Structure, Form, and Architecture: The Synergy

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Lecture - 12
Structural Requirements

Hello everyone, welcome back to the online course Structure Form and Architecture: The Synergy and now today we are at lecture number 12, which will be basically focus on the Structural Requirement. In lecture number 11 we have seen different you know basic properties of structure starting from the force, then strains and different kind of force like compression tension, torsion, bending, shear and like with that background now we move forward to the structural requirement to get you know structure as per the design, as per like our requirement to bring our architectural design into reality with satisfying all this need.

So, at the introduction of that, this is again a repeat slide to the earlier presentation, but I intentionally put it in this to start with that the basic satisfaction that we should get from our structural design component that my structure will give us enough strength to prevent breaking of the structure it should also give the stiffness so, that it will also prevent the structure from bending and again get it like you know deformed.

And then the stability is another important thing that the structural form we create or like not a single structure maybe the structural component, that combined together will have a form that will be stable. So, that it will prevent the collapsing of the building or the structure and the synergy is above all like the right mix of everything to bring the structural system, that will act together to satisfy the need to you know you know have a proper and optimized structure for our design.

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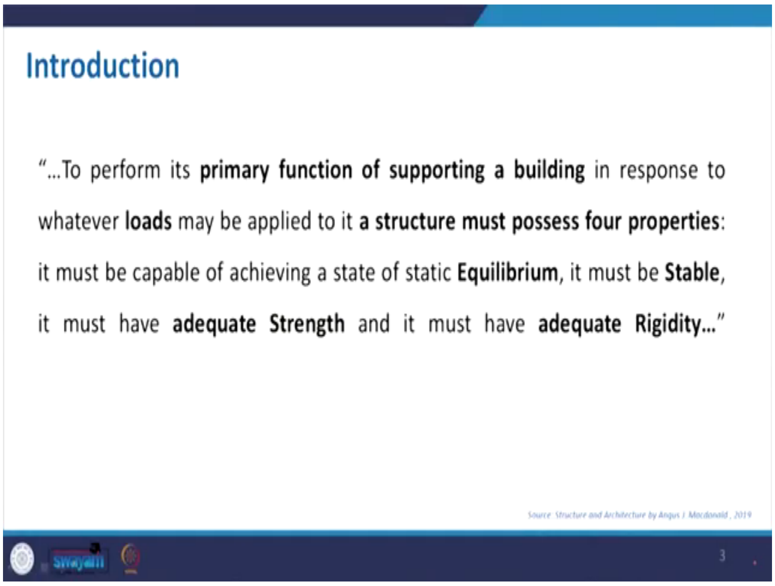

So, with that this are some text taking from the book so, here what it says that what exactly the requirement that a structure what for what reason we need a structure. So, the basic or primary function of a structure is to support the building against all imposed load into it. So, here what it says like to perform its primary function of supporting a building in response to whatever loads may be applied to it.

A structure possess four properties. So, in order to resist everything like all the loads it maybe the weight load, it may be the light load, it maybe the thermal load, it may be the lateral load, dynamic load, impose load, then it may be something else sudden load whatever load we have discussed during that lecture of different kind of loads are acting on a structure.

So, the structure should be you know resistant enough and for that they must have four properties what are those? Number 1 is static equilibrium. So, in the earlier presentation we have seen like how to maintain the structure like static equilibrium, there are some conditions to get all this net force equal to be 0 the net moment also need to be equal to 0 and then it must have the stability in the structural form and its stability should be there to prevent from the you know collapsing and along with that what they need? They also need adequate strength the material we use that should provide the strain so, that it will not really you know affect the building open load is applied and it will not break very easily.

So, it should go with the applied load all the calculations to be done accordingly and we have to decide the materials and the proper proportion so, that it will have the adequate strength. And along with that this overall things should have the you know adequate rigidity so, that it will also play the you know that stiffness and it can deal with stress and strain developed over the time like it may be due to the static load, it may be due to the dynamic load like earthquake or wind load maybe the flood load or maybe the rain load.

So, four properties equilibrium, then stability, then strength and then rigidity. So, we will talk about these four properties which has the requirement of structure to support our building to fulfill its primary function as supporting the building from all other you know applied force onto it. So, equilibrium geometric stability strength rigidity that already I mentioned.

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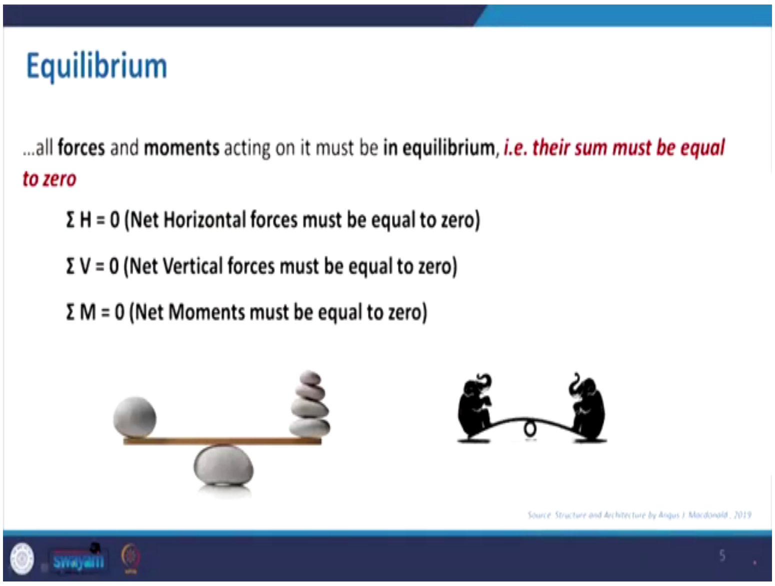

So, we come to the equilibrium. So, in this case this is already been discussed here we see another look into it. So, net horizontal forces must be equal to zero, net horizontal forces must equal to be zero and moment is again equal to be zero. In this case also we have seen the same example I have explained it earlier in the lecture and this is like something really funny. So, what exactly? So, both are having different weights. So, like they are balancing each other and you know they are lifting it.

