Structure, Form, and Architecture: The Synergy
Prof. Shubhajit Sadhukhan
Department of Architecture and Planning
Indian Institute of Technology, Roorkee

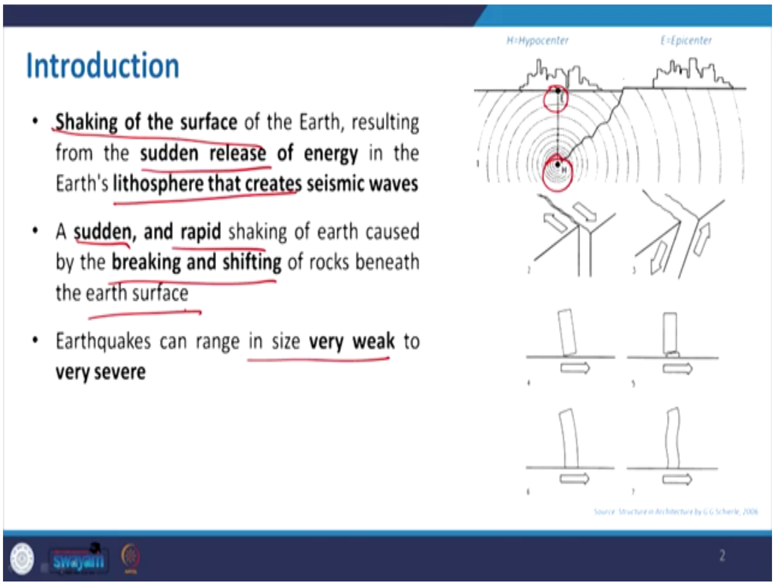
Lecture – 32
Structure and Architectural Forms in Seismic Prone Areas

Hello everyone, welcome back again online NPTEL course on Structure, Form, and Architecture: The Synergy. In my previous lecture, I have explained you about different structural arrangement, structural form in the area where it is basically windy or heavy storm is a common phenomena and we have seen how different form, different shape different height and different structural arrangement could help to reduce the risk associated with the wind and the heavy storm.

Like that in this lecture, now we are at the lecture number 32. In this we will be discussing on the Structural form an Architecture in Seismic Prone Area which is also very important, specially like if we consider in case of India also we have certain zones having high risk of earthquake.

So, in this lecture, we will focus on different form that are prescribed even different form that are not really recommended for seismic prone area and also we will see how we can reduce the risk of the damage of building during the earthquake. So, let get start this.

(Refer Slide Time: 01:40)



So, at the beginning of this lecture, let us just understand the earthquake or seismic activity. So, it is basically the shaking of the surface of the earth resulting from sudden release of energy. So, this energy may be generated due to volcanic eruption due to you know different pressure, different stress for the tension and compression and it is normally be happen in the lithosphere of the earth section and it is very sudden and it is very rapid shaking. So, within very few seconds we will really fill havoc shock of this kind of earthquake.

So, in recent time to in India, way back in 2015 during the month of April and May that time the part of the border adjoins like Nepal and Bihar, so, those parts actually felt a massive earthquake. So, it depends on the intensity and it depends also like where the earthquake evolved and then like depth of the earthquake. So, in this case if you see that below the earth surface where earthquake generates where it nucleates evolved that is called hypocenter and then just perpendicular to that point to the earth surface is called epicenter.

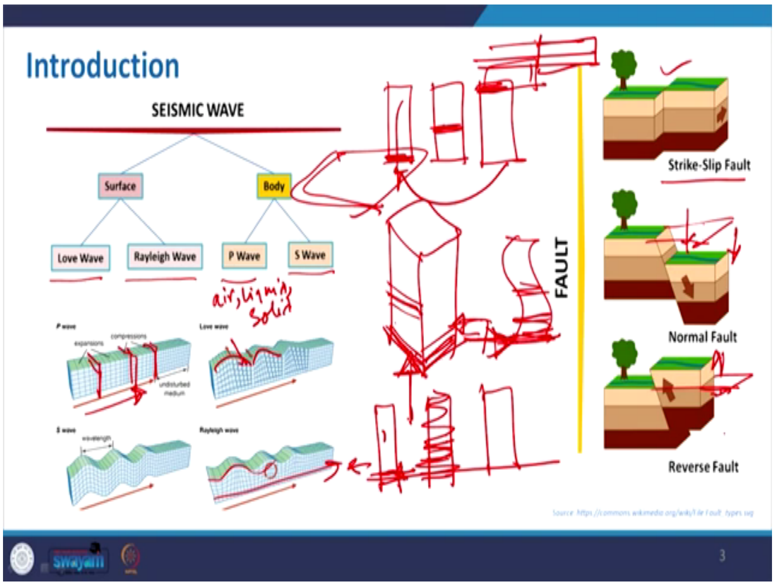
And whenever the depth is more and again the density again its intensity is very high so, that will actually propagate with some wave and that can expand over large area. And this earthquake the scale of the earthquake as we can see here in this slide that it may be very weak that we cannot feel. If you search in internet each day a number of earthquakes happen across the world, but hardly few of them are really failed because of maybe the intensity is not that much in Richter scale or maybe that depth of this hypocenter is not that month that it will really propagate enough.

But sometimes if it is you know very close to urban area or the intensity is quite high maybe more than 5 or 6 in Richter scale then definitely it will be havoc. So, in this sudden and rapid shaking, it is also happened due to the breaking and shifting of the rocks beneath the earth surface. As because we know the you know if you know the property of the soil, so, even the core of the earth is still very warm and then the portion is in very similar (Refer Time: 04:37) form somewhere.

So, sometimes due to you know the release of the energy, so, that the plates they will just you know overlap each other or they will slide on each other and that is the reason the earthquake generates.

Coming to the wave as I already explained that when the depth is more than the wave will also propagate and that will spanned over a large area.

(Refer Slide Time: 05:04)



So, basically the seismic wave being classified in two category: one for the surface one for the body and the body will have two type of waves. One is P wave and one is S wave as you can see in the slide and whereas, the surface the wave can be of the love wave or the Rayleigh wave. So, what exactly that is let us understand this. So, whenever like you have some object solid object like this and you just try to hammer it from the bottom, in that case what will happen that it the suddenly the lower portion will get a concentration of the stress. And then it will try to move to upwards. So, these are vibration is really move upward.

So, if we just try to figure it out with some phrases, so, first phase you get the stress concentration here, the next level it will go to the upper level and like that it will go at the top and again it will repeat from the bottom.

The time I have taken to explain this, in reality it happens even is very less time. So, it is the movement and this movement can be you know this wave can be passed through your ear can be of liquid and can be of solid.

Now this is the P wave that also generates where this movement can take place. So, you can see that the direction of your stress due to the earthquake is this and then how this particular fibers that you can get the stress concentration how it moves like this. Now coming to the S wave instead of hammering it from the bottom if you just try to hammer it form the side so, what will happen? Again just let us try to understand this.

So, when the load is being applied from the side, so the bottom portion will try to move towards this direction where the upper portion will try to be in static mode and then the next time like when it will try to adjust, so, this will move at the upper portion. So, then basically the motion will be something in this and it you will get a form of this particular rectangle like this.

