Structure, Form, and Architecture: The Synergy

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Lecture - 37
Highrise Structural Components - Part I

Hello everyone, welcome back again to online NPTL course on Structure, Form, and Architecture: The Synergy. In the previous lecture we have discussed about different structural system, the evaluation of structural system for high rise buildings and also we have seen some nice example from the history as well as from the modern world.

And then we summarized that lecture with the note that whatever the structure available it has four different types. And as per the council on tall buildings and urban habitat, but if we clustered them into based on the location of the structural member then we have a discuss that, that can be divided into two categories one is your interior structure, the other one is exterior structure.

So, in this lecture we will be discussing on Highrise Structural Component Part I. And preliminarily we will focus on that interior structure what are the structural type and we will try to see some examples well, already built buildings where this kind of structural system being used. So, let us start lecture number 37 that is the structural component for high rise building part I. And at the beginning of this presentation if you can identify the city skyline this is from the New York.

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So, you can see that how beautiful the structure looks like, so all vertical members and there is little bit alternation to the form. And then finally, it is making a skyline for the city just you know in front of the water body and how beautiful it is. But, not only aspiring the beauty, we should also know the structural components, so that we can also think of to develop such and at least to know the mechanism, the structural mechanism the way these buildings are built at least the typology of the structure.

At the introduction definitely we discussed in just in the previous lecture that mainly two kind of loads are acting on building. So, in that type one is your vertical load or the gravity load, here you can see just a minute yeah.

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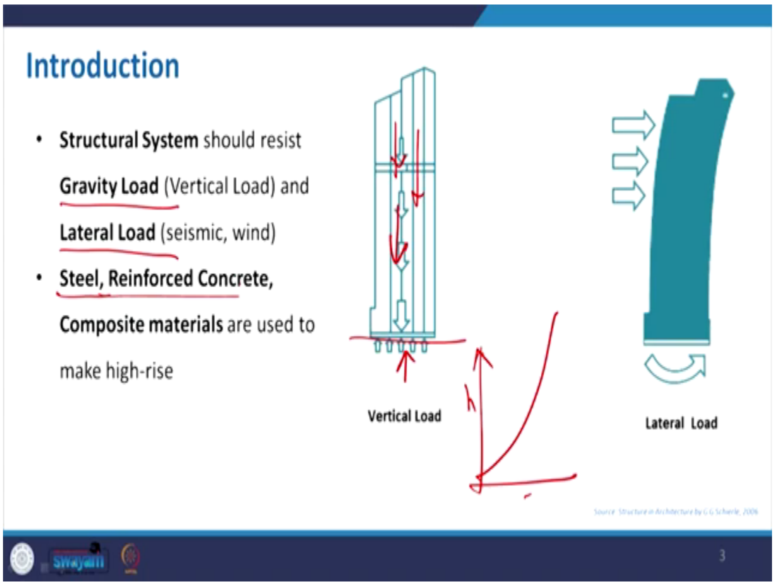

So, here you can see that all the date load of the building and all they are acting axially and they are transferring to the foundation and foundation will have a reaction. So, this is very common for all the buildings and even for once for the building as well. But, at the same time when you think of increasing height as because with the increase the lateral movement of a building will be more due to the wind pressure.

Because already we have discussed that with the increase that how the wind pressure will increase. So, if you just say this is the you know height and this is the wind pressure, so you can get this a special curve and it will be at critical situation. Along with that whenever you increase the building and where the height to the base ratio is also very high and that time the seismic due to any seismic activity during earthquake, so it will be vulnerable.

So, these two major lateral load to be well taken care of by different structural system and how to minimize that with the rigid or flexibility or with the hinge, that we will discuss in two lectures. So, in this case like definitely we will think of this lateral load and gravity load how that can be managed. Now, considering the material the steel, the reinforced concrete or maybe the composite material or maybe some materials which are in now in research stage can be applied to make the structure more strong and also having good resistance against the lateral thrust.

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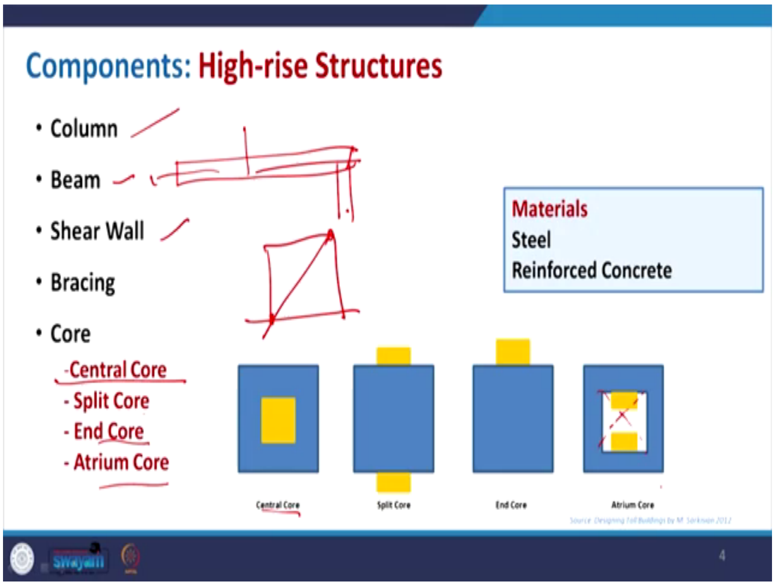

Now, coming to the component already we have discussed, so we will not go into detail. In this part column will be the part where it will be responsible to transfer the actual load to the footing, so this is mainly responsible. So, whatever the size of the column that will be decided based on the gravity load or the vertical load of the building.