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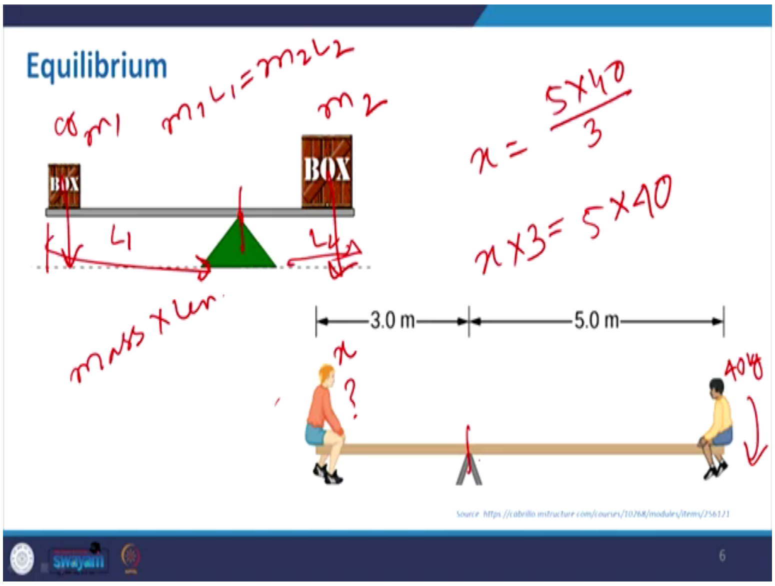

So, in this case we have the examples one with the seesaw the other is balancing it. So, again the thing is like how to manage it. When we are talking about the equilibrium due to moments, we have to remember that moment will be created by the your mass into the length, length from this particular point the pivot point. So, L 1 and this is maybe the L 2 form it is like c g or center of gravity.

So, this is m 1 and this is m 2. So, in this case in order to make it stable it always should be m 1 L 1 equal to m 2 L 2. In this case this is one like we can say some problem given to you like this is the point where this distance is 3 meter, this is 5 meter ok.

And I just give you the weight of this particular you know kid here is say 40 kg ok. Now can you just quickly calculate and give me the result in order to make it stable what should be the weight of this particular kid? You take few seconds and it will easily be done.

I have given already the required condition to get it stable. So, can you do it for me? Yeah, I think you got it. So, how to do it? So, here the thing is the moment created in this is basically 5 into 40 and here we do not know we just assume it to be x, then x into 3.

So, x will be basically 5 into 40 divided by 3 ok. So, whatever maybe the mass though I have taken randomly. So, you can get some fractional weight. So, anyway, so with that we calculate weight of that in order to get the you know equilibrium into this.

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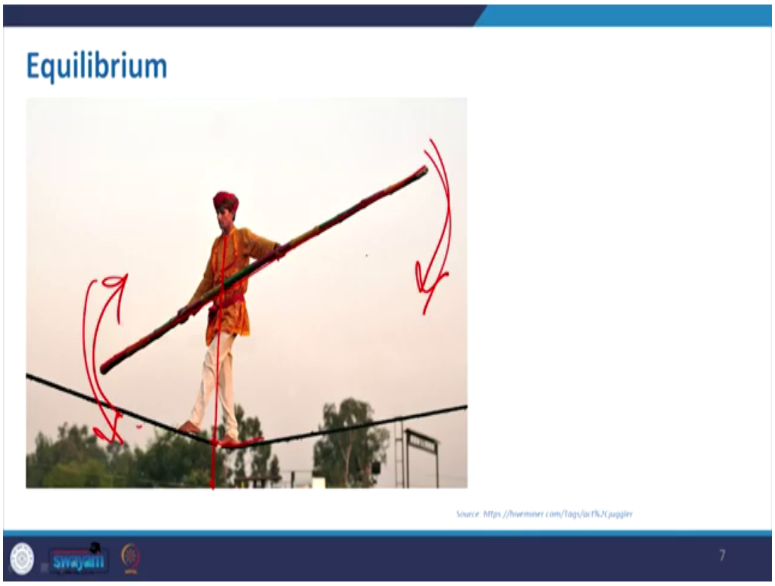

Now, this is another example many a times we also experienced it. So, this is really talent to do this, but here the basic principle the physics play the role to balance it out. So, the balancing with this stick this has tremendous importance which will actually adjust the center of gravity. So, that it will align with this particular rope to get it stable.

So, it is in a equilibrium condition. So, though it will sway and this is really challenging, it needs expert is and practice over the years, but then also like we really can see in this picture, how they are balancing with this. So, balancing is very important it may sway in this direction, it may sway in this direction or it may like due to this force, it may get a couple it can rotate. So, how they will balance it with the reaction and action is a challenge in this to make the building in equilibrium.

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Now, come to the building, as we discussed in relevance to the architecture. So, this is a Cinepolis headquarter in Mexico you can see this is another example where like the heavy mass you can see the projection both the side and how it is balancing with the centralized mass.

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So, it is very important to do say for example, if I take these two again like this is a very lighter material. So, I take it as a base. So, I can fix it up like this? No I cannot because it will fall I cannot glue it. So, with the normal you know position we putting it is not possible.

But if I put it at this particular moment. So, it is giving some balancing. So, anyway; so looking at this example in this building, we can see that how it is making the equilibrium and it need not to be you know equal like a balance sometimes your building may have a building like this with having the counterweight and that we see in the crane. So, whenever a crane is acting lifting up the material or so, you must have seen like in that arm whether this is elongated. So, they are always fixed with some heavy weight.

So, that it can easily work on that otherwise it will collapse. So, maintaining the equilibrium static equilibrium we have to design that. So, either this portion you have to make lighter weight this is heavy weight, to balance each other because the moment you put it. So, it will create moment in this direction. So, that we have reaction it can give a action and reaction that will finally, to be equal to 0 the summation, the resultant should be 0 so, in order to make it stable. Now, move to the next example this is the gateshead millennium bridge where it the structure visual looks very much unstable if we remove this.