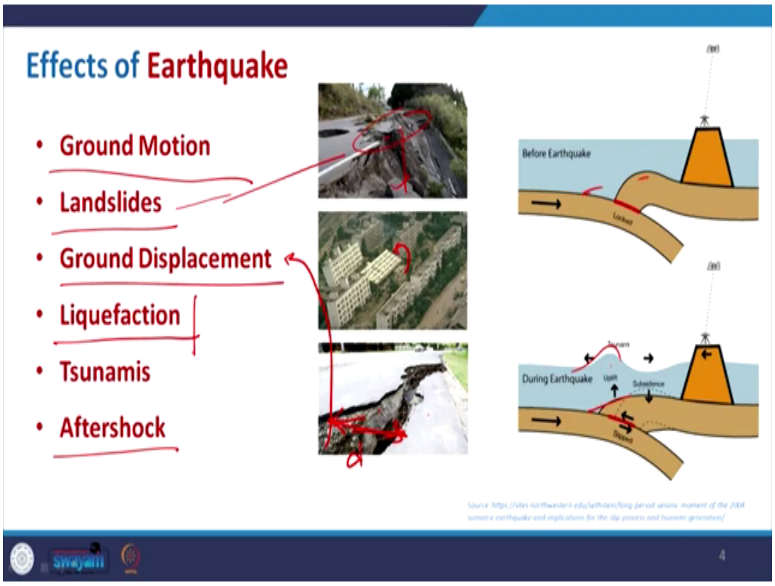
So, the earth whenever there is an earthquake, the stress applied to this will try to move these the inertia will try to keep it and then when it release the load release the stress and then it will move up. So, like that the S wave also you know be active during this. Now coming to the love wave so, then again you can see this is a movement of the soil where the portion how it can like shift from one place to other place with some displacement where is the Rayleigh wave is a rotation so, where it will form a wave and it expand.

So, during earthquake all of this happen together. So, basically there will be a shake. So, if I just take this as object and this is as the earth surface, so, that movement is very much like very much repetitive again the motion is really very fast. Now coming to the fault that happened like this is basically the deformation of the displacement of the soil like earth surface that happened during this fault.

So, it may be a strike-slip fault where we can have area and you have a river like this and then with the movement of the you know are during the earthquake so, this will display. So, this portion will slide on each other. So, this is the strike- slip. Now coming to the normal fault where some portion that basically sinks from that its actual level which was like this and then there is some slip.

So, this may be a normal fault. Sometimes it may happen due to the you know plate motion and all. The portion they slide up with certain angle, so, this is basically the original level in this and then there is a increase. So, this is basically the reverse form. So, these are different outcomes different effects during the earthquake.

(Refer Slide Time: 09:50)



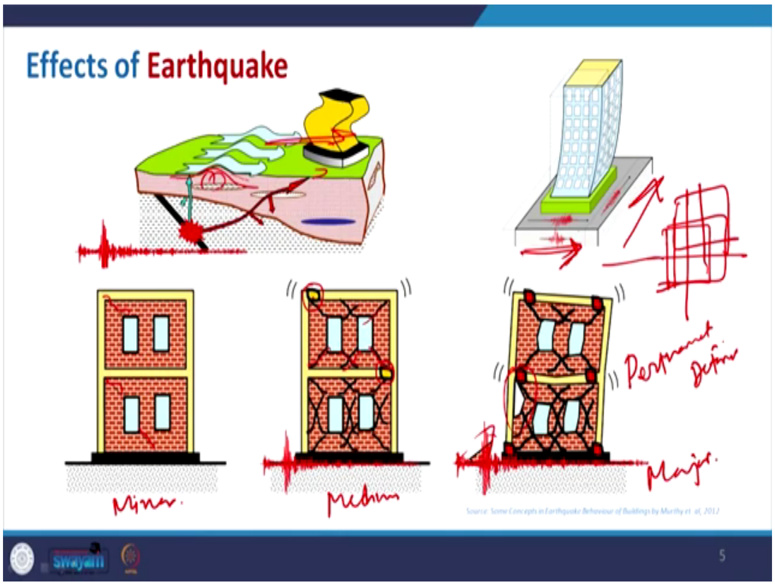
Coming to the you know effects of earthquake. So, again in this slide for we can see that there will be some ground motion there is maybe some landslide, ground displacement is also one of the major effect then liquefaction is very important where the soil will get saturated and that will act really like a semi liquid form. So, that like the whole buildings here you can see that due to this shaking in earthquake the portion where the foundation is laid that soil is giving like a liquid semi liquid form and then the whole building they just flip off.

Now, here you can see the displacement, the cracks being developed and the particular portion where we are adjoins, so they are having some displacement. So, ground displacement is also there then with this ground motion if something not developed on the soil may be that effect the building directly. But in landslides what we normally been seen that due to the motion it may create for like due to some flood activity or something man-made activity or blasting. But sometimes due to earthquake also, this landslide happened and here you can see that portion of this road just you know slide and they gone.

Now as a consequence sometimes if your earthquake the hypocenter is being under the sea. So, that may create the huge wave. Tsunami and in recent times for last 10 years, we have witnessed some of the tsunamis that really affect the people the buildings and damage havocly.

Now, the aftershock is something where with the main shock then we get a small earthquake due to the main earthquake. And here you can see that another motion. So, here the plates are just straight one after another before the earth quake, but during the motion it slipped and due to that there will be some upliftment of this surface and soils release the energy and that is why its creates wave on the water body and that create the tsunami.

(Refer Slide Time: 12:09)



Now, coming on the effects of that, so, here you can get this thing. So, here this wave basically this particular movement that is something rotational. So, now, you can relate it with the Rayleigh wave and then here is a shaking upward like in the direction of direction and the opposite direction of the earthquake wave. So, that is creating some kind of motion on the building. So, this is what exactly happened and here you can see that motion that how this can move on this direction at the same time in this direction.

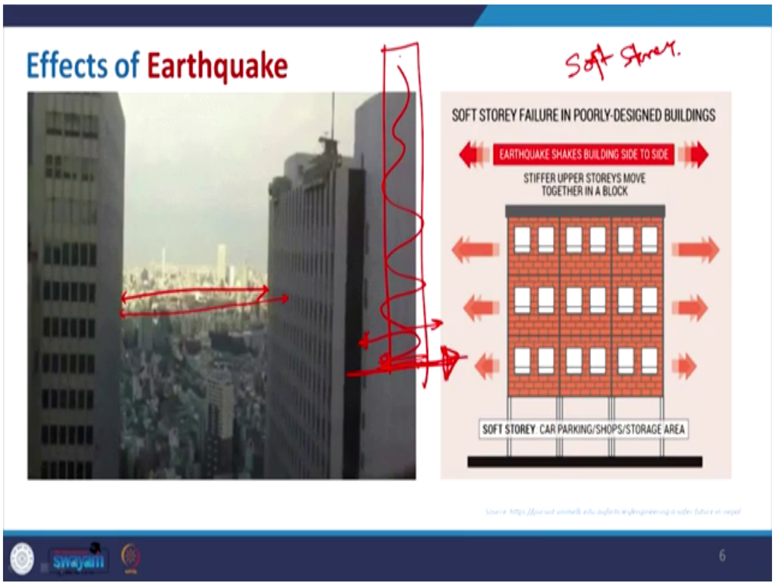
So, if you have these axis x y, so, first movement is basically it will try to move this side at the same time it will try to move this side. So, it is basically and the movement on both x y direction and then if the building is not properly designed with the structure that is resilient to the earthquake, so, that may damage. It to may have minor damage minor non structural damage or sometimes it is the total collapse.

Now, in this case if you see it carefully, the examples is this is the same building and this is with a very minor earthquake. So, here you can only see in detail like there is some cracks developed at the corner of this window and also remember these things whenever you your building materials will have some joints and the joint is of two materials then basically those portion are vulnerable.

Now, for minor to some medium earthquake where there is no such structural failure, but here in you can get the cracks and some of the portion at the beam also develop some cracks, but where is at the major and very sudden and high-intensity earthquake. So, there is a damage and this is serious damage where a portion of the wall you can see that it is like fall down and then this is a permanent deformation, deformation that happened.