It accounts all date load the self weight of the material structure and as well as the live load. Then where is the beam? The second component it has two purpose; one to transfer the load of the slab to the column and then also it will prevent the building initially from the lateral against the lateral force; that means, due to the wind or the movement.

When shear wall is again maybe a extended column look like in place of the column if we extend it, so, that will become a cantilever to the base and that can be a good instrument for resisting against the lateral load. The bracing is basically to be placed to you know connect to the frame or giving more stiffness to more rigidity and the stiffness to your structure like this.

And the core that we discussed that core for the high rise building, the services that can be group together and make core, and normally it can be you know the main structural element of the building or it be just as service core. So, we can place the columns very close to the you know area the central area or the core area that we decide. It need not to be core means always at the center and that can be made like a tubular structure or maybe it is just the shear walls.

So, here based on the position of the core we have four categories, one is the central core where you can see that you know this color, yellow color that being placed this is the core. The split core that can be like separated that entire core being distributed and they are put on different location. It can be an end core that it is being placed somewhere like it may be something like the staircase or some you know important services that kept, you know separate. Or it may be something like you make a atrium like you have these void.

So, basically this particular white portion is the void part and then we have the core in one side or two side or maybe in four side depending on the complexity of the structure, depending on the span of the structure we may have multiple core as well. But, in order to make the structure very simple and you know interior planning very simple mostly we can go with this central core or sometimes in some buildings we also have seen this atrium core.

The application of the core is very important for the high rise building and the decision on the core material like whether it will be the shear wall, the concrete shear wall or it may be the shear stress made up steel, or it may be just very closely placed column to make a tubular structure that we will be discussing not here, in the next lecture where we will be discussing on the exterior structure.

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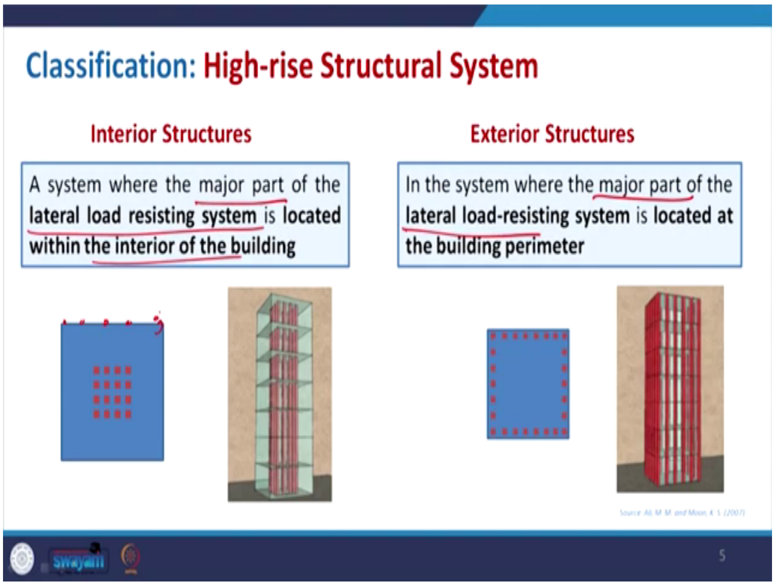

So, as we have discussed earlier where we concluded the last lecture that when you categorize the four types of structure whether shear frames and then the partial tube or maybe tubular structure those can be clubbed or cluster into two category, interior and exterior, so what exactly they do mean? Here is the answer. So, in this case, interior structure a system where the major part of the lateral load resisting system is located within interior of the building. So, whatever the structure which will be responsible for resisting the lateral load that is located at the interior side.

So, here you can just representation of this where the main you know structural elements at given at you know at the center at the interior of this particular floor and this is something where it is a 3 D presentation where this rate columns they are placed in you know inside the interior. Whereas in contradicted the exterior structure where the like major load resisting structure are located at the periphery. So, you here instead of making it at the center, this is placed at the periphery.

But, again we have to remember this is a mentioned that the major part of the major part of; that means, when you make this it will not say that you can have this as a cantilever there is no requirement of any column. But, definitely when you make your structure and depending on the height, on depending on the lateral pressure that it will encounter we can decide upon the you know number and spacing the distance between these exterior columns. It may be not non structural column or maybe not taking much load.

So, that can be something very thin or maybe when we think that building is too high that we have to give both your interior, exterior together or you have to have a center core as well, so then we can also go for that. But, in this lecture as I mentioned earlier we will be only discussing on the interior structure and their different parts. We have seen pictorial illustration where different kind of interior structure been shown. So, we will be discussing the same in this lecture and here is that particular image I was talking about there I skipped because I will discuss here it in detail.

