Retrofitting and Rehabilitation of Civil Infrastructure
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Lecture 51
A Few Seismic Retrofitting Techniques

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Welcome students, we are going to discuss today on the module which is retrofitting of masonry structure. And as you know for last two lectures we have spoken about this aspect. Today specifically, I am going to talk about the seismic retrofitting aspect as we have discussed earlier that the structures which are getting affected because of the seismic actions or because of the earthquake effect, the distresses we try to repair post earthquake scenario, at the post earthquake scenario, and we try to look into the aspects that how those can be attended too.

In fact, I had told you earlier as well if you remember, that there are several structures which were designed based on the seismic codes which were prevalent at that point of time when the structure was designed and constructed. However, subsequently when the Codal provisions have been changed, those structures which were designed based on the earlier codes are required to be looked into in greater detail to understand that whether they are still safe under the present stipulations of the conditions or not. And if, not then we need to strengthen those structures against seismic effects.

So, seismic strengthening or the retrofitting of structures against seismic forces, again takes two situations, one is the structures which are getting affected because of the earthquake scenario and we need to retrofit them in post-earthquake scenario, and the other scenario is that if the structures are vulnerable against a earthquake and they are required to be strengthened for any purposes, then we need to look into those aspects.

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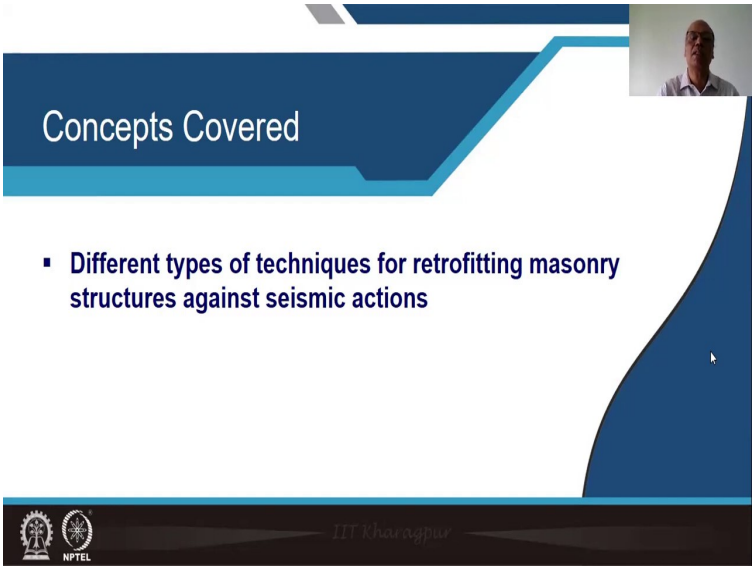

So, today, what I am going to do is I am going to talk about certain retrofitting measures that can be applied to the masonry structural system for these kind of actions. So, that is what we said the different types of techniques for retrofitting masonry structures against seismic actions.

So, as we have discussed earlier that in the event the masonry structures are subjected to some kind of distresses, then what are the actions you are going to take, how you are going to retrofit them in an appropriate manner. So, in this particular case we will be talking about on specific aspects for the retrofitting measure because of seismic actions on structural system, either post earthquake scenario or for preventing the structure against any earthquake that we expect in future.

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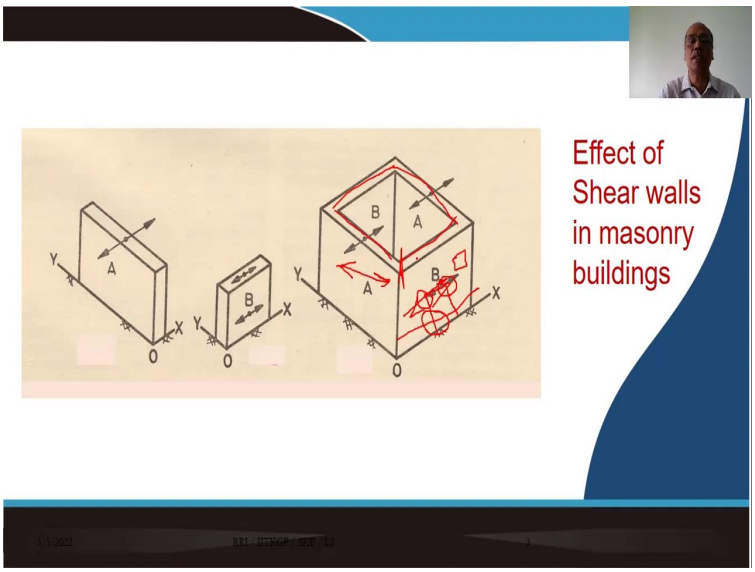