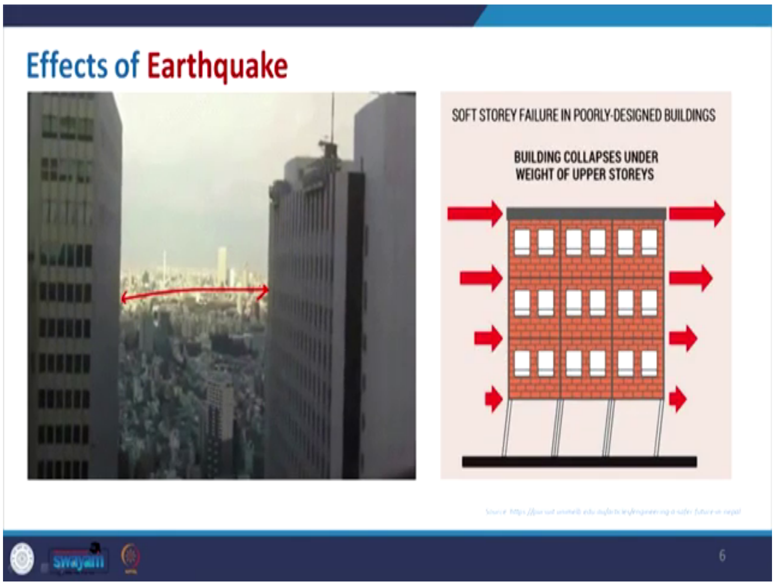
So, depending on the intensity and depending on the building materials their structure the effect will also vary.

(Refer Slide Time: 14:35)



Now, if you see this two jeep image, so, first one I just would like to see you this is very slow motion if you see this image very carefully and if I try to draw a line between this.

(Refer Slide Time: 14:50)



So, you can see that the line I have drawn is static, but the it is varies that there is a very slow motion due to the wave and then if I draw the line again, so, basically it will increase. So, in this case it will have height. So, the same building its typology building is there and then how the deformation take place.

Now coming to this, it is basically one example where it is also called as soft storey. So, here the ground floor is basically a tilted you know arrangement where this being normally used for the parking or maybe sometimes shops. So, it is not properly filled

So, the heavy mass they will get some sway and we have to remember one thing during the earthquake especially for the tall building, so, when earthquake attack the first contact area is this surface. So, when these particular surface is try to move with the direction of the earthquake, it will try to be in inertia to get a move in this direction. Now the moment it propagate the wave. So, it will try to move in this direction so then it will try to retain back. So, for that it will create the wave and then there will be a shaking. So, left right and then forward backward movement

so, like this it happened here and then there is a collapse.

(Refer Slide Time: 16:22)

Now, before getting into the different structural form or which is at recommended which is not prescribed in different codes. Let us just go through some of the images which like we can see the devastated scenario being created due to the earthquake and this is mean to randomly taken some examples from the recent Nepal earthquake some of them are from the Bhuj earthquake and then some of the pictures that I have taken from the context of some you know countries beyond India.

(Refer Slide Time: 17:09)

So, here you can see that damage. It is self-explanatory that how this has collapsed. This is one of the landmark in Nepal and that collapsed totally during this 2015 earthquake.

(Refer Slide Time: 17:19)

And this is the scenario again where this is just looking heap of you know building scrap material, but exactly like this is the after scenario of major earthquake.

(Refer Slide Time: 17:31)

Here you can see the collapse again especially this particular core being just demolished this part.

(Refer Slide Time: 17:38)

(Refer Slide Time: 17:40)

Then here it is another similarly you can also see and some of the structures are still standing because of maybe they are new in terms of the construction age and then maybe something like the structural component they used to they are somehow restrained that particular they can they resisted resist that particular whip. And now here you see also it not really collapse, but the cracks developed which may collapse like after a mini shock or something.

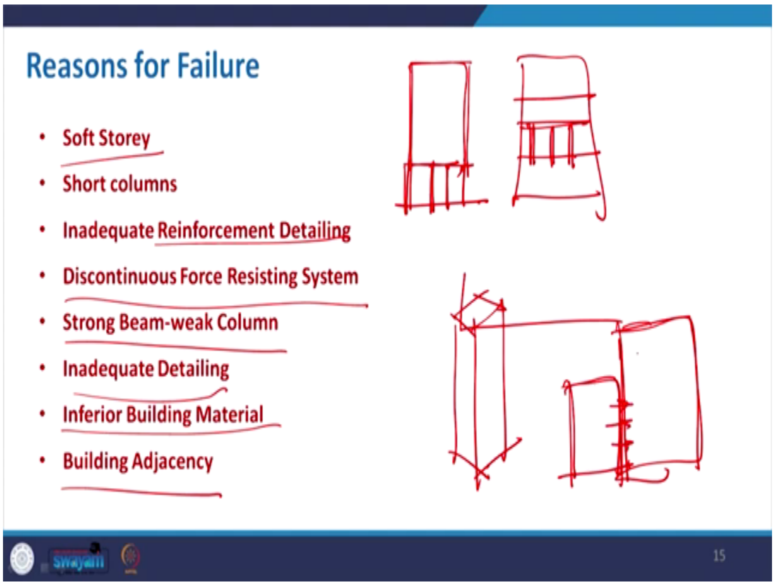
(Refer Slide Time: 18:20)

Now, this is another one you can see that how devastating this could be.

(Refer Slide Time: 18:25)

And then this is another one.

(Refer Slide Time: 18:29)



Now, reason for failure: so, there are major many reasons like normally the earthquake, it depends on the intensity. If it is too high probably there is very little scope to really do something we cannot stop that, but what we can do we can make our structure earthquake resistant enough so, that we can get the evacuation time. The time taken to just you know come out from that house which is considered to be very unsafe during that. So, that there will be not that life risk and this is one and the other you know things that we should do to make our building safe for this kind of disaster through different measures, like maybe the selecting of the right material selecting of the right building form that we will be discussing.

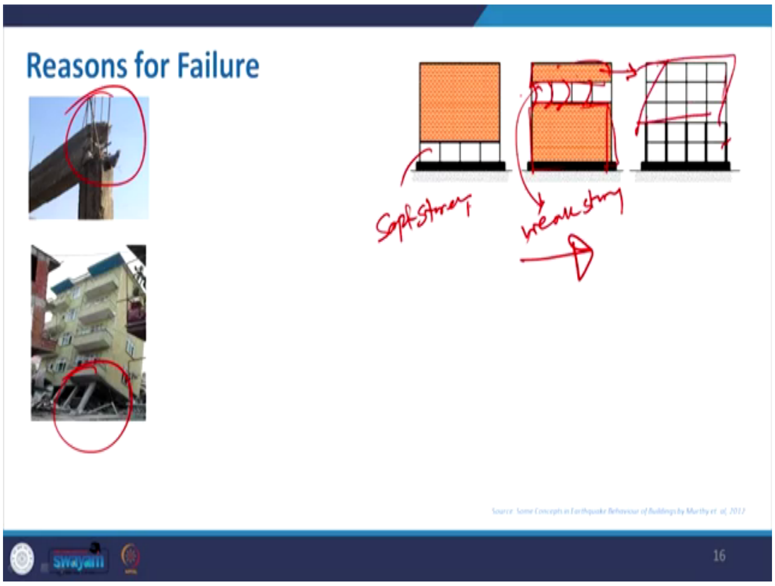
So, in the reason of failure if we just focus on this slide, so, it is relate to the soft storey. So, soft storey is basically where a building heavy mass is being there, but the ground floor is being supported with some columns and normally this is very common for the apartment building where this is being used for the parking or any shop area.

Short column sometimes we may have a building where you have the mass at the bottom and above and then maybe a small area where we just use some columns, these are there. And then inadequate reinforcement detailing is one of the reason where like sometimes we just in order to minimize the cost. We use less amount of reinforcement and that lead to damage during the wave during the earthquake.