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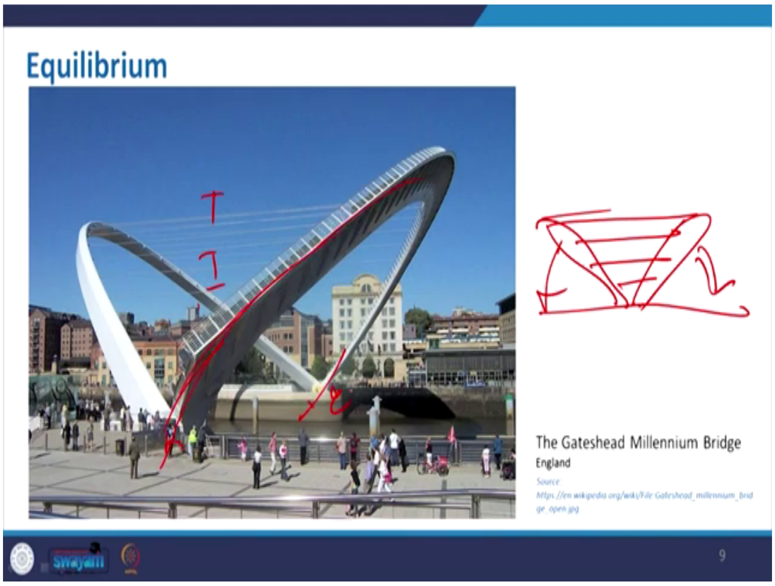

So, two structure going each other direction. So, there is a feeling that it will fall both the side, but it is tied up with the tension cable which will make this structure stable.

So, it is balancing out with this. So, enough tension is developed in this direction and then it is stands for and then there will be some compression this bottom, which is making it out as in a equilibrium stage and then it is standing.

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Now, come to the geometric stability, it depends on the overall arrangement of the shape. If it is a single object like this, so, it has no issue I can put it here, but on my hand if I put it here, you can easily guess that the surface area that particular orientation is something which is stable. Now, if I want to make it like this, though it is stable, but not as much as this because the grounding the anchoring to the ground earlier it was this is more than this one. But now I just want to like tilt this building and put it on is one of the corner. So, its really unstable.

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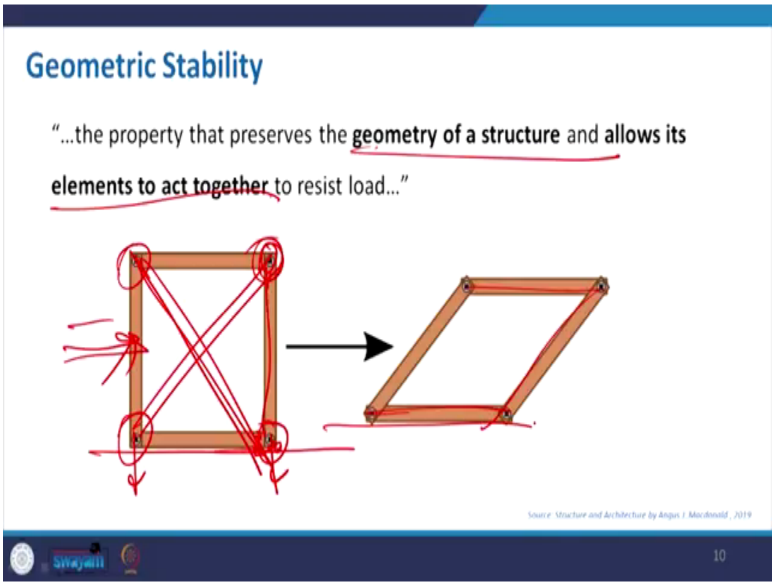

And in this case this is the frame you can see that where these you know these are not a single mass rather the four components they fixed one after another, and then applying force into it can give you the bend so; that means, this particular arrangement is not much stable. Now, in that case I just anchor this portion. So, bottom portion will have no move, but this will again move into this direction. Now, what are the options I can do? Instead of this I just make it in a monolithic form.

So, then I can protect it or else, I just make some diagonals connection maybe one or two. So, then it will make more strong. So, then basically this property preserves that geometry of a structure and which will really basically act together, it may be a single object as I mentioned or it may be multiple of such. So, basic idea to get a proper form and shape which will give the stability.

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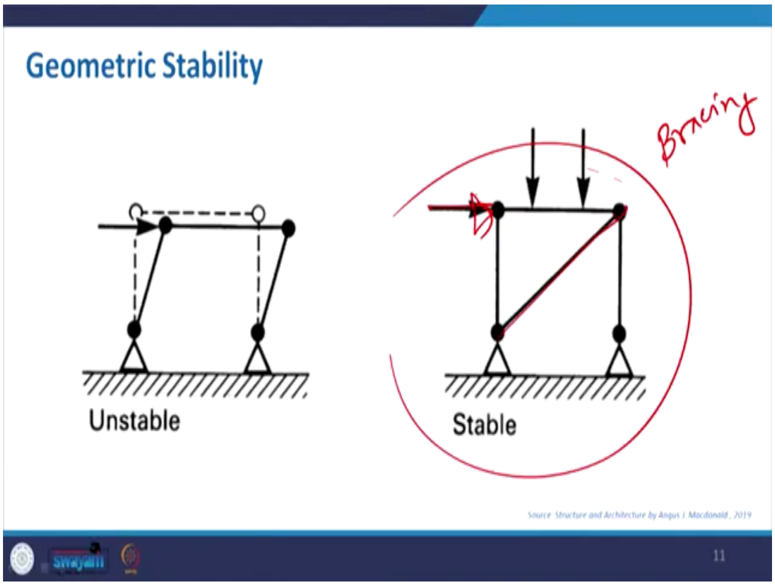

Now, this is the same example as I mentioned that earlier, it was something like that and then this is connected. So, then the that particular arrangement is giving more stability. So, this kind of arrangement is called bracing. So, we will be using this bracing term quite a time, then in when we discussed about the high rise structure because in order to protect from the lateral load which is something like that. So, we need such kind of development.

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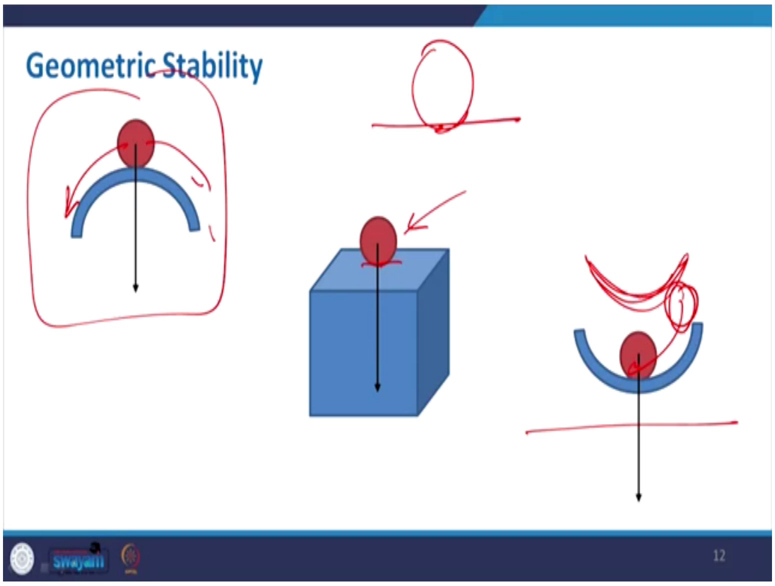

Now, geometric stability these are some schematic or theoretical thing. So, looking at this particular arrangement. So, this is a sphere and this is some you know your convex surface.