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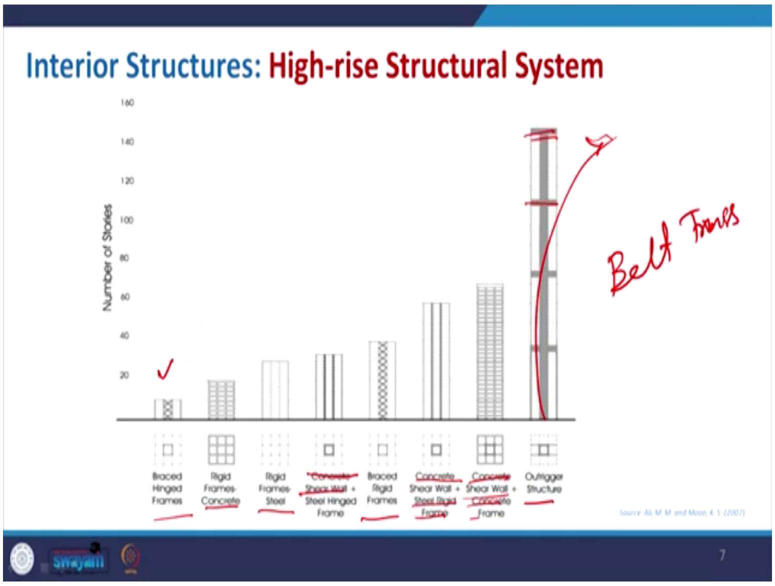

So, if you see that here in the y axis it is given as a number of storey the number of floors you may say a standard floor, and here is basically the improvement of structural element. So, when you go with the braced hinge frame you cannot really go much because of the hinge condition where it will again have some you know flexibility it will allow some rotation and bending and all.

So, for some multilevel parking and all we can have this kind of structure. Now, compared to that when you make a rigid structure, so, it can be made of your concrete it can be made of steel. So, basically when you go for steel structure as because steel will be very good for your tensile you know taking the tensile load and all so we can built little bit higher than the concrete. And here also you can when you use the rigid concrete frame you can even go a little higher, so 20 storey, 30 storey.

So, these are some representation where we can really you know go very safely. Now, compared to that when you move towards a little bit more height then it is very important to solidify or make your interior structure very strong. And then basically the concrete shear wall is you know comes into picture and then along with that when we have this if we give bracing added to that.

That means, it will again give more protection against the lateral sway of the building due to the wind pressure and all. And then when you move forward the concrete shear wall and steel rigid frame they combined. So, this is basically where your steel truss or concrete truss they are interacting with the frame, it can even give you a better result, I will show how. And then when you move further with the concrete shear wall plus concrete frame, so that can be combined.

So, we have the core structure at the center at the same time if you see the plan. So, again you have your concrete frame in the outside. In this state concrete shear wall is there, but still frame are placed in exterior like in the outer periphery. And then basically when you go and move to your outrigger, so, where in alternative or maybe with a certain interval we just provide the truss which will nothing but the cantilever to the core that will actually you know allow building to go high. And because of this the bending of this building will be restricted, so I will show one by one.

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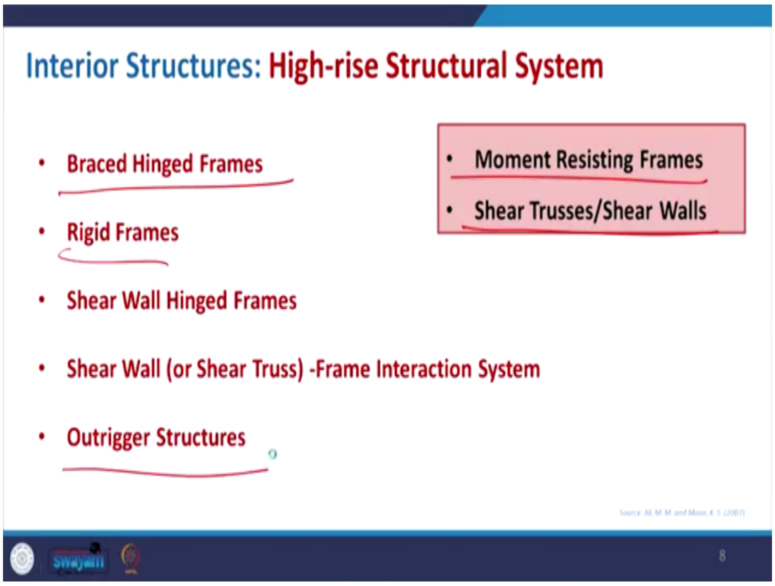

So, if I move forward, so basically for any structures structural system, two important parameters are there. One is your moment resisting frames which will resist the moment due to the lateral load and the other one is your shear truss and shear wall. So, these two components these two components they are playing the crucial role in any structural system. When you combine both of them together it will give you better result and we will see that how that can be combined.

But, if we go for the classification of this interior structure there are five components. Component number one is your braced hinge frames, second is your rigid frames, third is your shear wall hinge frames. And then shear wall frame interaction system where the concrete has steel frame and then the shear truss both they are actually you know combined and they perform in a better way.

And the outrigger system that just I explained in this particular phenomena, where at different interval we provide some you know what we call that horizontal structure maybe op truss. It may be made up concrete maybe, made of steel but that will give you a thickness compared to the normal beam and all some depth to that beam. Or maybe we can use the belt truss, this is I will explain this when we take the example.