Then discontinuous force resisting system: sometimes some potion, we just make it strong, but that should act comprehensively and then if it is discontinuous so, that may develop some unnatural behavior during the earthquake and may collapse. Strong beam weak column: so, many at times we do not go with the,you know strong column and we just make the beam depth increase the depth. So, in earthquake, resistant structure is basically it says that strong column and a week beam.

So, here it is the reason were strong beam and weak column combination may not perform very well during the earthquake. Inadequate detailing; again it is related to the reinforcement and other connection to different parts of the structure. Inferior building material and definitely it plays a crucial role even the design is perfect, design is tasted, but during the execution the material used for that making that structure is not up to the mark then that will be a serious concern. Then building adjacency is another one where you have two buildings in with a very minimal gap to each other. So, maybe this building is strong enough, but this building is creating is hitting like the other building very close to its proximity and that may damage.

(Refer Slide Time: 21:53)

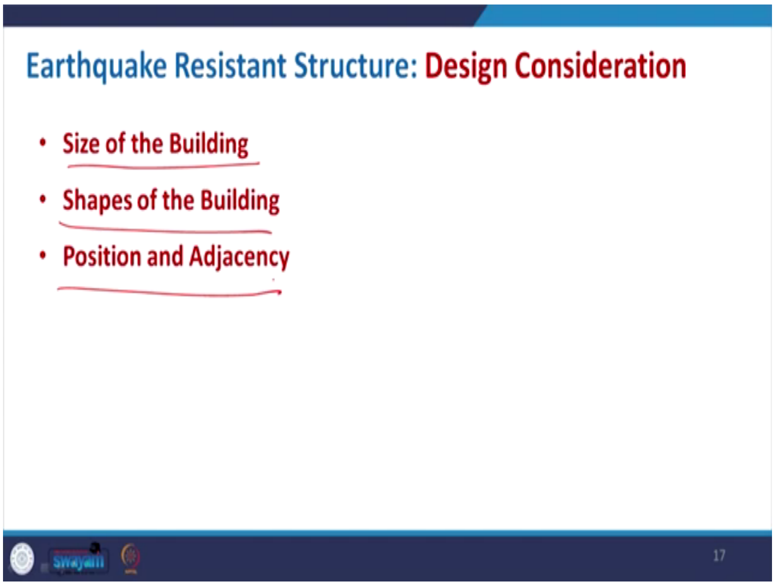


Now, coming to describe the same thing, so, here you can see that very minimal reinforcement being given and here you can see that the failure due to the soft storey and here you can see that your building may have a infield like there and then these are the very you know weak column that being placed and it create the soft storey and then that may be vulnerable similarly to that sometimes we can have a weak storey.

So, maybe this is this portion is in case of this in place of these you have this infill and then you have top fill, but in between it is there. So, during the motion with the heavy mass that will try to go in this side if the earth quake wave direction is on that side and this will try to restrain. So, this portion will show some unnatural behavior. This is also true when you have very heavy mass at the bottom that may sustain, but the upper floors that are not continuous like that particular restoring power is not continuous and then they may deform more than the bottom.

So, this is another one and already I have told about the building material and then what you need to do is basically to avoid this soft storey. So, as I told you like we have to be very much sure about the you know arrangement of the beam and column and we should really go for very strong column and weak being combination instead of the strong beam and we column which lead to the failure during the heavy earthquake.

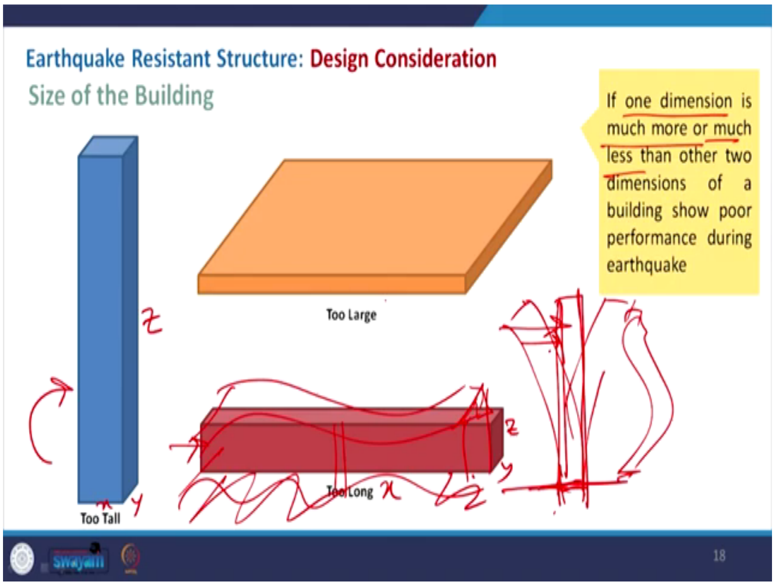
(Refer Slide Time: 23:48)



Now, earthquake resistant structure the design considerations that has a relation with the size of the building, the shape so, the basic shape that we take for the building and the position and adjacency. So, these are the design consideration that we need to make along with the structural design. So, that is also very important and we will discuss that different structural arrangement different structural system by which we can really make our earthquake resistant structure to you know reduce the risk a during the earthquake.

Coming to the size of the building: So, any building will have three dimensions the length width and like the height.

(Refer Slide Time: 24:42)



So, in this case like in all this representation if you see that if you see the dimensions this x y and then z. So, z is much more than this x and y. So, this is very tall building. So, it will be very vulnerable because like again like if we just omit this earthquake, but even this tall building will be vulnerable and due to the lateral wind pressure, but even for this like when it is anchored. So, this will have much more deformation during this earthquake ok.

So, this will create some kind of structural failures this will be very vulnerable. So, simple frame structure may not be appropriate for this if this is being constructed in earthquake prone area. So, normally earthquake cannot be predicted that much surely accurately, but the zones are being specified. So, that; obviously, we have to take that chance as a factor when we go for the structural design. Now in case of just we just make a flip then it will be too long.

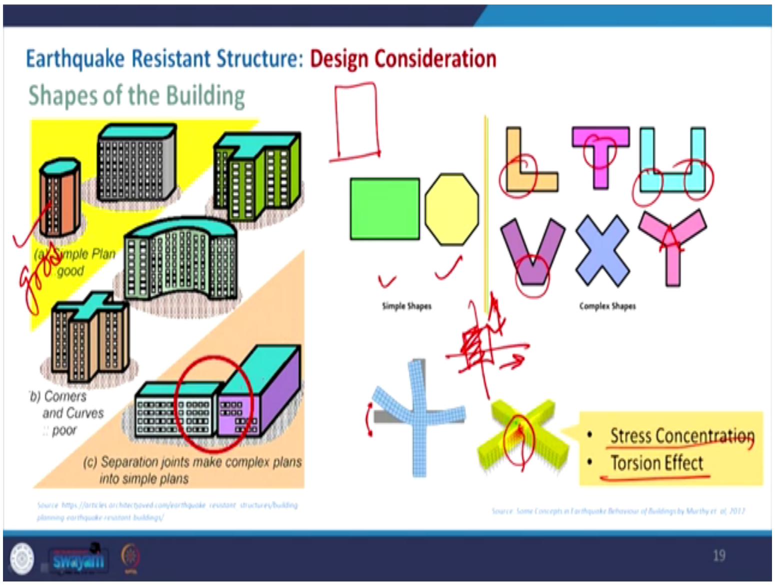
So, whenever a building is too long, so, here x y and z. So, x is much much more then y and z. So, in this case even on the motion like as because if this is too long, so, whenever the wave being replaced with the motion over the area that will have some difference and then this will developed some kind of you know stress concentration and then torsion effect.

So, the moment like what we have seen in the in case of your S wave, so, that may deform something this surface like this. So, this is again not really you know preferable to have it or sometimes even the two different motion from two different parts will be causing more damage.