So, you put it there and it is acting like that. Looking at this do you really find this is not attached. So, that is why I have given in different color. So, it is really looking very unstable why? So, looking at this it always give a feel that this ball or this sphere may fall either this side or this side.

Compared to that this one is still considered to be stable, but it is basically the neutral because again this particular sphere is just connected to this in a single point if you theoretically see that if this is having no deformation. So, if you draw. So, only one point resting on a point, but still as because it is a flat plate. So, it is if no external force being applied to it, it will be like this only.

Say for example, when in a cricket match someone hit a boundary. So, till it has that particular friction and the force it will reach to boundary, but after it stops somewhere, it will not move here and there unless someone add some additional force. So, this is something like that. Compared to that it is giving a sense of more stability because we have this concave surface and with the c g even you put the ball here, it will come here and get stable. So, there will be some periodic motion, but after all it will settle at the time.

So, it will give the sense of more stability, but in practical life what we see that, we can go with this kind of arrangement even with some other you know adjustment to the structural system.

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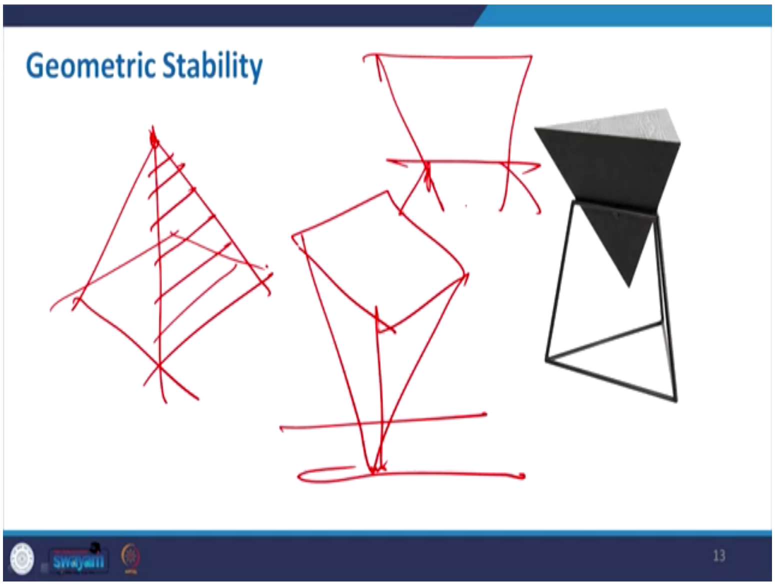

Now, in this geometric stability. So, if we just take example of a of a pyramid. So, very stable because at the base it has a connection, and then it that you know cross section that reduces and it is a peak of that. So, it is very stable, but what about the inverted pyramid?

So, looking at this itself it is looking very unstable and here the picture I have shown that to protect it to give a sense of stability, we create another set of like truncated pyramid or something like that to give the stability. But in reality in architecture we have seen enough building where this kind of form being created. So, adequately the foundation is to be designed, adequately the other material for the construction to be adopted so, that even if visually unstable structure can give you the actual stability in the ground.

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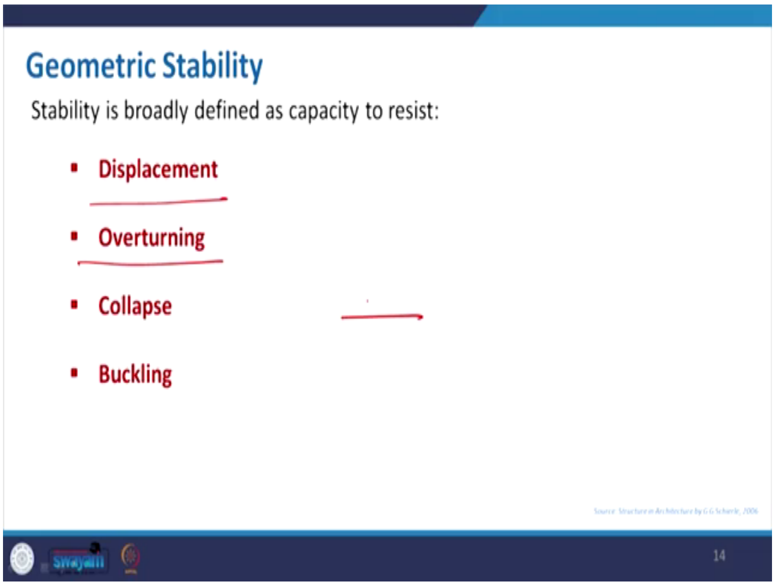

Now, geometric stability broadly classify to resist what exactly it will help. So, if I say that this is very stable so; that means, it will resist the displacement, it will not really move here and there overturning of the structure that it will just overturn how it can be again I am taking this example. So, if it is not stable say for example, instead of like putting my hand. So, here it is being placed like this already tilted.

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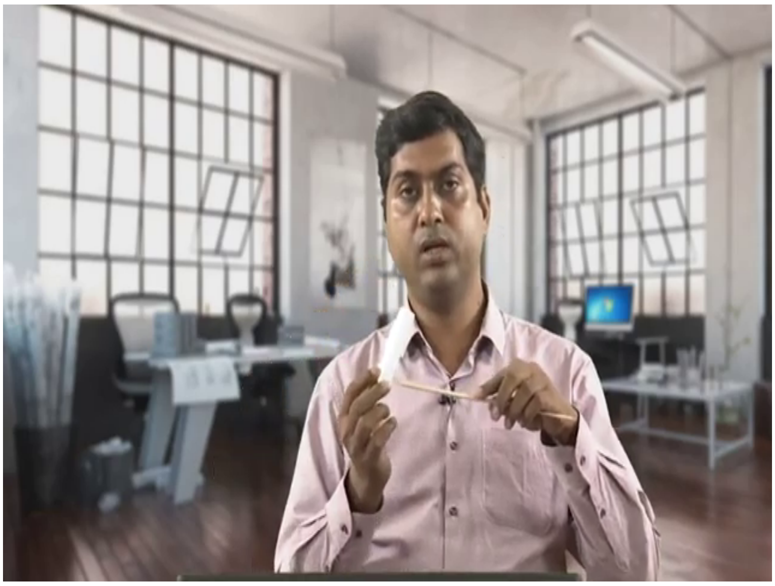

So, with the minimum force applied to it, it will overturn and buckling already I have seen shown you that like when you put the pressure. So, how it will get this particular bend and then finally, it may collapse.