Well, as we have discussing about the masonry structures, we, let us talk about the systems that we see normally in masonry structural systems. Now, here is typically as you can see this is a kind of a box section that we have, and these are the walls. This is one wall, this is a perpendicular wall to this, this is another wall and this is another wall.

Of course, these walls will have openings for doors and windows as the case may be but these four walls connected together effectively constitute a box. Now, what happens is these kind of systems are subjected to lateral loading because of the earthquake action. So, actions could be as it is shown that from in this direction or in the reverse direction. So, it can happen in any of these directions.

Likewise, you can have the earthquake forces acting in the, on the face A as well, in this particular direction. So, anyway it comes, we bring in the concept of the shear wall. Shear wall is basically a structural member which is connected to the structural system to primarily resist the lateral load in terms of the bending of the shear wall system.

Well, the name shear wall in that sense is a misnomer because people tend to think that since we call this as a shear wall and as if the loads are going to be registered by the shearing access, but that is not correct. The shear walls primarily resist the lateral loads in terms of bending.

So, when you will get the lateral forces due to seismic actions then the walls which are connected to the system, two of the parallel walls when it is acting in this direction will resist the load in terms of bending, and these two walls when they are subjected to lateral loads in this direction will be will be resisting the load in terms of bending.

So, that way, all the four walls are effective in a sense that depending on whichever directions the earthquake forces come from, they will be able to resist the system and eventually the building will be strong to resist this lateral forces. So, that is where in fact this kind of systems play a role.

Now, what happens, I had told you earlier that the corner of these walls, the junctions between these two walls, basically this particular region or all four corners, are susceptible. And these corners are to be strengthened in an appropriate manner to resist the earthquake forces or the lateral forces which will be regenerating because of the earthquake actions.

So, in most of the masonry buildings you will find that anyway these walling systems are there and they can be made use of to resist the lateral forces in an appropriate manner. Now, when you have openings in the walls because of the doors or the windows, you may have the opening for the doors at this place, or you may have the opening for the window at this place, as we have discussed earlier that if you take a section at this, particular region where there is a change in the section, that is cross section has an opening over here.

So, entire cross section is not available for resisting the stresses, thereby there will be a jump in the stress at these corners, and these corners of the openings are vulnerable against cracking.

And so these corners are to be strengthened in an appropriate manner for doors and windows, available you have. Normally, we try to provide some kind of a reinforcing element in this, could be some steel bars, so that the corners are strengthened and thereby you do not get the cracks generated because of the lateral forces.

So, that has to be designed properly so that you can resist the lateral forces which are getting generated because of the earthquake actions. So, even for masonry system this

kind of detailing can be done and you can achieve the effectiveness of these walls against the lateral actions.

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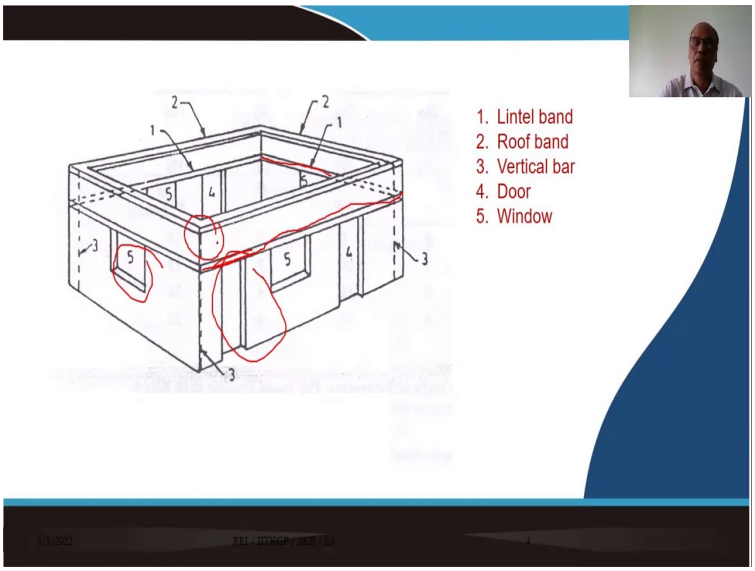