So, what it says that it one dimension is much more or much less than the other two dimensions, it will perform very poorly. Now if we take a large without any expansion joint and all, so, a large portion of the buildings and then also it will be difficult and it will not really perform well the earthquake because of if it is covered a very entire area. So, the motion of the earth and different settlement during the earthquake of the sub soil may do like affect this kind of form.

Coming to the shape of the building:. so, it is advisable that you just select some basic shape, make the plan very simple and focus on the performance.

(Refer Slide Time: 27:35)

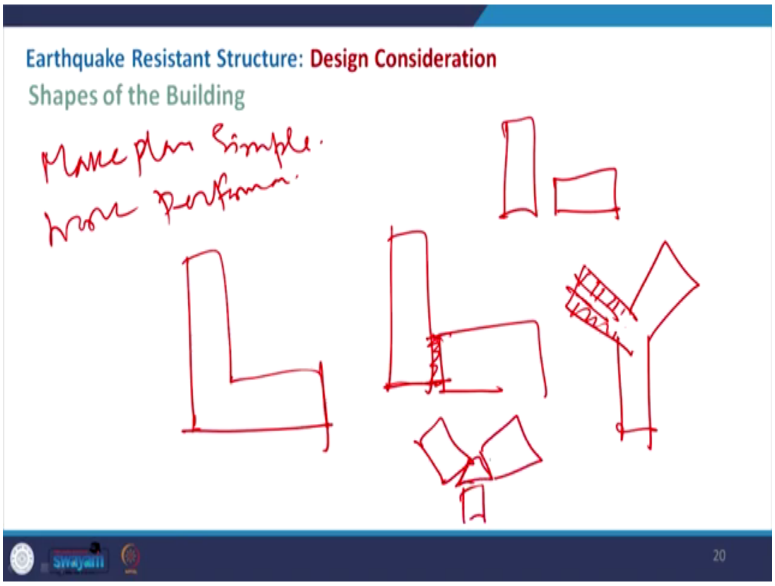


So, in this case if you see that very you know squarish or rectangular shape or maybe octagonal shape. So, these are considered to be good performer, whereas, whenever you make some joints or make something very curvilinear then that will not really perform well during the earthquake. And if you increase the number of joints and then your plan will get complicated that will unnecessary you know get affected with the stress concentration and again that torsion effect.

And that is why like yeah if I just want to get it correct, so, we just go with a very simple plan like this which is very acceptable and the shapes where this kind of joints being made T, L or U or maybe H, then this kind of corner then may be a plus building or the cross building or Y junction. So, these are the portions where the stress is being developed. So, here you can see the stress is developed here. So, cracks will developed if there is a havoc earthquake and also like the motion.

So, depending on the motion like as we have discussed that this object will have motion this side as the same time on y axis and the x axis. So, this will create some torsion as well. And when your building is again very in a close proximity, so, one may get affected with other. So, they will hit each other during the motion and then probably that may damage some of the structural component.

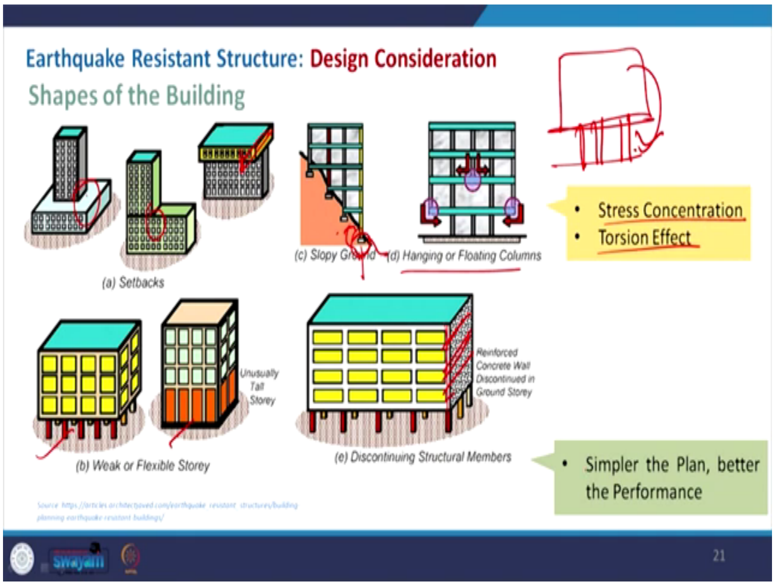
(Refer Slide Time: 29:17)



So, what we exactly want to do is basically to make plan simple and then just work on performance. Now, sometimes it is not possible with to go with the basic shape and we have to design something like this like many school building hostel buildings are like that. So, it is advisable that you make this building as a two buildings and then you create expansion joints, if possible you just make it apart from each other.

So, there will be no such problem of adjacency as well. So, they will not really affect and you know that is very important when in this in this context. If you want to make say a building of Y shape and many such towers we have seen having this where the hotel rooms are placed and the corridor is being placed. So, it is better to just make it separate and then this portion you connect it with the expansion joint. So, that way we can also take up those shapes, but these are not recommended as long as we can solve our design problem with very basic shapes for especially the building in earthquake prone area.

(Refer Slide Time: 30:41)

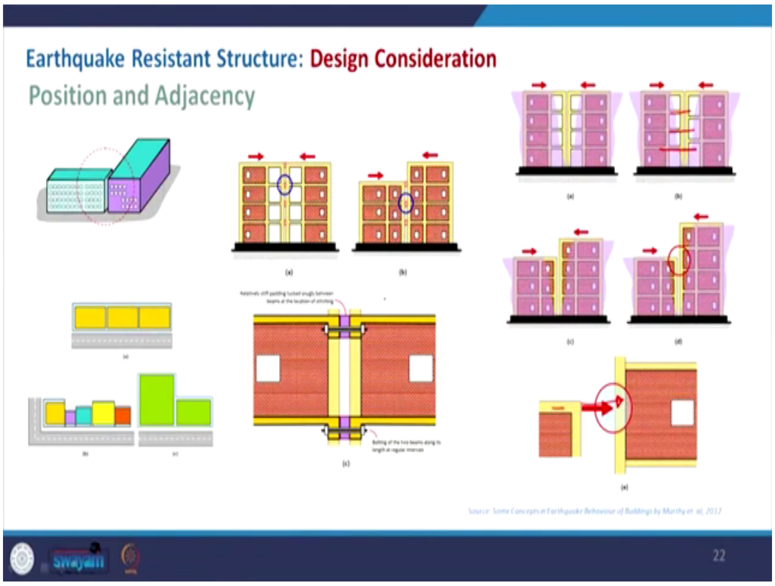


The shapes of the building if you see the elevation, then also like whenever you have some setback. So, two different towers so, that is also vulnerable here in this case and if you have the overhanging portion and also they will also get you know some kind of issue during the earthquake if your ground is very slopy, so, during the motion. So, there may be some landslides so and there will be unequal settlement. So, this building may collapse.

So, in that case we have to also take special care. If we want to make something hanging or floating column then where like you have the heavy structure and then at the bottom you have a very minimal say structure. They will be also very vulnerable. Then again the soft storey and weak storey already we have explained and then the discontinuing structural member where the beams and columns that being stopped, it is not really anchored in different side.

So, that may also create the problem. So, the stress concentration and torsion effect are the responsible factor for them, the simpler the plan better the performance during the earthquake that we have to acknowledge.