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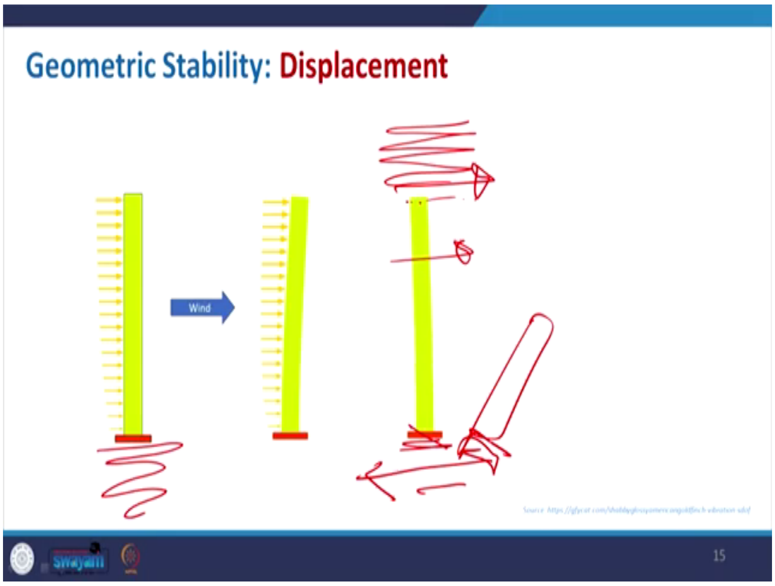

So, move forward with the displacement, here if you see in the GIF image it is very slow but here you can see that how it is going to act when you have applied or you consider the wind load. So, during the wind pressure in this tall structure it will give a bend and due to that it will have so, in original position. So, as true during the earthquake when the motion will take place at the ground. So, ground will start move, it will propagate at the top and then one will go this side the next moment the upper portion of the building go in this direction.

So, basically then there will be some kind of oscillation. So, due to wind, do to your earthquake there will be oscillation and if the proper arrangement has not been taken. So, your building will have you know permanent deformation, it will have displacement from this position to this position, it may be a permanent bending from the bottom, it may just go for the overturning. So, this is all about the displacement.

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And here you can see the overturning where it was a cap failure of the foundation and other things. So, it is really very dangerous where like you may not you know you may not have considered like other soil condition, the water pressure or the soil pressure and that is why this kind of thing may happen and it is more prominent when you have high rise building with the soft story means you have at the ground floor some of you know void and all.

So, it has to have some kind of anchoring at the ground if not. So, this may collapse with the lateral load or sometimes even if it is unequal settlement. So, it may also overturn. Say for example, you have a building like this where you have the foundation like this and there are the settlement is more in this column and this is not. So, this building will tilt. So, the leaning in tower of Pisa is one example of the settlement load that already we have discussed, but with you know maximum like if you not care about this. So, this is the result in front of you.

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So, overturning due to unstable. So, there it is the collapse. So, this is a testing model and actually during the earthquake this is the case. Again what I mentioned that heavy mass on top of the column and on is very much dangerous. So, for the earthquake prone area anyhow you have to really go with some good structural arrangement like shear wall or else you do not go for the soft story otherwise, due to the motion it will happen. So, what exactly happens during the earthquake?

So, the motion created at the you know underground, the epicenter and then first it go in this direction the next moment is this direction and it will take much much lesser time the way I explained the time I have taken to say this. So, with very fraction of seconds, it will move in different x y direction and it may go even in the longitudinal lateral direction. So, in that case what will happen? Your building will move to the left and then the top portion is try to be like same and then is propagate it will go to right it left.

So, opposite moment will really shake your building and then those joints if it is not properly taken care of. So, it will collapse. So, the collapse are in the you know first slide we have seen that a beam is being placed like this just a put on there. So, if you put the applied for. So, it will just try to bend and it may collapse. So, additionally we have to support it.

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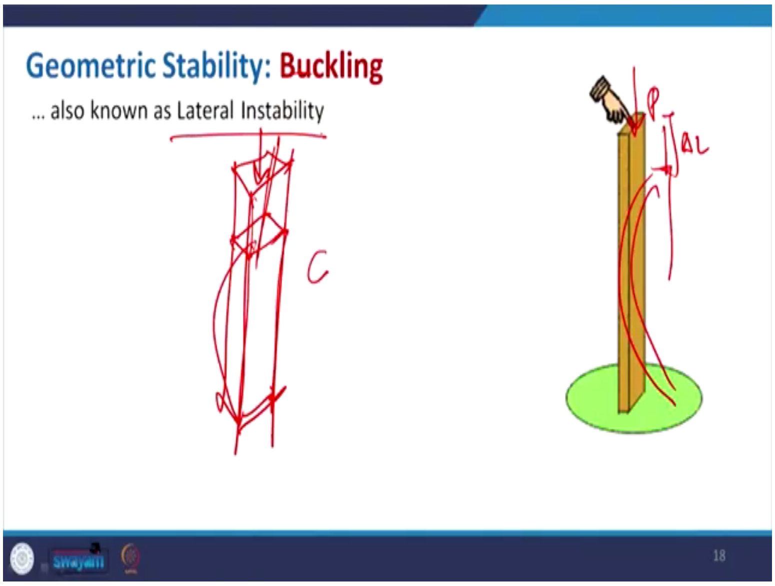

Buckling is the another one, where one end is fixed and the other side you put the pressure you see that in this case what is happening. So, earlier like this is the structure and when you put the pressure. So, first it will try to get shorter.