Now, this is typically a building system where different components have been shown. Apart from having the four walls on four sides you see the openings for the window, openings for the doors, all have been shown over here. Now typically, if you are designing this as a new system, it is expected that you should have these elements in these kinds of buildings.

And if you are trying to retrofit a structural system, and if you find that this kind of systems are not available, then it is expected that while retrofitting we introduce this system in the building which can be made safe against the seismic actions.

Now, for example here, as you can see that number one item is the lintel band. What it means is that above the opening you need to have an RCC beam, reinforced concrete beam to hold the load for the wall above it. Now, normally instead of providing a small beam at the top of the door opening or at the top of the window opening, this beam is made continuous over the wall, and then it moves all along the periphery.

So, the purpose that it serves is not only it holds the load above the opening but this creates a band which is like an enclosed sections which is holding the wall together. So, this kind of band is very effective in resisting the lateral load.

Now, when the lateral load will be coming on this building, not only this beam will be subjected to the axial force because of this but the beam which is in the perpendicular direction also will be taking this load distributed in the entire region. So, because of this, this kind of bands are very effective in resisting the lateral loads.

So, it is not only at the lintel level, same thing we try to do at the roof level as well. In the roof level we provide again a continuous band on all four sides we normally, which we normally call as a roof band. So, even in the masonry wall, we see brick masonry or stone masonry, we provide a reinforced concrete system, a reinforced concrete lintel beam or, and reinforced concrete rope beam or a band, is better we call it as.

So, this bands which runs across all four sides of the wall and the buildings are very effective in resisting the lateral load. So, this kind of systems should be introduced to resist the lateral load. Now, if you are designing this as a new building, it is absolutely a must that you must do it.

Now, for a building for which this kind of systems were not introduced in the beginning, you should try to introduce this system even in the existing walls by proper actions which can be done. The corners as I said again and again, the corners between two walls are very vulnerable, and these tries to get separated out from one another.

And because of these what we do is that we strengthen this corner sufficiently. We try to introduce some kind of a bar which can create some better connectivity between the two elements. Better strengthening of the corner will definitely help you to resist the lateral load in an effective manner into the entire system.

And of course, these are the openings for the doors and windows as I said. So, one aspect must be known that when we are going to talk about a masonry system and we are introducing, we are making this building safe against the lateral forces due to earthquake or the seismic actions, having the lintel band or the lintel beam all along the periphery of the building and a roof band all along the periphery building are must. And these two systems must be provided to resist the lateral load in an effective manner in a masonry system.

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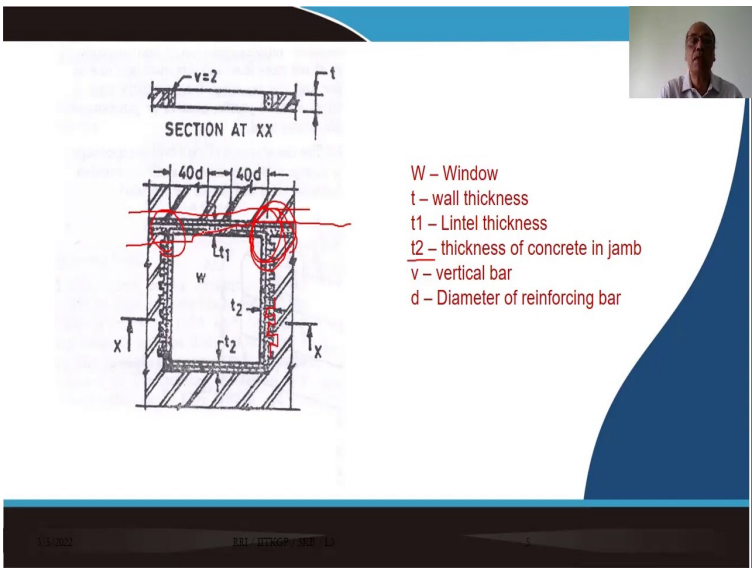