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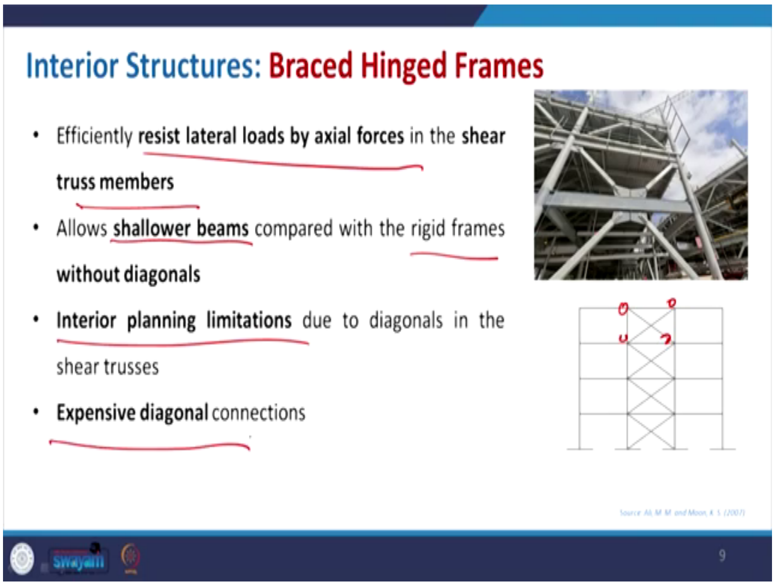

Now, coming to the braced hinge frame that I mentioned that it will actually you know connect those particular joints with the beam and column and can resist, but as because these are a hinge. So, that will not give that particular you know advantage that the rigid frame can give. So, efficiently resist the lateral load by axial forces or shear truss member that being given here. Allow shallower beams compared to the rigid frames as because the height is also very low and this bracing is taking care of the movement.

But, the problem is whenever you place this diagonal at the exterior surface, so it will be little bit difficult to make the interior or the you know the outer facet. And expensive diagonal connections, so sometimes it may be like fixed end or sometimes we can use the dampers. So, dampers being used for the earthquake resistance structure that we have discussed earlier in that particular lecture. But, this will have limitation and we can build up to say a few storey; up to 10 storey or something like that. Coming moving forward, coming to the rigid frames.

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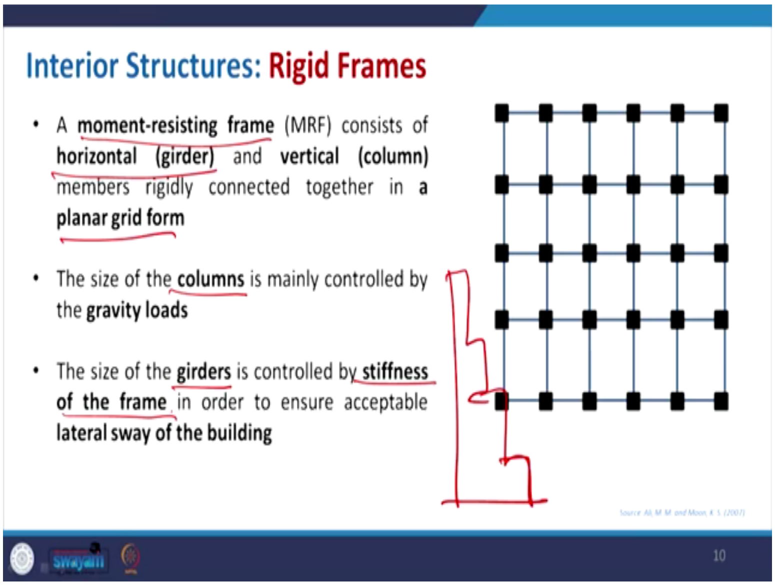

So, here it basically a moment resisting frame that consists of the horizontal girder and vertical column, so they are actually linked fixed rigidly and they are co planar. So, it is basically a linking then this you know very typical grid structure. The size of the column is mainly controlled by the gravity load that already I explained to you. That whatever the axial vertical load is being paid based on the column size will be decided, it may be a send throughout or it may change when you go because the when you calculate the load based on the accumulation.

So, load being added then if you like your cumulative load at the bottom will be too much, so we can have a larger section compared to the section the top. But, it depends on the structure other concentration as well where the uniform cross section is taken up. Now, coming to the size of the girders or the you know connection.

So, it is basically the stiffness of the frame and it is ensured by you know the what should be the acceptable sway lateral sway of the building. Like there will be sway because if you go for say some high rise building there will be the sway. And definitely there is a acceptable limit and based on that this the stiffness and other thing will be controlled for your horizontal members.

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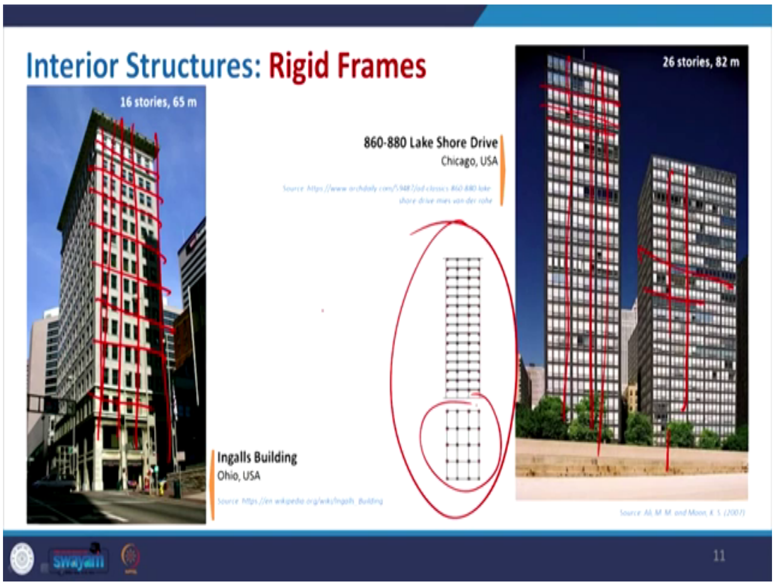

