Structure, Form, and Architecture: The Synergy

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Lecture - 11
Basic Structural Properties

Hello everyone welcome back to the online NPTEL course on Structure, Form and Architecture: The Synergy today, we are at the lecture number 11 that is basically Basic Structural Properties. So, far whatever we have discussed is more or less related to the building structure different architectural style their synergy, we have also learned about different kind of loads acting on a building.

So, there we have seen some static load, dynamic load, and also discussed the evaluation of evaluation of structure form like pre historic age to the modern age and we have seen the transformation. So, in this lecture we will focus on like some basic properties that I am sure that you have come across like in our like 12th standard physics.

So, different kind of property related to the force, then stress, strain and then we will again actually recap these things which are very essential to know about the structure. So, accordingly we can make the structural element and we can make the structure stable and also having good strength by putting the right material to it and maintaining the overall synergy with the architecture design.

So, let us start this particular session with some of the definitions that it is again a recap. So, here you we see that basically the property that we discussed about a structure. So, this is coming under the mechanics. So, this is basically the study of structures, where like different behavior of we know structural element will be studied based on different loads applied on it and it has two dimension, in a two way we can do it one basically on the statics and other one is dynamics.

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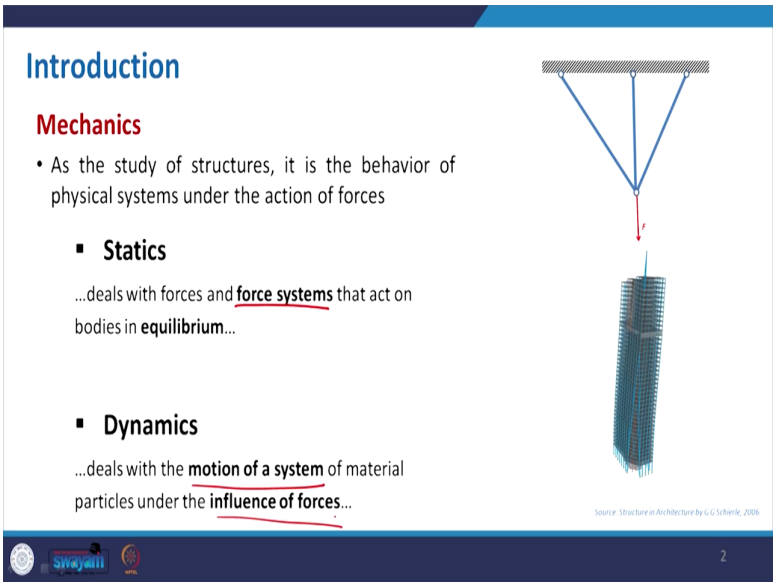

So in static, basically it will deal with the force system and, that we can see to make the static equilibrium. So, what exactly it is to give the example. I have this slight changer ok. Now I am holding it and giving a support and it is acting like a cantilever ok, but still I am holding it that is why it looked very stable.

But if I just want to put it in one finger. So, I am scared because, I do not know the exact position where I can support, but with these two fingers I can hold it. So, now it is in equilibrium, but still it is you know having some sway and when I make it like this on a stable platform. So, it is more stable. So, for a building also, due to the gravity load or lateral load like; wind load or seismic load.

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So, then the problem is the building will really try to adjust itself with that external force acting on it and try to maintain a balance and try to create the equilibrium. So, static equilibrium will come to that in the next slide the other one is basically the dynamics where, we study the property of structure in some of the dynamic forces like during, the high speed; high wind flow, how building will sway. What will be the deflection on it?

So, we will focus on that. So, basically deals with the motion of a system of material and it is under the influence of forces. The other one is basically the overall statics is the equilibrium we want to say and the other one is the dynamics where, we will study the nature of a structure how it will go. So, with that we proceed further to just this is a brush up of the idea that already we know like, force and moment.