Likewise, the detailing that we need to do where you have the opening for the doors and the windows as I said earlier that from, when there are lateral loads the, right at the corner of this opening, this part is quite vulnerable because at this cross section, you get the entire width of the wall which will be resisting the load and if, thereby your stress is uniform all across because of the vertical load, but at this cross section since you have the opening coming in this, so you do not get the entire cross-section available for you which is the load, and thereby these corners will have jump in stresses.

And thereby to take care of that additional stresses that will be occurring at this changeover, we need to strengthen these corners in an appropriate manner. So, different kind of actions are provided. Though the system is a masonry system, masonry building, it could be brick masonry or stone masonry, alongside the opening, all along the four sides of the opening we try to provide some kinds of concrete elements. This particular part, as it has been stated here t2, is the concrete jam. We call it as a jam in the window.

So, these are provided in the concrete, and as you can see here, some kind of a toothing has been made in the system. This toothing helps to create a bond between the masonry and the concrete. Also, we try to provide some kind of reinforcing element into it both in the horizontal direction as well as in the vertical direction to integrate the masonry system and the concrete system together, so that this entire system along with these four sides

becomes quite strong to resist the lateral load, thereby the expected cracks that we have at this corners will be prevented to take care of.

So, you talk about the lintel band, you talk about the roof band, and alongside these, along with those two the corners of the openings for doors and windows are to be sufficiently strengthened so that you can prevent those corners from cracking because of the lateral loads. So, this is what is the objective, when we try to do the detailing. If it is a new building, you are going for it, then you need to take care of this. But many a times what happens, because of some reasons these aspects might not have been introduced in a system.

So, either in a post earthquake system, if you find there are distresses or for a system which you feel that these are non-existent, you can use them to strengthen the building further to take care of the lateral load. So, these aspects are to be taken care of in an appropriate manner, so that proper strengthening against seismic forces can be achieved.

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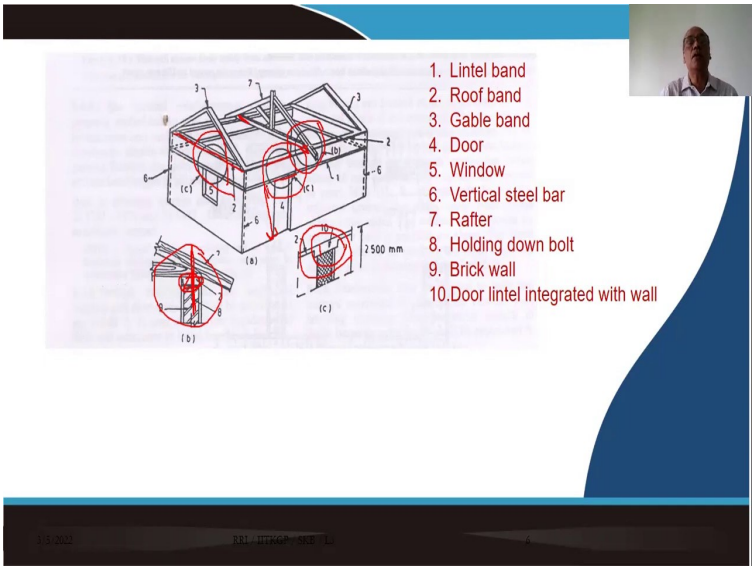

Well, this is again a building similar to the earlier one which we were talking about where you have the lintel band, you have the roof band. Now, along with this what is shown over here is a rooking system that you have which is that of a truss. A truss system is provided.

Now, when you provide a truss, and this, onto top of the trusses, there will be purlins and then they will be covering, but to prevent the entire truss system along with this roof, building system, you need to integrate the trusses with the walls in an appropriate manner. So, what is needed is along with the trusses, the trusses could be made out of different material, it could be timber, could be steel.