Now, coming to the rigid frame structure, here are two examples and here it is a typical plan where you can see typical plan and elevation where the beam your you know the girders and the columns being actually compiled. So, in this case if you see that this is your Ingalls Building in US there is 16 storey's 65 buildings. So, here it is a very simple structure. If you just see from the exterior, so their vertical members like this and then it is been connected.

So, this is floor wise very uniformly designed and so as true for this case as well, you can see that each floor with the you know connection this frame in both the case is the buildings, it is very straight forward. Like if we just want to represent very simple manner, so it is something like that where the rigid frame being used.

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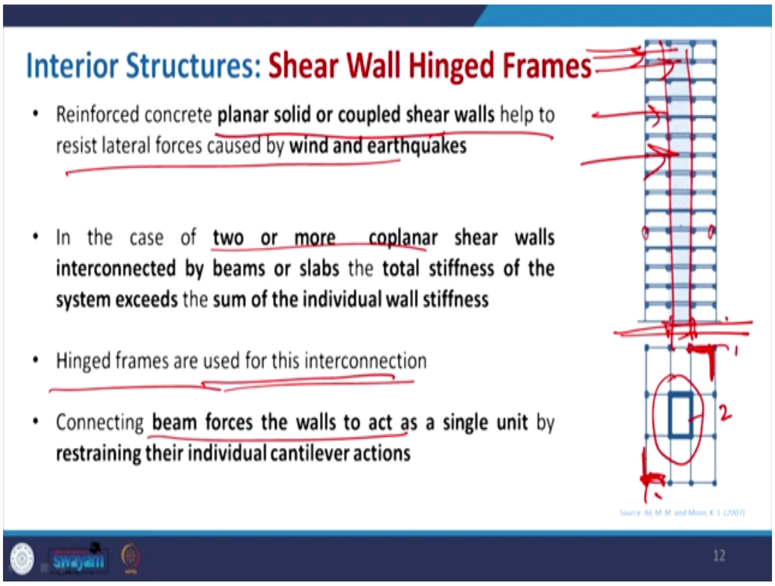

Now, coming to the shear wall hinge frame where it is not the connection, all the connection being made with only the column and the girders. So, here in state of that at the core as interior structure that we are discussing now, we use the shear wall. So, shear wall is basically is maybe the RCC wall which will act as basically as a cantilever to the base, so it can sway. So, other structure is holding it is giving the support, so main lateral force the this being resist by this core.

So, reinforced concrete planer solid or coupled shear walls, so, this is basically what I mentioned, helped to resist lateral force caused by the wind or earthquake, so this will anchor the building. So, during the movement this core will control the you know acceptable sway either due to wind or even during earthquake. In the case of two or more coplanar shear walls, so which maybe something where it is not the core maybe in some of the buildings you will find that maybe at the corner you know you have some portion the shear wall.

So, then each of the shear wall will have some stiffness, but when you add together the cumulative stiffness is even more than the sum of individuals. So, suppose if individual it is giving 1, it is giving 1, it is giving 2, but when you combinely if the equivalent stiffness is more than 1 plus 1 plus 2 that 4, so, it should be more it will be more than 4.

The hinge frame are used for the interconnection, so the other connection to the exterior column is basically to this. Then connecting beam force to the wall, so all whenever wind struck to this particular thing. So, this beam will actually you know transfer the load to the shear wall and shear will act about like then transfer the load to the ground.

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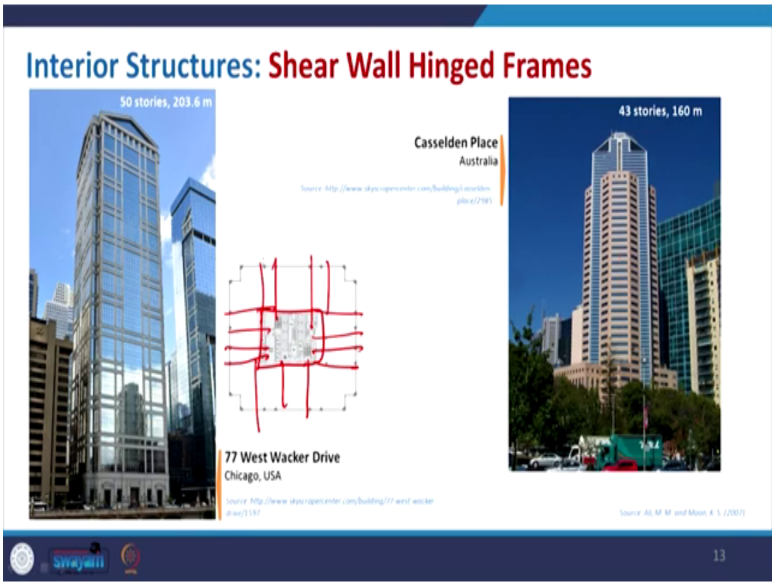

Now, coming to the example here we have a your two examples one from Australia and other from US where you can see that this is basically the core and how the other placed or that they are linked very symmetrically with the various symmetrical structure it is. So, it is making this shear wall hinge frame which is basically the shear wall at the center and then this is the case. This is so true for this and we can go reasonably a good storey 40 to 50 storey building for that and if you search for this building you will get more details.