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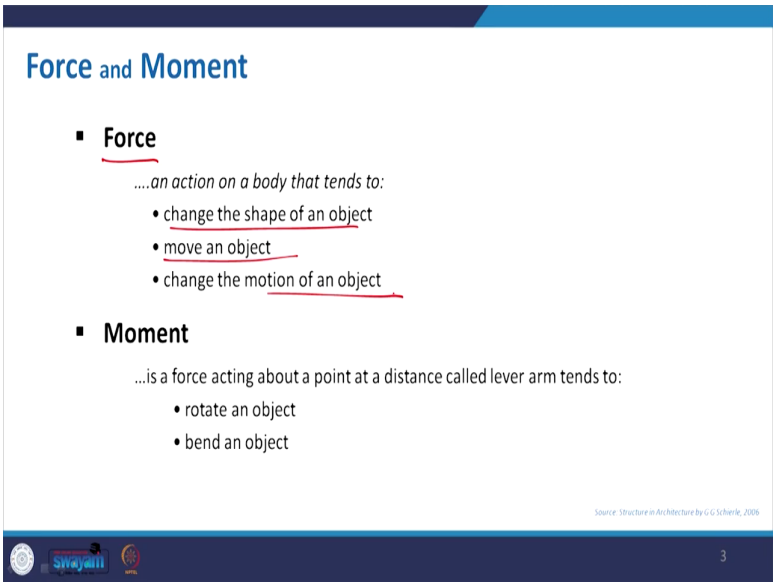

So, force is basically an action on a body and, what will be the result into that. So, it may change the shape of an object it may move an object or change the motion of an object. So, how exactly it is? Let us take one example the first one the change of the shape of an object. So, here I have like, thermocol a piece of thermocol.

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Now, this is like in a free state now and I want to put a force. So, you can see that how it is going to change the shape. So, if I put it like in a column position. So, you can see the size of the thermocol is getting reduced and sometimes if it is not really equal and opposite direction. So, it will also give a bend.

So, it may be a permanent deformation or it may be return back to its original position based on the elasticity. Now, we use the rubber band for the different purposes. So, sometimes you know we just elongate it and then when we release the force. So, it will get back the original shape, but sometimes with repetitive use and we will get some permanent deformation.

So, it can change the shape of an object move an object definitely it can move. So, if no force is being applied to it; it will remain stand like this all through its life, but if I just put finger or if

I blow with some wind. So, it will change its position. So, from static it will just give a kinetic start to that object and the third one it can change the motion of an object.

Suppose it is moving towards this direction and if there is no obstruction it will move on, but the moment I put my you know hand here. So, it will stop the motion and it will force is to be in static condition. So, force is that action which tends to do that and what about the moment, it related to the rotation of that object. So, it is again a force which will acting about a point with an arm or we call it lever.

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So, that will tends to rotate an object or bend an object. Say for example, I take this exam you know model this is you consider for this timing is a high rise building. So, it is fixed to the ground with some foundation and this is open end. Now when we put the pressure and we put

the pressure from one direction. So, it will try to bend it as because it is anchored at the bottom.

So, we will only see the bending as a option, but at the same time if something is like having some pivot point to my hand and I put the force here and this is the lever acting. so, it will give a rotation. So, all the propellers and other thing the wheel, that is acting on the moment. So, in this slide we come to know the force is the action which can either change the shape of the object, permanent deformation of the object, or else it can move an object a static object to the kinetic one or it the reverse; something is in motion so, we can stop it with putting the force it is applied.

So, say for example, when we are driving a car and all of a sudden we have to stop. So, we put the pressure or the force on the brake and it will stop the car with desired distance and there are different formula how to do it but basically, we know this force and the moment if it will try to bend an object that is way we are I have shown this.

In this example where like this particular you know wind direction can try to bend it, and when it is like simultaneously show us that, we know like wind pressure is high here it will try to bend this side or during the seismic activity the plate will try to move and it will try to maintain its original inertia. So, like that it will be like you know both way swing and there will be a deformation.

So, it may be a bending or else I put extra pressure on that. So, I will show with some picture there also we can see that due to opposite direction force with a particular you know point and then a lever. So, it can bend and whenever we have a pivot point like this. So, it can also give a rotation. So, with that let us move forward.

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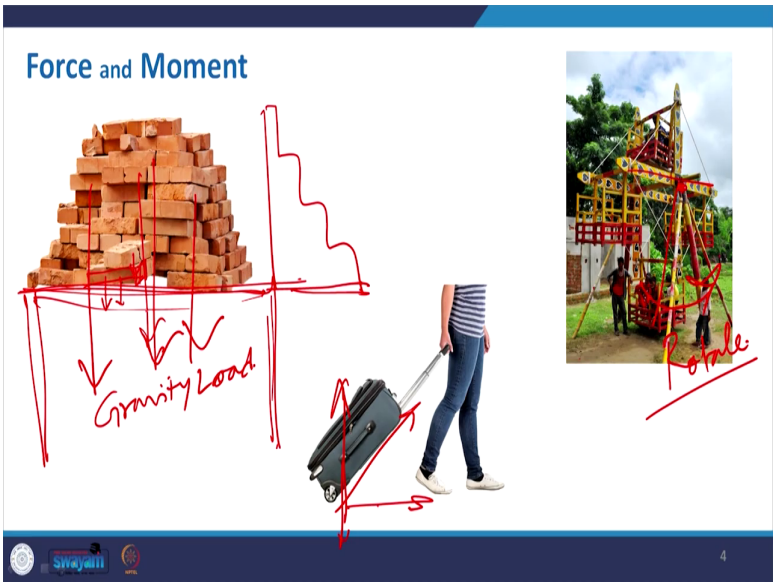