And then what you do is that at this junction which is detailed over here you can see, in this particular junction, this is the masonry wall. Above the masonry wall, where the truss is resting over the wall, at this place we try to provide some amount of concrete. It is a concrete band.

And over concrete band, this truss comes and rests, and here we try to provide a connecting member, which we call as a holding down bolt. Now, this holding down bolt holds the truss against this masonry system. Now, because of the wind actions when you get the lateral loads, if there is some upward loads that are acting on the roof, this truss will try to move upward, and as a result this particular part will create some tensile pull in the bolt.

The bolt should be able to hold that tensile pull and at the same time this part of the wall which is also experiencing tensile pull should be able to resist that without causing any cracking in the system. So, this has to be designed in an appropriate manner so that the holding down bolt can withstand the requisite force that will come because of the wind actions on the system.

So, the trusses normally are integrated with the wall system. Now, you can see here, you have two types of trusses. One is the central truss, and there are two end trusses which are little different than the central. The reason being, in the end trusses, the end trusses, at the bottom chord, they are continuously supported over the wall.

Whereas, in case of the middle truss, the bottom chord is supported only at the ends and which is spanning over this opening. So, as a result you need to put these internal members so that the stresses in this bottom chord can be reduced. And at these places you do not need to have as such any members unless the size of the truss is large.

You can have these three members kind of a system, which you name as a gable band or a gable truss. And this can be adopted at the end. So, in these kind of systems, mind that to connect the trusses in the longitudinal direction you will have to have purlins.

And sometimes, if you find that the lateral forces are large, we need some kind of a bracing system to bind these trusses, bracing in the plan level so that the loads can be distributed amongst the trusses in an appropriate manner so that the lateral load can be taken care of. So, these kind of systems are also adopted to resist the earthquake forces.

Also, you must note here many a times you will find that you see normally the distance between the top of the door opening to the top of the roof level, the roof level and the top of the door opening may not be much.

And as a result, say for example, if I say that the height of the door from the plint level is about 2.1 meter and from the top of the door level to the top of the roof level is 3 meters. So, effectively you have a gap of about 900 millimeter between the two. Now, since we are providing a lintel band, and depending on the size of the opening that you have, your thickness of this lintel beam will depend on that.

So, you will have some thickness of the lintel beam. Likewise, when you are giving a roof band, to have its effectiveness, it will have an appropriate thickness. So, if you take thickness of the roof band, if you take the thickness of the lintel band, and then out of 900 you will have hardly any space where you can provide the masonry wall.

So, what is done is that in the localized area where you have the openings for the door or the opening for the window in these bands you see this kind of detailing is done, both the lintel beam and the roof band, they are combined together to give a deeper depth of the beam, but as you are going away from the opening, again you can come back to the depth of the roof band only so that you get some cost effectiveness in the system.

But to avoid a small amount of masonry in between which may be difficult to provide between the beams, the two beams, reinforced concrete beams can be connected together so that you get a beam of this much of depth, from the top of the opening to the top of the roof level.

So, this part of the beam essentially is functioning as both a lintel beam as well as the roof band. So, this kind of systems are again very effective and important when we are talking about the seismic retrofitting or seismic strengthening of an existing building which is not so strong against the earthquake actions.

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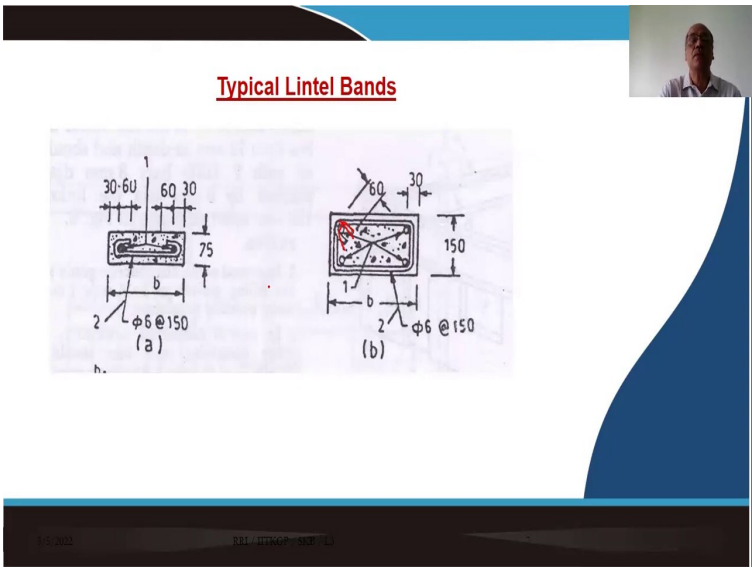