(Refer Slide Time: 31:50)

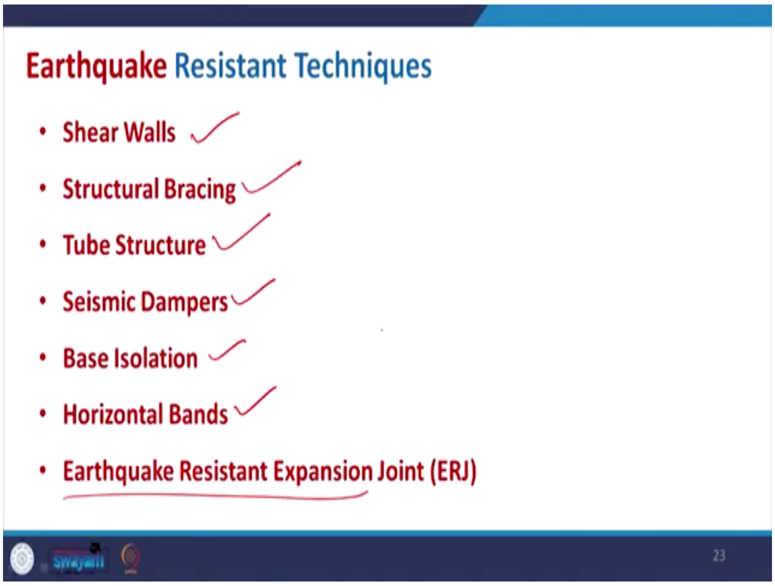


Coming to the position and adjacency again, this is what is happening like wherever two buildings and here it is the depiction I have picked up. I have given the source; you can get some more information if you go by this link.

So, in this case 2 buildings are identical and there will be some motion. In this case two buildings are looking identical, but if you see that their floors their you know slabs they are not meeting each other. So, the point is they are really hitting this particular slab is hitting the middle of the column which is more vulnerable and here also difference like different height of the building and all.

So, in order to avoid that what we can do we can use some kind of stiff padding absorbing the wave and then we bolt it the two structures, so, that may like help this particular adjacency problem of the buildings.

(Refer Slide Time: 32:53)



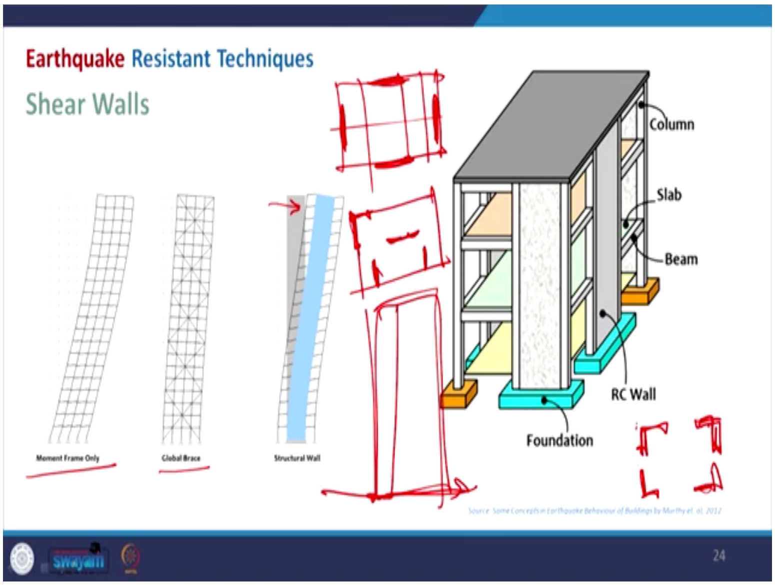
Coming to the earthquake resistant techniques where the structure different structural element different you know component that may help to reduce the risk of failure of a structure during earthquake.

So, here is the least, if you see the slide now the shear walls or the structure wall could be one of the option structural bracing who can be helpful to you know resist again the lateral load. The tube structure that we will be discussing again when you when will discuss on the high-rise structure in upcoming lectures. Then the seismic dampers which will actually be you know help to damp that movement and then there will be less effect on the structure.

Then the base isolation is another technique where during the earthquake your whole superstructure being isolated from the base and with some base isolated then there will be less impact on the building. Horizontal band is also low-cost solution where the you know the beam different beam to be provided at different level at the sea level inter level. And then also we can go with the earthquake resistant expansion joint where there is some two buildings are very close to each other or two structure is too large, so, in order to give the joint between them we can use it. So, this being used for the building this may also used for the bridges to save that bridge during the, you know the motion the shaking during the earthquake.

So, we will quickly go one by one and then try to understand what exactly it is.

(Refer Slide Time: 34:39)

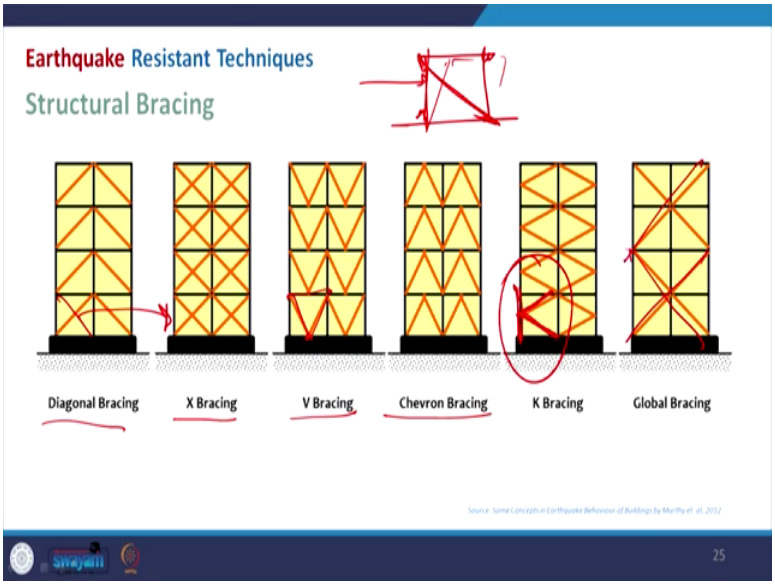


Coming to the shear wall is basically what we can say that a column if you extend it in forms of a surface which is cantilevered to the base is basically the shear wall. It is basically made by the RCC; Reinforced Cement Concrete and it will perform quite better considered to the moment resistant frame of the simple beam column structure.

So, moment frame only you can see the deformation with a similar wave and then when you go for the bracing you will have another one. So, when we will discuss the bracing will get the advantage and when you have the shear wall, so that deformation if you see the displacement is considerably less for the tall structure. If it is to be placed for multi-storey building not too tall it will really perform well. But what we need to remember in this case when we please the shear wall, so that should have some symmetry.

So, if we want to place this year wall. So, that should be placed something like that apart from the columns and other thing. In that case if we just place the shear wall like this a very random selection so, that may not really be giving the performance what the way we desire. So, always if we want to secure the corners which are vulnerable to the lateral load. So, we can place those shear wall at the corner and all.

(Refer Slide Time: 36:12)



Coming to the bracing of the structure that we have discussed previously in various cases where we have this frame and then due to lateral load it will always try to deform. And if we just use a diagonal start, so that may act that will increase the stiffness of the structure and depending on the position and depending on the shape the bracing can be classified as follows in the slide.