So, here I just randomly picked up some of the photographs and put it here to just get the idea of what is happening here. So, these are nothing, but like stacking up the bricks for use. So, in construction site often you will see that how these being stacked up. Now the thing is if this is the ground level.

So, if you consider the dead load and we already know, what is dead load that is the self weight of that object or structural element so, it is putting some pressure on the ground and when you put another one that will give additional pressure and like your force profile will look like this. So, when at the bottom it is a huge pressure and it is acting towards the center of the earth which we call gravity load right.

Now, the other picture here what we see this is just example of pulling a trolley back. So, in this case also we have to put some pressure to bring that you know this particular motion

towards this direction and along with that it will have some pressure then the reaction and then basically, that vector analysis for the force how it will be distributed in the direction, but in this case this is the load to make it stable if this is the ground it can bear the load if it is some table or so, it has some capacity to hold it after that it will collapse.

So, this is a gravity load. So, here the load is going towards like center of our earth in this case it is basically to change the position of that object and in this case this is sometimes in you know like a small form of a roller coaster or like in this case merry go round sorry, in this case what we normally do, we just use this particular point and this arm to create a torque and it will rotate.

So, this is one example of the moment and these are two like the force one force is the pulling force and this is the you know self weight gravity force acting downwards. So, with this picture my intention is to make it little bit easier to understand the force and the rotation. Now, this time it is your turn what I wanted to show here can you guess.

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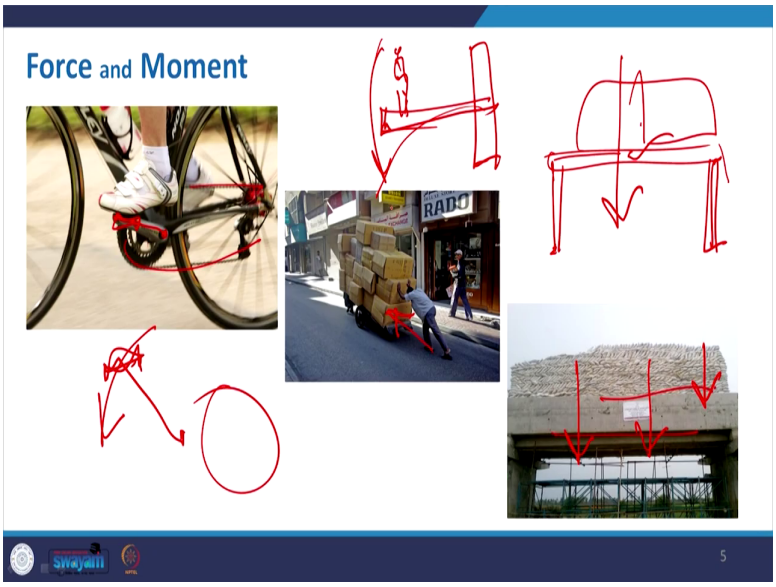

It is basically again a rotation. So, here you can see this is that pedal is acting as a lever and where, you have you know this particular rotation being created and which is also carry forward with this particular chain and your cycle rotates. So, we put the pressure we give the moment to this particular gear and then it will and depending on different action, now we have the motor how to start this other one we have seen in that it was a pulling force and here it is a pulling plus a push.

So, pushing this object to change the position for the movement. So, this is again a force example and here if it is you can see it in closer look. So, basically this is the slab load testing process where you know number of sandbags being put one upon another with desired level of load that this particular member can carry. So, it is again acting on this. So, earlier I have shown you that the brick start up on the ground, but if we just put it on a table or a slab to test

the bearing capacity or maybe the desirable ultimate strength of this ah, structure made maybe concrete rcc or maybe some other steel member.

So, whatever the load we put on this. How like, if there any change or deformation the changing shape of this section. So, like as per the definition here in this case we have seen that one example how like, this can change the shape and whenever you apply more load to that you know the slab along with more sandbags so, definitely there will be some ultimate or critical stress or strength label after that it will collapse so, that will deform the object move an object push and pull we have seen.