Now, these are typical lintel bands which we normally provide. Apart from having its width and the thicknesses depending on, its width is dependent on the width of the wall normally. We try to keep the width of the wall as the width of the beam. And the depth of the beam depends on the opening span you have. So, we decide about the depth of the beam.

And then we provide the reinforcing parts. You provide the longitudinal parts, you provide the stirrups or the ties so that the bars can be effectively tied. Now, to have the effectiveness of the of the stirrup, normally this hook leg that we call it, as you see the hook that has been provided over here, we say about 10 times the diameter we provide so that you get this effectiveness in the system.

So, these kind of bands are quite effective when you go for having the lintel. And many a places, the lintel bands are provided. And if it is not provided then it is desirable that we go for such kind of retrofitting actions to achieve the resistance of the system against the lateral forces.

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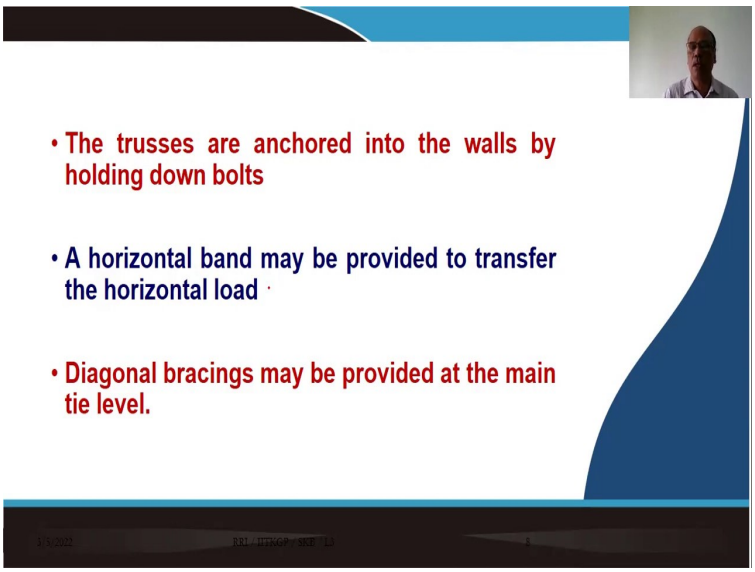

So, what is being said is that the trusses are anchored into the walls by holding down bolts which I have just explained. So, if you want to make a structure resistant against the seismic effect, then, and if you have a masonry system where you have the masonry walls and the roofing is provided with the different kinds of material like GI seatings or other things, then what you need to do is that you need to provide appropriate trusses.

And if you are going for the trusses, those trusses must be connected to the masonry walls by holding down bolts so that you can achieve the proper connectivity between the two systems. The horizontal band may be provided to transport the horizontal load and this is what I have just explained that the horizontal band is absolutely important to transport the load and to distribute. You can visualize since on all four sides you have this band and they are connected together.

So, it gives some kind of a confinement or rather it is kind of a closed system which can distribute the load among these four sides. So, effectively this can resist the lateral load in an appropriate manner.

I talked about the bracing system, diagonal bracings may be provided at the main tie level. As I said that you have the trusses, and when you are expecting the lateral loads due to earthquake, well, the band is expected to distribute the load but if you feel that band alone is not adequate to distribute the load, between the trusses in the horizontal level we can provide members which we call as a plan bracings.

The bracings which you see from the top in an appropriate manner either in the form of eggs or some other types as it is required or desired, you can provide the bracing system so that the lateral load can be distributed amongst all the trusses in the system and thereby the whole system will be able to resist those lateral loads.

So, you can depend on the bands made of concrete or you can go for bracing system and bracing system can be the material with which you have the entire truss system made. It could be with the steel, it could be the timber, whatever you have, you can make use of those material for the bracing system as well.

