold the load in an appropriate manner, transport the load to the soil below, so that the system becomes efficient and effective. So, that is what we try to aim for.

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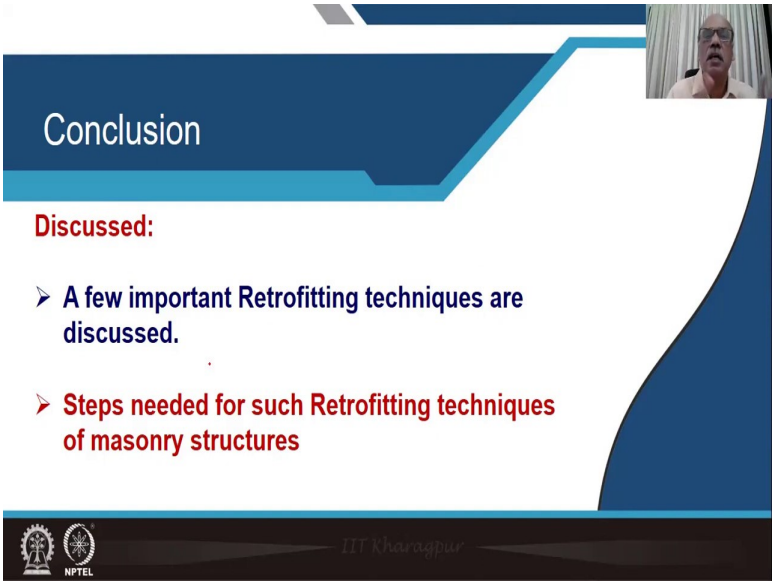

So, these are the kinds of techniques that we normally try to adopt. And as I said that it is not that for a particular type of retrofitting technique will be adopted, it is I have discussed a few types of techniques that are available, that are used, that are known to us, but with these concept in mind, we can in fact think of other techniques which can be evolved, which can be designed, and mind that, when you are trying to repair or retrofit a structural system, any of these techniques either in isolation, or in combination can be used, so that we get the desired result.

And this is what tried to conclude over here, that we have discussed a few retrofitting techniques, and the steps that are needed to adopt or to implement these techniques in an appropriate manner in the masonry structures has to be understood, and these have to be applied so that you get the desired result.

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So, this is what are certain features of retrofitting the masonry system, and you need to understand that, and you can adopt depending on the cases that you come across. So, this is what I wanted to discuss with you. Thank you very much for your attention. And in the next lecture, we will try to look into some of these techniques further which can be implemented, and can be adopted to retrofit the masonry structural system in an appropriate manner. Well, thank you, thank you very much.