The motion definitely we have seen that how applying brake we can stop moving vehicle or we can start a motor to you know make a static one to the moving one and the for the moment it is basically again if we just see here that if it is uniformly put some load so, there will be moment. So, say for example, in a building you have cantilever ok, the moment you stand on a balcony or something like that it is try to bend in this direction.

So, it is creating a moment and that is so, true if you see the you know the swimmer they give a dive in a somersault from a height to the pond. So, then again you will see this particular moment. So, with that I move to like force and that is action and reaction. So, we should remember two basic principles in this that force always act in pair if there is action then there will be reaction along with that also you will see that in this case like it will act in opposite direction.

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So, in this case this particular hand is pressing on the wall. So, we put some action there will be reaction force from this. Now depending on the material we use in case of you know taking this brick if it is something like you know elastic material or sponge. So, when you put pressure if the spring are install inside. So, it will give you a pressure back so, you can feel it. Now this is a you know tug of war where you can pull the rope from two direction.

So, whenever you take the rope towards you. So, you there will be a reaction back to that and they are going in opposite manner. So, as to that principle work for the rocket ok. When you launch a rocket so, it put tremendous pressure gas pressure to the ground and with that it will have this particular upward force to go the rocket up and that is so true with other aircrafts and other thing that can go with that.

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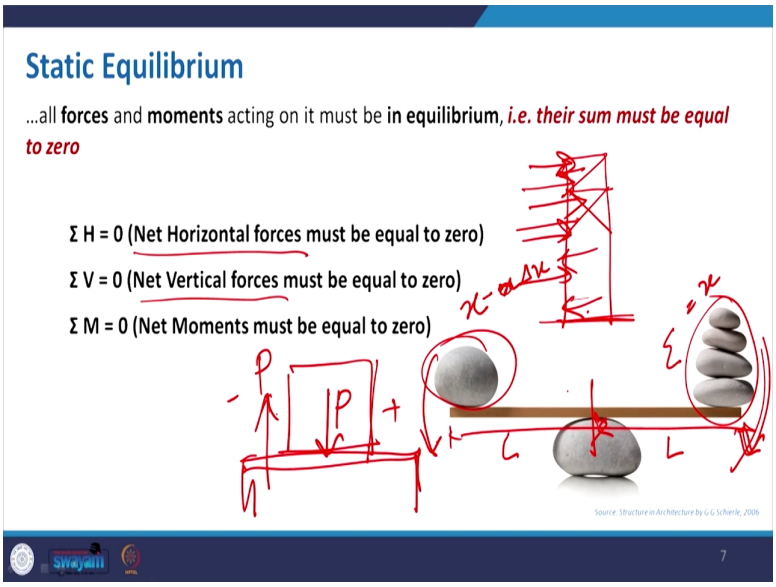

Now, come to the static equilibrium that we mentioned earlier that in order to get a structure very much stable. So, we have to satisfy the static equilibrium conditions, that in this picture before going to any other thing. So, what exactly it is. So, it is looking like a seesaw and like this is the pivot point and they are almost equally placed, but here this is like bigger pebbles and here it is set of pebbles and they are making a balance So; that means, essentially if this length is L and this is L if this is x the mass of these particular pebble is x.

So, the summation of all this should be equal to x then only it will be stable otherwise definitely it will go to the higher mass. So, that we need to satisfy even in a building or any particular structure we make on that and there are three basic condition that always we need to check to determine the static equilibrium of any structure that is; net horizontal force must

be equal to zero, then net vertical forces must be equal to zero and, Net moments should be zero.

Now what about the horizontal force? Like horizontal force is basically, suppose you have a building and then there is some pressure ok, horizontal pressure to this and then along with that there will be reaction from the structural element so, they should balance each other. So, it may be in a linear form or maybe the help with the truss or structural bracing so, depending on this height and requirement the size scale we determine different structural component which will balance out this and the net result the horizontal force summation 0.

The vertical one is the same when we a take example of a table and you know heavy mass on the table. So, it put pressure on the table the P load is given to that and this table will give a reaction and that should be equal to P. So, one is giving pressure is P and positive and the other one negative. So, whatever the positive negative that will balance out to be 0 and the moment is the same that is given here.

So, the moment created in this side and this side is balancing each other, if you reduce a small small very you know small portion of that very negligible person like delta x then also you will get momentum here so, it will pivot. So, then as a result what will happen if it is not in equilibrium so, it will collapse or it will overturn so, we have to be very much careful when we design the structure.