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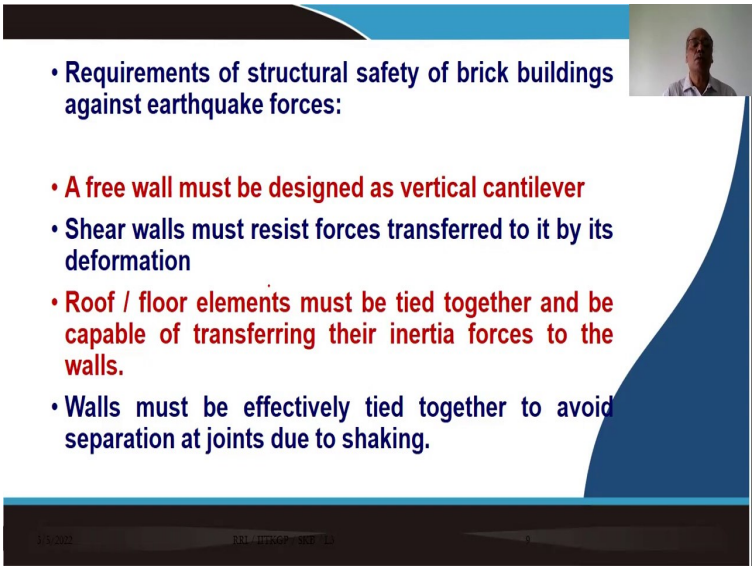

So, if you look into from the safety aspects of the masonry building against earthquake forces, what you should definitely have is that the walls that we get, four walls that you have in the building, these walls are designed when you try to achieve the thickness, when you try to find out the stresses, consider that as a vertical cantilever disregarding the supports that you have. That is of course on the conservative side, that you will be designing the wall as a vertical cantilever.

And shear walls resist the lateral forces. And as I said, shear walls are basically resisting the loads in terms of bending. So, the walls that you provide to distribute the load in the adjoining walls, it can undergo deformation and that deformation in terms of it, it can induce forces in the adjoining members. Then, roof elements, roof or floor elements if you have number of storey, then roof or floor elements must be tied together.

So, what happens is when you have the four walls onto top of it, you have the roof, let us say, instead of a truss you have a flat roof provided made out of concrete. So, that flat roof along with the roof band should be connected with the masonry wall in an appropriate manner, anchoring should be done in an appropriate manner, so that when the lateral load comes at the interface between the concrete beam and the masonry wall it should not shear out.

So, there has to be enough connectivity between the two so that it can resist the lateral force in an appropriate manner. Walls must be effectively tied together to avoid separation at joints due to a lateral shaking. Now, earlier I have told you that at the corner between the two walls, those junctions are quite vulnerable.

And if you remember, in the previous lecture, I had shown you a detailing where you can use the wire mesh at those corners and connect them together so that you get a better resistance against lateral forces, and also the connectivity between the two can be established in an appropriate manner.

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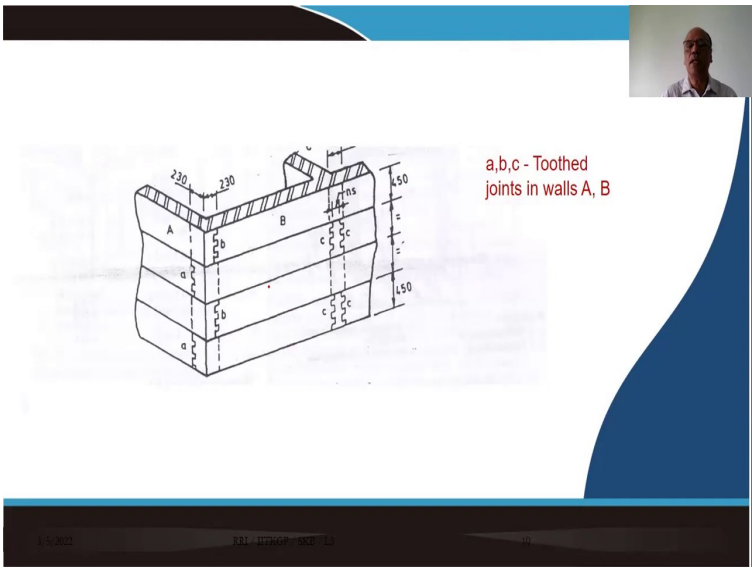

So, you can make use of that kind of a detailing, or sometimes we can go for a detailing of this kind. As I said that corner element could be, may be made out of concrete with some kind of a toothing, and these toothing can be connected with the masonry system, and thereby your corner becomes effective, and thereby the cracks will not be generated.