So, it is basically you can now say this is the compression. So, it is getting, but getting the shape the some lower position, but when it is already been compacted then there is nothing to get compacted more. So, what we will try to do? So, then there will be the bending like this. So, here you put the pressure. So, what is happening? It is getting shorter height. So, there is change and then finally, the bending. So, this is another problem to make your structure in stable and this is also referred this particular buckling as the lateral instability.

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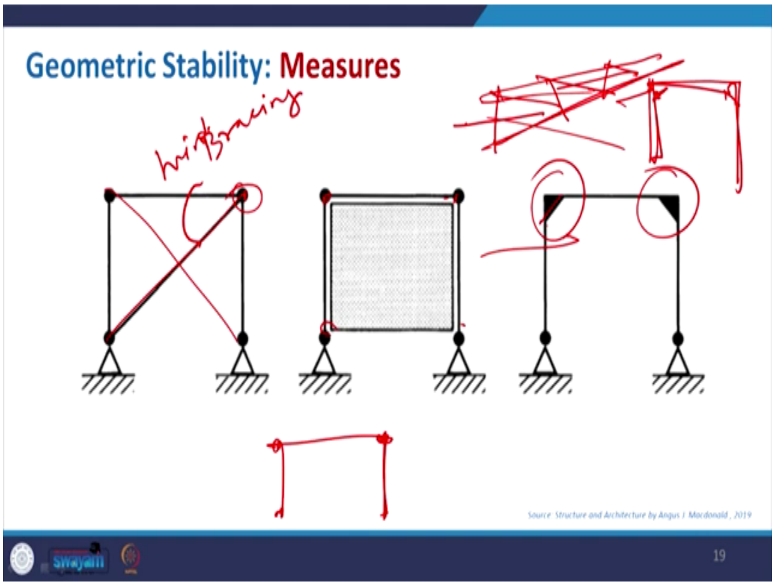

Now, what are the ways to protect it? So, one is a very simple way that you connect those points with the diagonal, it may be one direction, it may be two direction and there are some way like the minimum requirement of this particular bracing or sometimes we also call it wind bracing, sometimes if it is placed horizontally below the you know your what we call the you know the bridge over a river.

So, we can see those kind of you know horizontal bracing which will also help. You can also go for a you know some kind of diaphragms to connect all these points. So, it will also give stability to not rely on simply, you know post lintel kind of structure and also it will depend on the thickness and then sometimes you can also go for a rigid frame. So, where you can see that it is not joint a; soit is rigid. So, you just make your frame the portal as rigid structures so, that it will not really allow to get the deformation. So, it is also going for you know some kind of stability to the structure.

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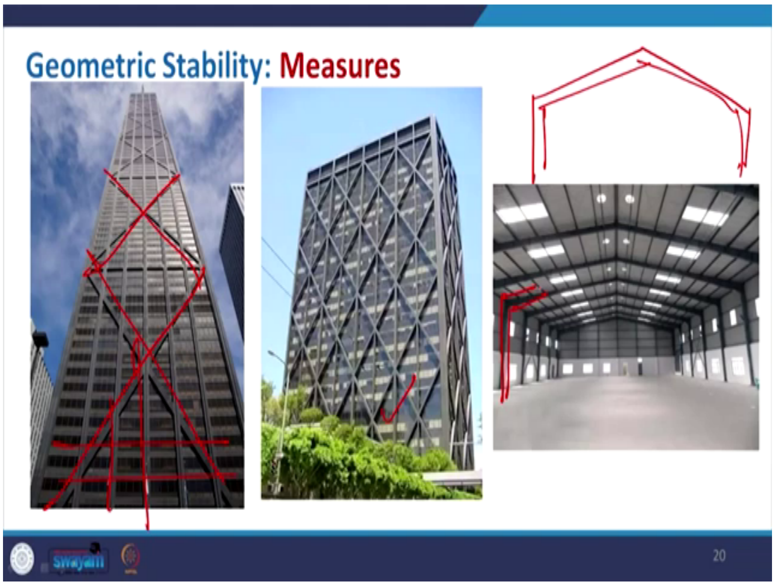

So, in this case if you see that this is a high rise building additional to the your you know vertical and the horizontal member beam column member the frame. So, they also use this particular bracing to give extra support to it to resist against the lateral load. This is show to in this and here you can see this is the rigid frame at this corner. So, basically this is a section where it is being rigid.

So, it is being fabricated normally in the you know for the warehouse manufacturing unit. So, they can go with that where they really face this kind of difficulty for you know resisting again the load.

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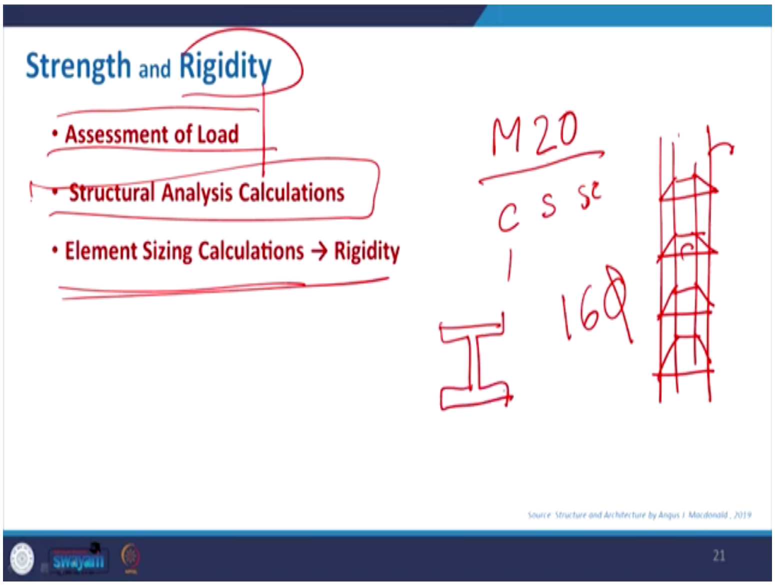

Now, come to the strength and rigidity. So, strength is the property of any structure or object, which will prevent from breaking. So, that we already know and for that what we need to do? Basically how to design the structure having that strength and rigidity so, first is the assessment of load.

The moment we get any design assignment, so we start developing it with the concept and finally, putting all requirement all human information there we create the space and then what is happening? So, we design the structure and we calculate all type of loads to this particular section. So, what kind of load is applicable? So, for a region like Delhi or something where snowfall is not really predictable.