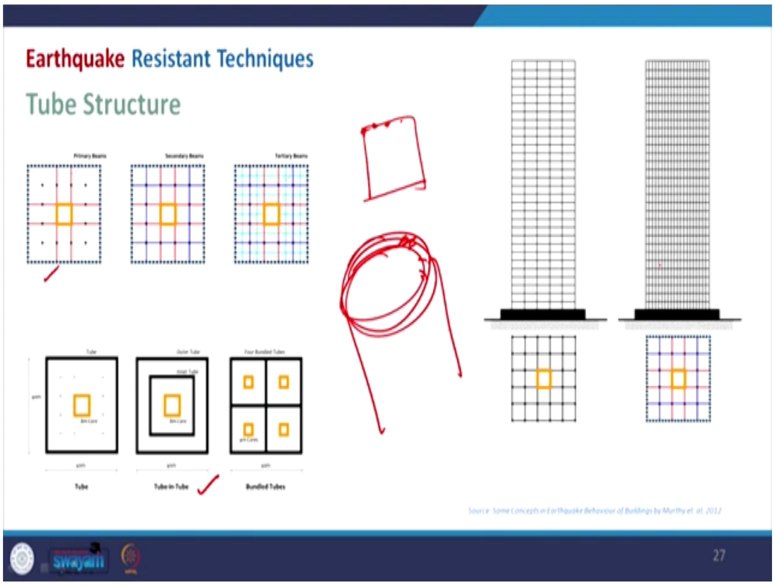
So, it may be diagonal where diagonally it is connect your floor to floor where the cross bracing is also possible where instead of one if we add two. So, this will resemble it to this. So, V type of bracing or K bracing is something where the two corners are being connected to the middle then the Chevron bracing is just the opposite of the V bracing.

So, then we also have the K bracing. So, the form of this is basically that K. So, this is called K bracing and the global bracing where it is not each floor being connected with the diagonal start its basically alternate floor or maybe few floors are connected with a large diagonal bracing. So, this will help the structure to get better stiffness and it will perform in a very you know in a better manner during the earthquake, the during that motion. And here these are the examples that where this bracing used.

(Refer Slide Time: 37:44)

And you can see that here it is something which is global bracing and where it is basically the, again at global one not each floor being connected, but it is a different form.

(Refer Slide Time: 37:57)

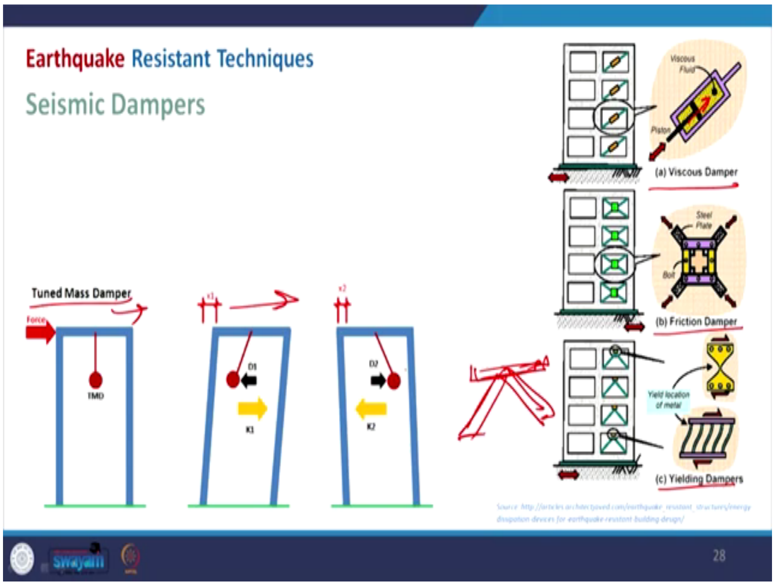


Now, coming to the another solution of this is instead of a simple frame structure why do not we go for a tube structure. So, we will discuss it in detail for the tube structure when you discuss the high-rise structure.

But in short it is basically where the parameter, the external exterior of the building which is more prone to the lateral force due to the wind and specially, so we place the column very close to each other and then that is connected with the internal core and that will create a form of a tube with a thickness. So, normally if we take a tube example of a pipe and also this thickness being maintained, we are like the similar thing being placed where you know the columns are placed is almost core but with some opening and we can have normal tube we can have like bundle tube where different tubes made together.

And then we can have tube in tube structure like this where the internal tube is also been maintained. And here you can see the difference like wherever you have multiple such columns. So, that will perform in a better manner to resist the lateral load.

(Refer Slide Time: 39:13)



Coming to the seismic dampers which is very important tool nowadays to reduce that in like intensity of the earthquake wave and then that will act to just you know damp turn that motion.

So, here different types; one is your viscous damper where the diagonal dampers being placed and this particular piston is having the motion with a viscous fluid. So, whenever there is a shock, so, that will move and that will absorb the shock. Whereas, we can have friction dampers where the plates will slide on each other and then again damped that motion.

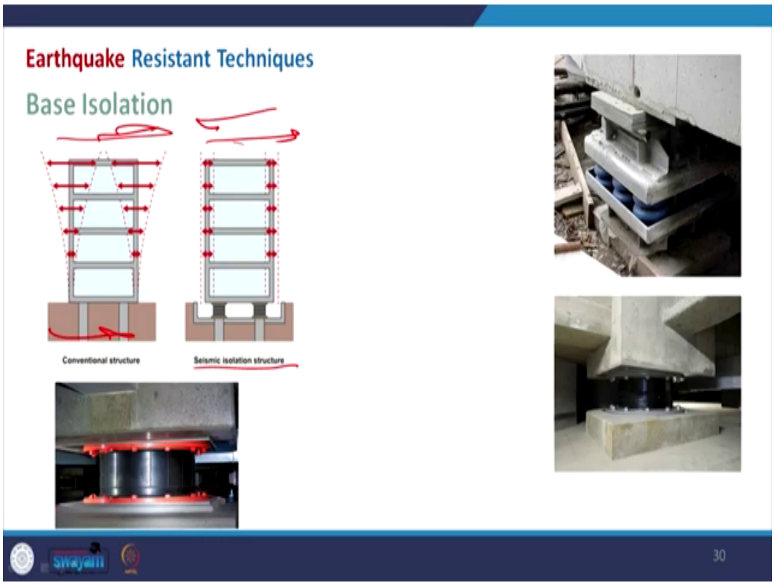
Now, in state of that sometimes we can go for the yielding - dampers which are very low-cost solutions where we use the member the metals which will really you know get this bend to the yield level that and then with the elasticity it will help to damp the motion. But one of the very famous such dampers is called tuned mass dampers, where heavy mass like a pendulum that is being tuned. And you can see that when the force is applied so, with that motion the building will try to bend on this direction at the same time this will adjust it to the opposite direction and when it will try to sway on the other side then it will go on the other side.

(Refer Slide Time: 40:50)

So, that it will manage and this being installed in type A10101 tower which is very helpful during that particular motion and specially this being also helpful for you know the to resist the lateral load due to the wind and here you can see the viscous dampers that being placed like this which will reduce that sway.

So, these are the techniques by which we can really reduce the risk of you know the collapse of the building.

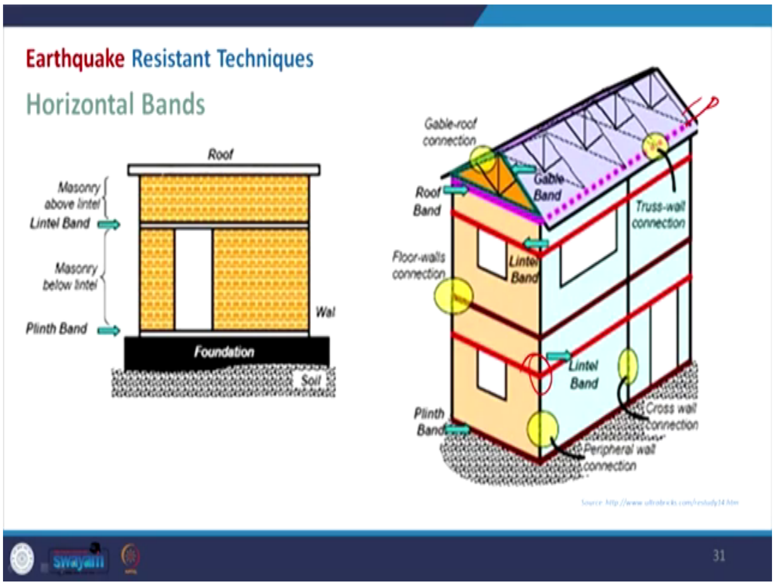
(Refer Slide Time: 41:24)



So, here with the conventional structure it is attached to that and you see that motion with the ground motion, the motion is quite enough. And instead of that if you use some seismic isolation isolator which is some kind of you know, the rubber material or spring material, so, during the movement what will happen that the whole building will try to shift together.