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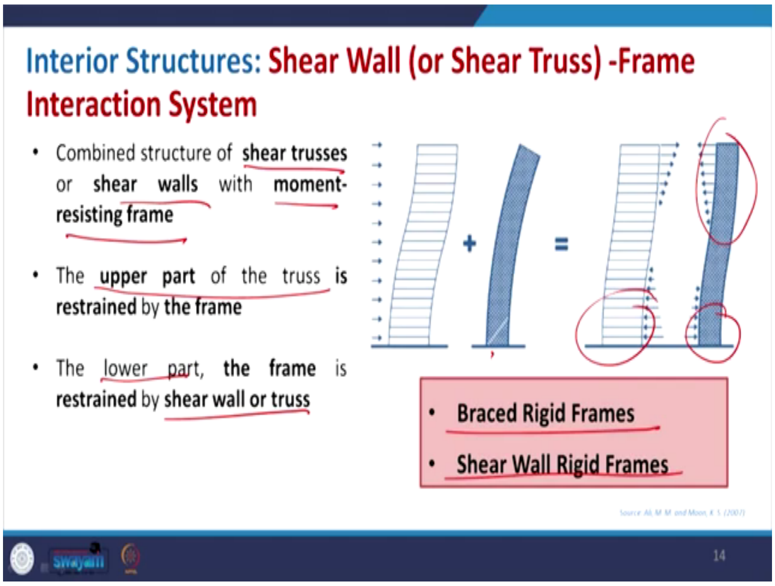

So, I would suggest that you go through you will get more information about that how it works. Now, coming to the interaction, yes. So, here it is basically where you just use your frame moment resistance frame, so it will have a movement and then this is basically the shear truss or shear wall and then when you combine. So, the combination of shear truss and shear walls with moment resistance frame.

In that case the upper part of the truss is restrained by the frame; the upper part is restrained by the frame because of the behavior. And the lower part of the frame is restrained by the shear wall, so the lower part being restrained by this, so this will act in a better manner. And in this case two types are or sub category we can have; one is your braced rigid frames and other is your shear wall rigid frame, so let us see.

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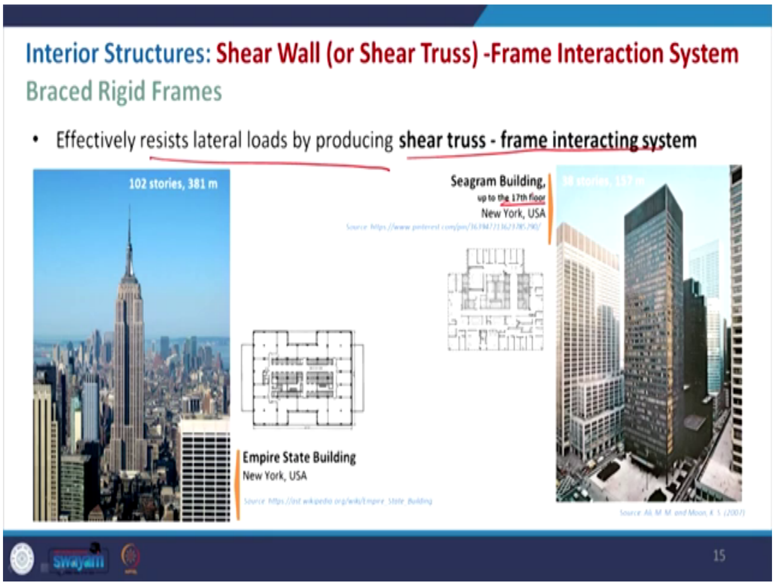

So, in this case if you see, this is the braced rigid frames where effectively resist the lateral load by producing shear truss frame interacting system, it is common for both. And this is example for Empire State Building in New York. And here also it is the Seagram Building both are very commonly used building examples in architecture there this system being used; moving forward the shear wall rigid frames.

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So, in that case, in state of your braced frame at different interval, so, here we use the shear wall and then the same example that I have given. So, this is basically up to 17 floor, we will see this phenomena of the braced rigid frame. But whereas, from 17 to 19th 29 floor we will get this you know shear wall frame interaction system, so, where the portion is being made of the shear wall of this building.