So, we will not calculate that, but along with that the other thing the extreme temperature variation the thermal load will be one crucial thing, it is also in really you know seismic prone area. So, those kind of you know features to be added all kind of probable load that may act on a building, we have to calculate we should not miss a single otherwise what will happen? So, the moment you get that particular load all of a sudden which was not taken into consideration your building may not get the stability.

Though we have we take some factor of safety or we go for high side design, but definitely we should not miss out the relevant load. So, assessment of load is the first step, then the structural analysis calculation. So, we accordingly we design alternative.

So, during that time we create different kind of arrangement of beam column putting beam, column position and all. So, how it performed? How we the building will perform against all applied load to it? So, we do the study and then to get this rigidity and getting the proper stiffness and adequate you know adequate stiffness and rigidity to your structure we also go for element sizing calculation where we pick up the cross section, we pick up the you know the material and they are equivalent cross section which is required to make the structure.

Like we know RCC there will be concrete, now in concrete what grade of concrete will use whether it will be like m 20 or m 25, m 15 what are the different grade of concrete. So, basically it depends on the mixture also like this grade means like m 20 means after it is curing, it will able to have the compressive strength of 20 Newton per millimeter square.

So, like that you can go for the higher side and then mix of your cement sand and you know stone chip. So, that will change. So, it may go from 1 is to 1 to 2, 1 is to one and half is to 3, 1 is to 1 in 4. So, depending on different grade of concrete we decide it. So, as true for the cross section of like the rebars or reinforcement bar whether it will be the 16 mm dia or it may be like just for the stirrup like whenever we make this you know reinforcement. So, what we normally do? There we connect those thing with the stirrup of. So, this will act to prevent it from the shear failure.

So, what will be the size of this rod? What should be the size of this rod? They are binding? If we go for some I section or C section of the steel member. So, as per the code what should be that thing so, that we can calculate everything on that accordingly which will take care of.

So, these three part is very important we know the requirement, design the building and then we try to calculate the all possible load that may act on the building, then accordingly we design the that structural element, putting the position of the column beam and then we go for simulate it under different load condition. And along with that we also select the cross section and the material which will give the rigidity to the structure to prevent against the bending and other option.

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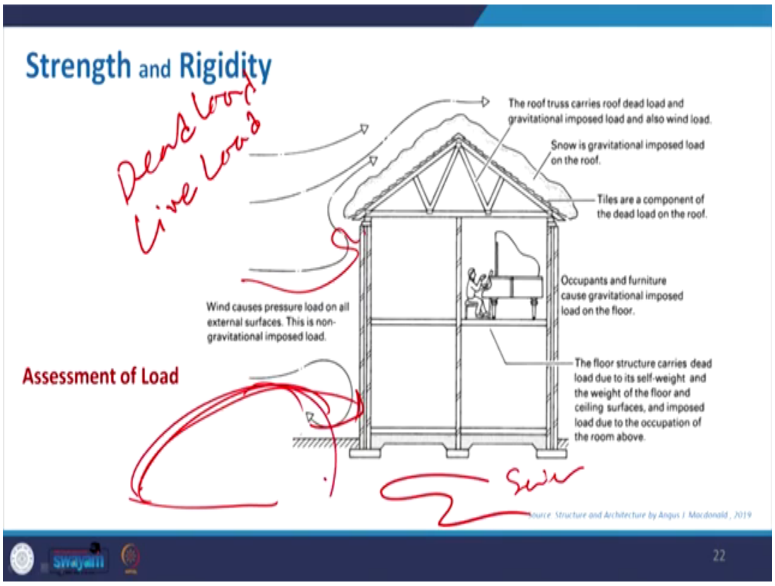

So, in the assessment of load is basically calculate everything. So, starting from the self weight of the material which is referred to the date load, the live load that is basically the load of the people and as well as the furniture's which are movable in that and some of the dynamic load is basically the wind, it maybe the earthquake, the seismic load so, everything is taken into consideration.

So, where we will make our building based on that we take it we take it and whenever like if we want to make it in a coastal region, where like storm or the wind from the sea will be more prominent. So, we have to take some aerodynamic shape or size. So, depending on the structure whether we go for this kind of structure, shell structure or maybe frame structure that is really required.

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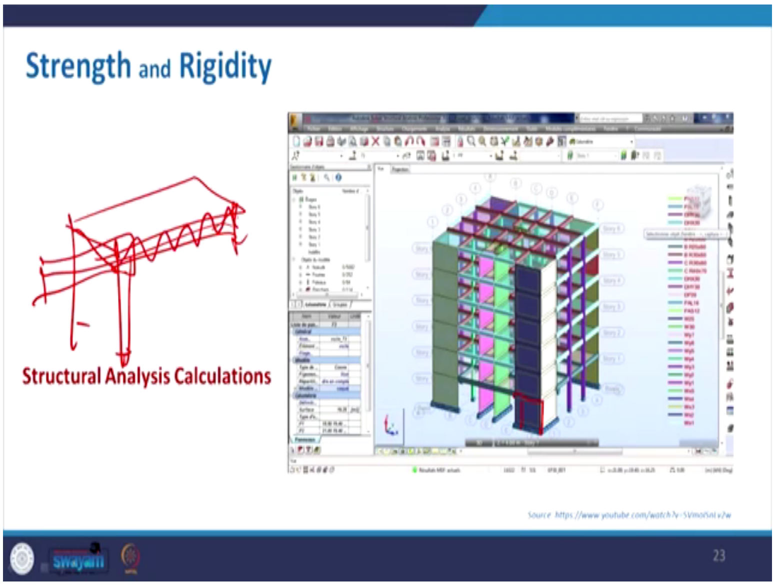

Now, in that second stage is basically the designing the structure. The column where we have to provide the shear wall, the concrete wall where we can remove it so, it is depending on that calculation how it will go.

So, in this particular phase, we just try to check to optimize the structure that is required because sometimes we move in a architecture we want some huge cantilever to be made in the building, but during this analysis we find that it may collapse.

So, we have to adjust it with the say you know counterweight or maybe something like it is to be made not the regular RCC work or reinforced concrete work or it may be done with the some steel framing or space frame we will come to that also like how you can go for this kind of structure.