This kind of detailing can be introduced. Or in simple words, the corner of the two walls must be strengthened in an appropriate manner, so that you can get a better resistance.

In fact, from this concept that the corners of these walls are to be protected or provided with this kind of a concrete system, and combining the whole systems together gives rise to another kind of system which we call as a confined masonry.

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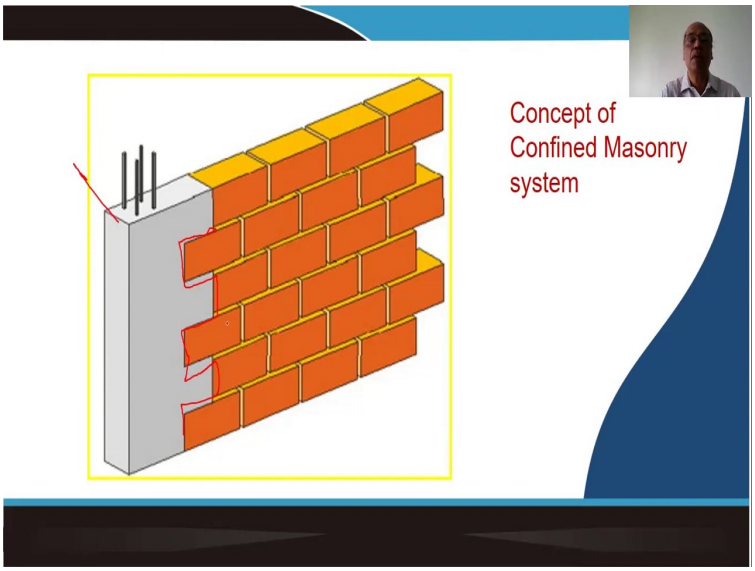

In fact in confined masonry what we do normally, we create the wall and where the walls are coming and getting joined together, at those corners we leave some space. And let us say you have a rectangular building plan form, and all four corners, at the four corners you have reinforced concrete columns. So, what we do, create the reinforced concrete columns at the four corners and then the columns are connected with the masonry wall so that you can get the form of the building.

Now, instead of constructing the reinforced concrete column first, what you do is that you call create the masonry walls and at the junction between the masonry walls to the sides of the column, you leave the space. And now, you create a column keeping the two sides as your framework, put two additional sides as a print book, and then put some reinforcement concrete into it.

So in the process what will happen, concrete will get inserted. You see as it has happened over here, the concrete is getting inserted into the masonry system, and thereby is

forming a connectivity which is giving some kind of a bond between the two systems. So, this happens on this direction, and this happens in the perpendicular direction as well. So, by doing so, this corner of the joint are connected in an appropriate manner so that the lateral loads can be prevented very effectively.

So this kind of a system is quite prevalent these days to take care of the lateral forces. So concept of confined masonry, in fact, is good to resist the lateral forces in an effective manner.

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So, what I wanted to tell you or I wanted to demonstrate to you over here is that the buildings particularly the masonry buildings when we are talking about, we can retrofit them in an appropriate manner by suitable detailing, and the buildings which are vulnerable where you find that they lack proper seismic treatment, they can be provided with these elements so that the whole system can be made stronger to resist the lateral forces generated due to earthquake.

So, and also I have given you some input about the confined masonry system that how a confined masonry system can be used effectively for resisting the lateral loads. So, this is in general about the detailing for the earthquake actions or the detailing of the masonry structure for the earthquake action.

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So, thank you very much. We will try to move into other areas to demonstrate that how effectively the retrofitting actions can be adopted in those structures. Thank you. Thank you very much.