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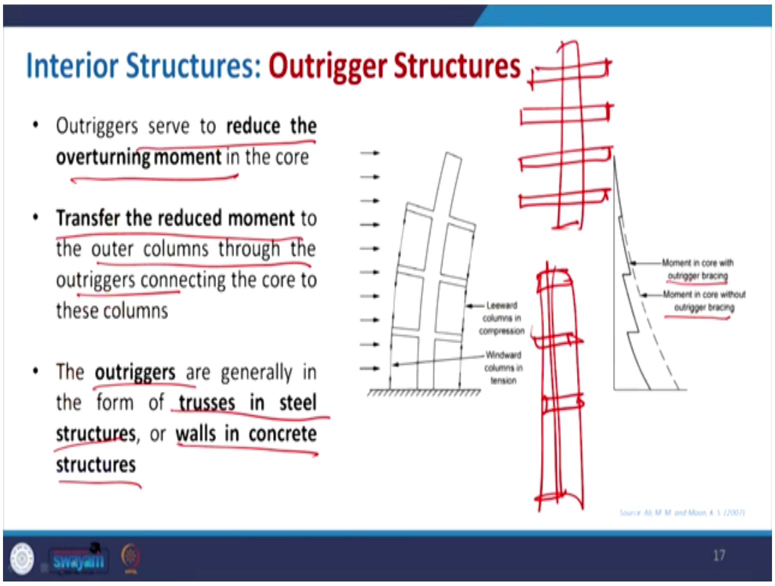

Now, coming to the last category of this is basically the outriggers. In this case outriggers serve to reduce the overturning moment of the core. So, here if you see that this is the core this is in a tilted position, but the original position is something like that. And if you have only the you know slab in that case it will bent a more, but as because if you provide some thickness.

So, the lean suppose in state of that you would just increase the thickness of this slab and just check that the movement during your the lateral sway, so it will be minimized. So, in this curve it has been shown that the moment in core with outrigger bracing. And then moment in the core without out trigger mission based on the height this is the same building if you see that how this can you know take place.

Transfer the reduced moment to the outer columns through the outriggers is the property here. The outriggers are generally in form of trusses in steel structures or walls in concrete structure. So, it may be steel or it may be wall, but it to be placed at certain interval. That in the beginning we have seen that you know building where this is being placed along with the core, so, it is been placed at some you know maybe a 5 floors interval or 10 floors interval.

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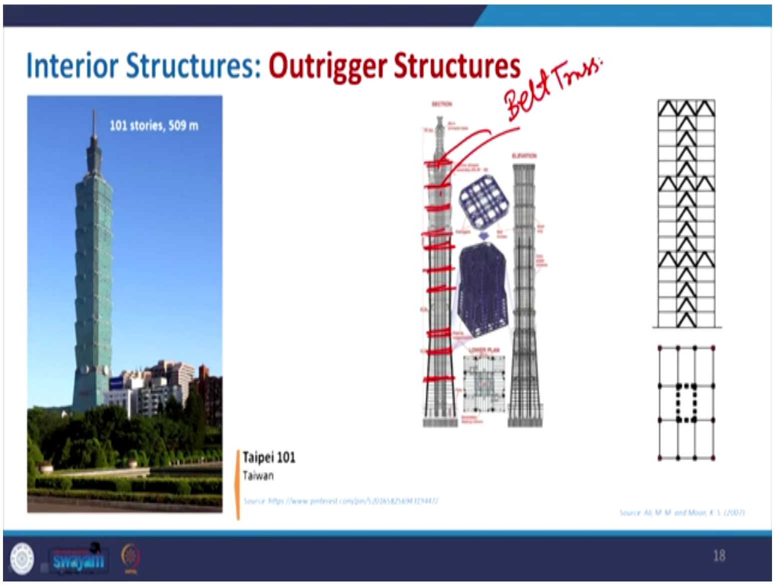

Coming to the example this is a the example of Taipei, so here you can see that in different levels, in the section though it is not much clear, but you can see some of the places where this being used at different you know interval. So, along with the core truss that we have, so also we have this kind of truss system this is also called belt truss.

So, this will help this structure to go and if you see that now this is something with the interior structure and we can go up to 100 storey building. If you go beyond that, so along with the interior structure we should go for some exterior structure where the outer periphery of you know perimeter was the floor like at the periphery. We have to provide some structural members as well to resist again the lateral load.

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Now, this is another example for this is Jin Mao Building in China, here you can easily see this is the finished product, but here you can see that how this floor being managed. So, here also you can get some bracing structural bracing that being made and also in this floor it is basically giving this truss which is made of concrete and then it is giving this particular belt truss.

So, here also you can see that how this being made, so in different floors it is being maintained. And finally, it is similar to this if you compare these two example it is the outrigger structure which will help us to go even for the larger height.

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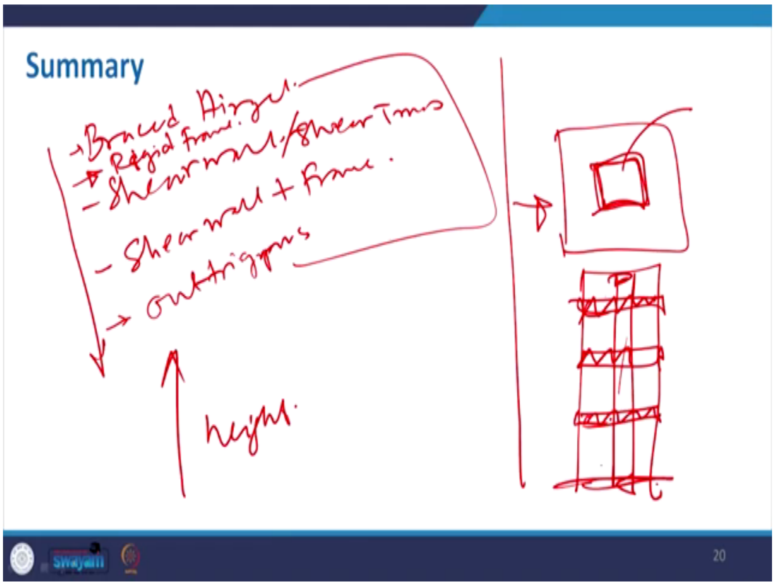

So, this is all about the interior structure where we have seen this. So, if we just try to summarize we have the braced hinge structure and then we have the shear wall then also we have seen the shear wall or shear truss is the same. And we can use a concrete or steel to make this then you have your shear wall and then your frame interaction.