So, there is little deformation on the structural joint. So, this has been useful and here are some live example how the base is base isolated being used for the structure.

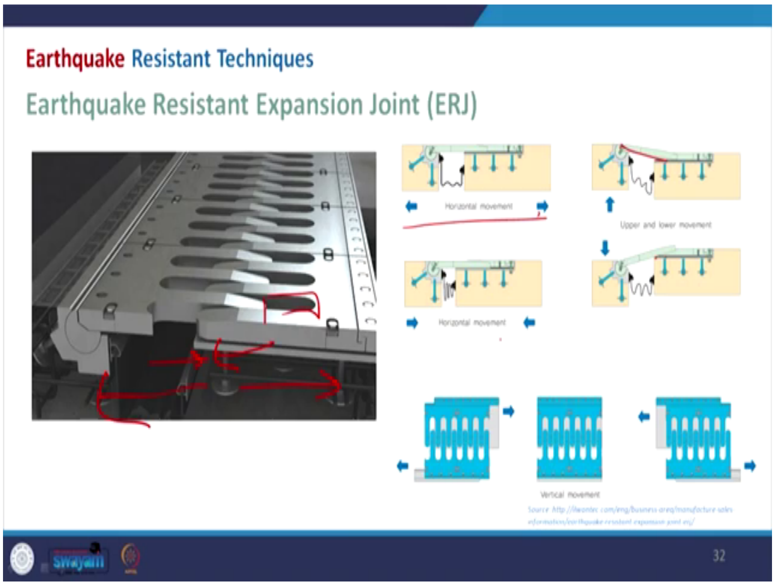
(Refer Slide Time: 41:57)



Coming to the horizontal band: as I mentioned that this is something which is low cost solution and the area which is very vulnerable to the earthquake. So, there at the lintel along with the normal beam at the ceiling level. So, at the lintel level this RC, see beam is being laid and then that will really help.

So, again for the roof the root band is being grated, but the pitch roof and where it is a flat roof. So, we have already the RCC structure. So, this is really going to be helpful.

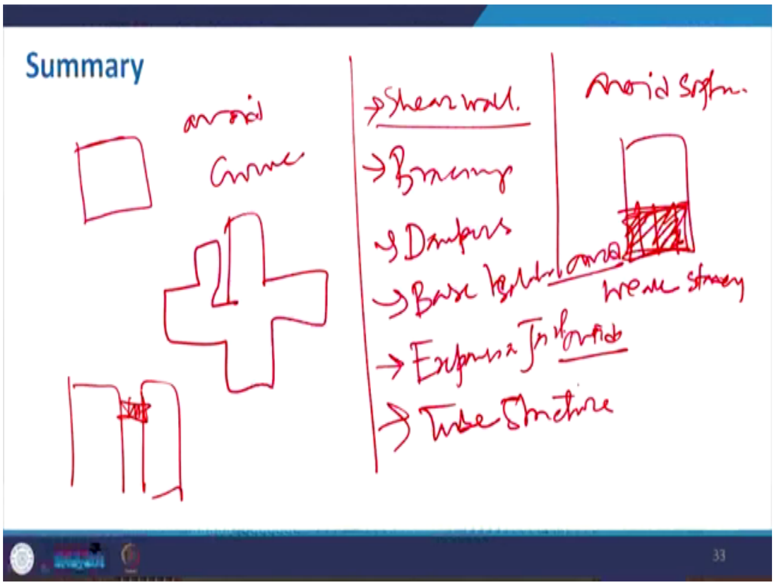
(Refer Slide Time: 42:29)



Coming to the factor like, another technique that is your earthquake resistant expansion joint. So, this will look like this and you can see the movement when there even is a horizontal movement, away from each other, so, they will go apart and then when there is a opposite motion and then they will just you know try to close each other and that gap is being maintained and that being designed with different frequency.

And when there is a movement up and down movement, so, it can go up like this it can bend and it can also go down. So, it will raised on this, so, basically this expansion joint. So, wherever is the movement up and down and then you have you know the construction and then they will go to each other, so, that will help with this joint.

(Refer Slide Time: 43:22)



So, now we are concluding this lecture what we have seen in this that earthquake is essentially not killing people, but the bad design which will not really sustain during the earthquake will be very much afraid to the people. And that is why we have to make our building earthquake resistance and the form that we should take should be very basic form and we should avoid the curve form along with some joints like this or maybe some irregular joints which will be really vulnerable and be affected with the stress concentration and the torsion effect during the wave and then we should really avoid that.

So, whenever you have two buildings close to each other we can either use that shock absorber or maybe we can use this expansion joint that we have just discussed in the last slide and the structural system we can use the shear wall instead of a normal wall or in field we should avoid the shop storey ok. So, basically if you have the column. So, it is better to fill this area and use that ground floor right you have to use the wall.

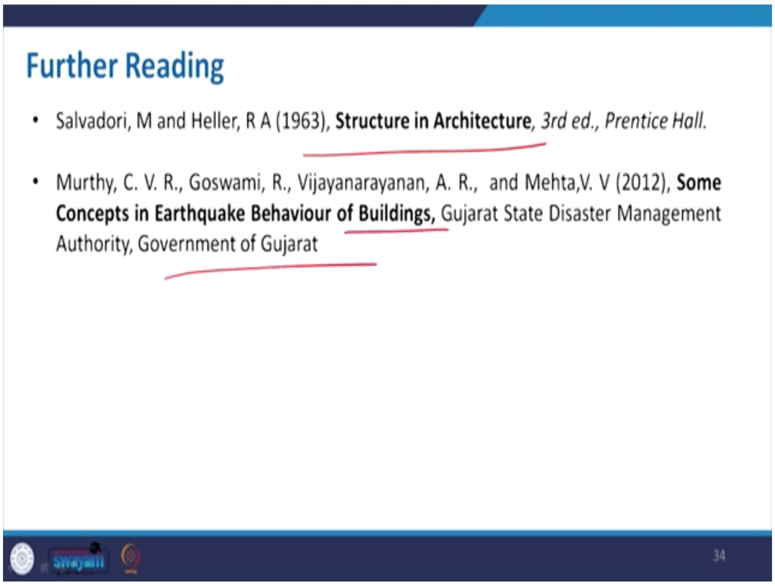
So, we do not make it like wall free and only the column being there with the soft storey. We will also avoid your weak storey we you weak storey, we have to avoid and then also we have to avoid the structural like deficiency. So, the detailing like the whatever the reinforcements it is required we should go for that.

Now, shear wall is one component. Then we can go for the bracing, we can use the dampers different kind of dampers we have seen. Then we can go for the base isolator and then also we can go for the earthquake expansion joints.

So, expansion joint may help that to just you know adjust the structure and also we have discussed something about the tube structure. So, there are some advanced structural system, for the high-rise building to protect against this kind of you know lateral forces.

So, with this I conclude here and I am sure that this discussion is very helpful to understand about what type of design we should take to just avoid those vulnerabilities.

(Refer Slide Time: 46:02)



So, these are the readings material for the readings that you can get something and this is one of the document that I found very useful you can go. So, you will get some you know different information, some more information about the earth quake resilient structure and all. And with that we will move forward to the area you know Structure and Architectural Form in Flood Prone Areas. So, we have covered the wind prone area what should be the case and then currently we are we have just discussed about the earthquake prone area and now we will be discussing on the flood prone area in the next lecture.

And before closing this, again I thank you all to take part in this course; we will be meeting in the next lecture.

Thank you very much.