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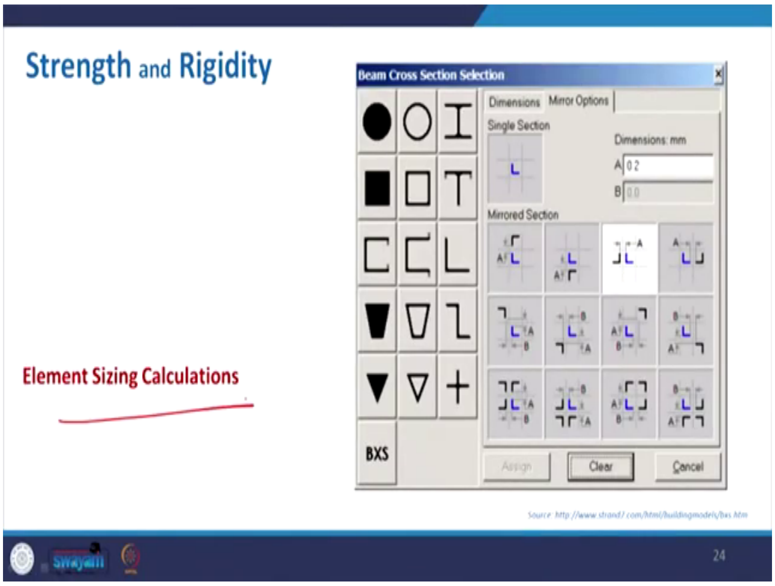

And then basically the selection as we mentioned that cross section, that will give you the adequate the moment of inertia that it take the stress or stain that it can hold along with the material whether it is like your the steel or stainless steel or type of steel or some composite material, that will pick up and then we will determine the rigidity of that. So, along with that this three step the assessment of load, then calculation regarding the structural analysis and its performance along with selecting the element size, we will figure it out this strength and rigidity part of the structural requirement.

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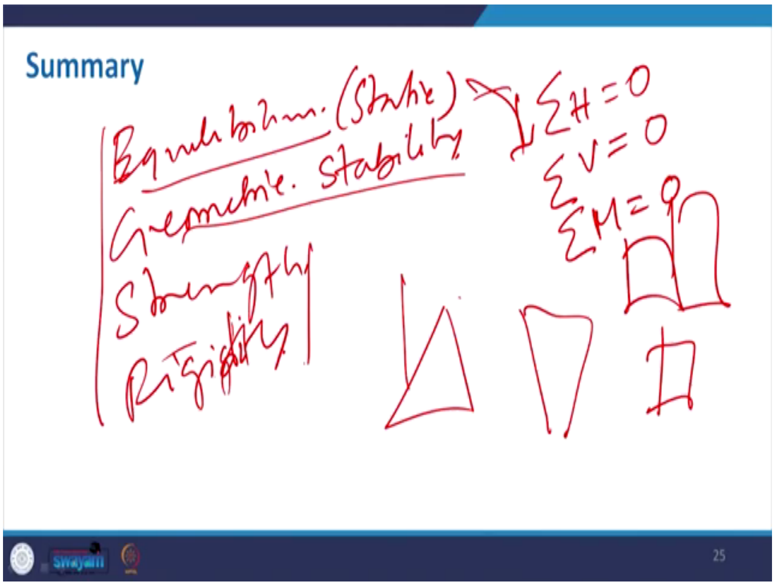

So, in the summary. So, it is very simple we know that the requirement is basically we have to satisfy four properties to make our structure support it started with like what we normally call that is the equilibrium, and then it is the static equilibrium we want to when, then what we have seen this is basically like geometric stability. So, how your structure can be stable, which particular form you can take, then you have the strength and like rigidity.

So, strength and rigidity it depends on the load calculation the you can calculate the load and then the corresponding structure and then finding out the suitable cross section and the material as well so, that you can encounter with all possible load that may affect your structure and can make your structure unstable. To make the structure stable equilibrium, so everything will play together. So, this is very important you know discussion that we had in this lecture.

So, these are the structural requirement, the we know that to make your structure you know resisting against all imposed load. So, equilibrium it maintained the three condition all horizontal force should be 0, summation of that the resultant the net horizontal forces it should be 0 and then net vertical force should be equal to 0 and then even the moment should equal to 0, then we will get this static equilibrium otherwise my structure will not be stable. And in order to make the stability different form we discussed, it may be like the pyramid or it may be inverted pyramid, it may be a single object or it may be a composition.

So, depending on how you calculate to be done and strain and rigidity is depend on the all possible loads, selection of the material, different structural arrangement and its performance against applied load to it. So, these are the requirement.

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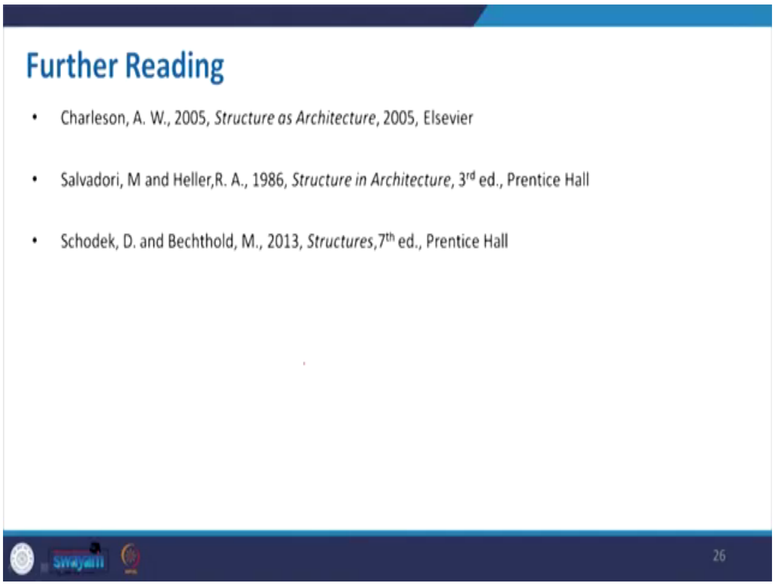

So, this is the further reading to that and you go through it and also like in the earlier lecture I mentioned about some books on structural mechanics, that you can also go through that so, that it will give you some inside that will also you know freshen up your idea that only do we had in the school level of the structural mechanics or in the earlier stage of our course.,

And then next lecture we will be discussing on the structural arrangement, on different kind of arrangement how their pros and cons to go with that arrangement, where it is from format active or it is inactive post beam or maybe post Linton we will discuss on that and till then I again thank you for taking part in to this.

So, thank you.