Then also you have seen the outriggers, and then what I mentioned, I forgot to mention that is the rigid frame. So, when you just move from this to this you can increase the height of the building. And the complexity the cost definitely it will increase, but at the same time, like in order to make your structure safe and to design as you desire, so you should go for that.

But it is all about the interior structure and why it is interior structure we have to remember that major part of the lateral load resisting system is actually placed in the interior of the building. So, in terms of core and then in order to improve it sometimes you have seen that in the outriggers that along with the core, so, we also go for these outriggers which will help or resist the sway to certain control. And that can be made with something with the truss that we have seen in Taipei.

I am just this example also Jin Mao Building we have seen this. So, with this I will conclude this lecture here and we will be looking forward to the discussion on the exterior structure. Then we can see the difference between these two and what are the other applications and some examples. And then we will move to the case study of different mega structure in from the different parts of the world.

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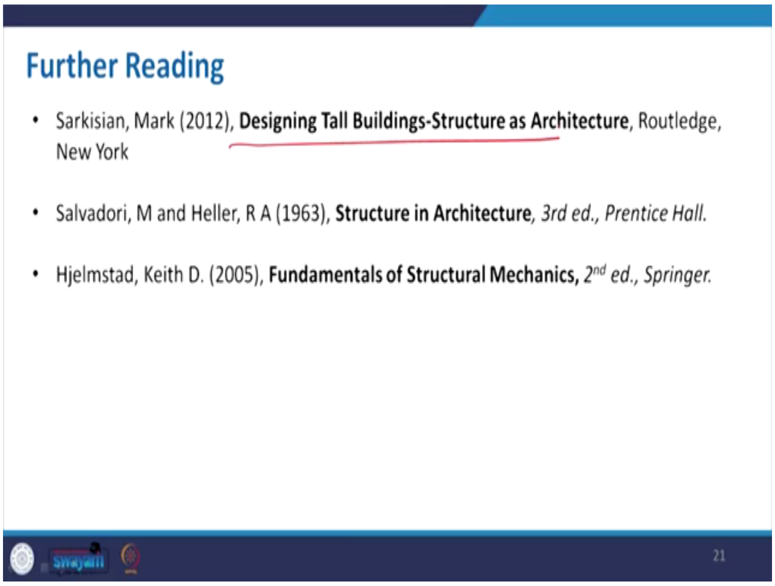

So, again for the study material you can actually go through this book this is very useful. If you have access to this book through the library or some you know subscription, so you can get enough information or else you can go through the links provided to the slides in relevant slides, so that you can get more information about that.

So, here whatever we have discussed mostly these are being controlled the information many other information's available in the website of your council on tall buildings and urban habitat. So, please browse through their website and get more information about that evaluation and different category of the buildings the type and then you just add on more examples.

So, these are very few that I have shown you with the stipulated time, but there are good number of buildings that is coming into the category. So, you just try to figure it out based on the structural component, based on the composition of different members that which category of interior structure that building fall under.

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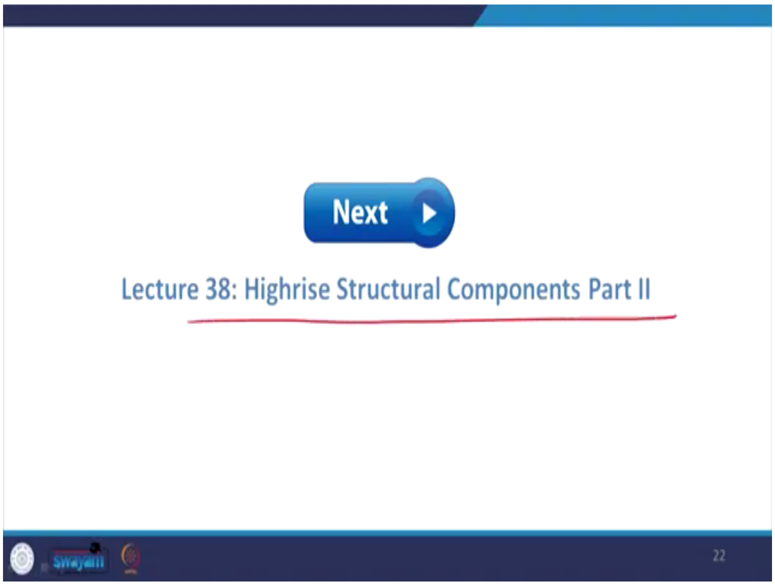

So, with that again I thank you all to take part and we will be discussing the next on the lecture number 38 that is your Highrise Structural Component Part II. And we will be discussing on the exterior structure and their application, so till then bye.

Thank you.