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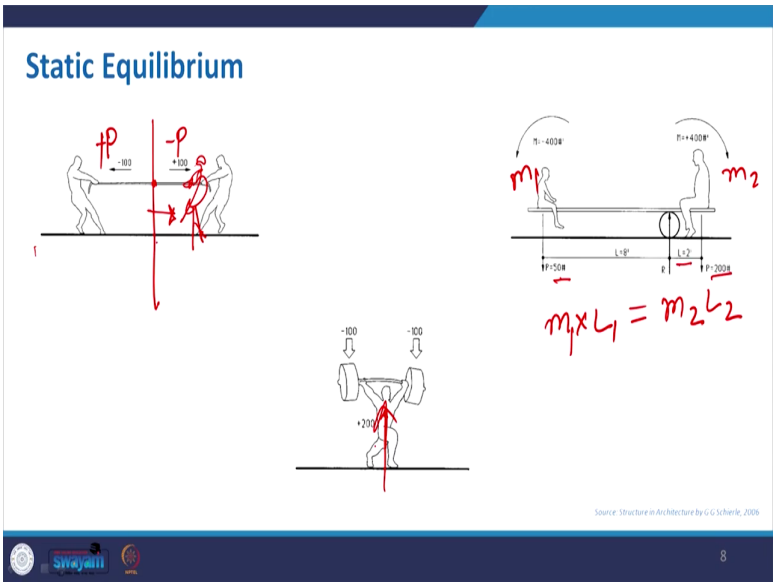

So, in this case these are the schematic taken from the book structure in architecture. So, in this case this is again you know pulling the rope to each other and consider that both are giving the same amount of pressure like force in different direction. So, basically then if we take plus minus then it will summarize to 0 so, whatever the point it will remain same.

Now you add another person to in this category and then; obviously, this particular point will shift towards this because then both will not be equal. This case is very interesting the earlier one where that particular pivot point was at the middle and we have equal length, but here it is not equal length when still it is stable because of like when we calculate the moment it is basically the mass into the distance.

So, in this case it should be equal to m 1 L 1 equal to m 2 L 2. So, this is we just call m 1 and this is m 2. So, in this case if you see that it is being given like 40 is maybe 40 kg are like 50

pressure is being given and here 200, but 200 into 2 is the length for 400 here also 400. So, even if it is not equally placed, still it considered to be stable. So, structural equilibrium is maintained. So, as true with the body matching when it is a weight lifting equal weight.

So, reaction force should be equal then only one can hold it if it is beyond that limit the capacity. So, one cannot weightlifter cannot hold it. Now, come to the you know type of load or force we can say in this case like that load also can be referred as force. So, it may be compression, it may be tension, it maybe shear, it maybe bending, it maybe torsion.

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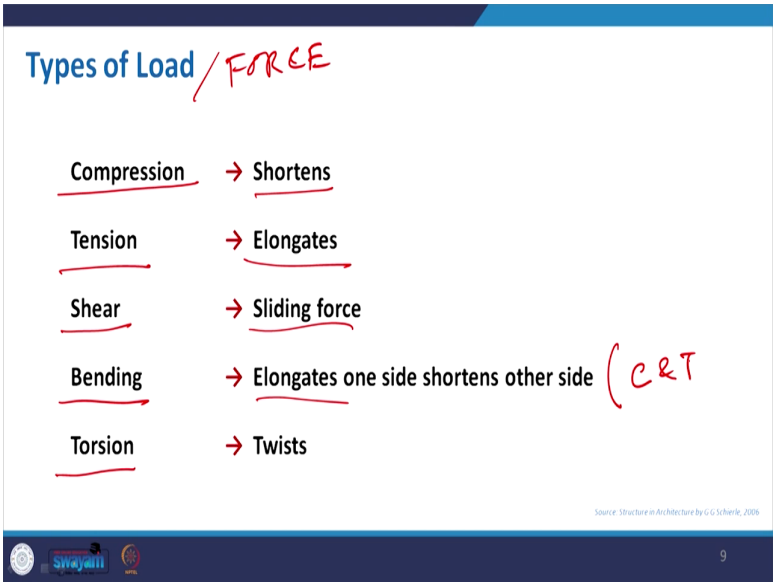

So, grossly we can divided into 5 category and all will have an indication. So, if something you know compressive force being applied. So, object will be shortened, if tension. So, it will elongate if it is shear it will slide to each other and if it is bending then it is elongated may get bend and also shorten the other side. So, it due to bending one side will have compression the

other will have tension. So, both will happen in terms of bending and torsion is basically the twist. So, with this very schematic we can see that how it is going to happen.

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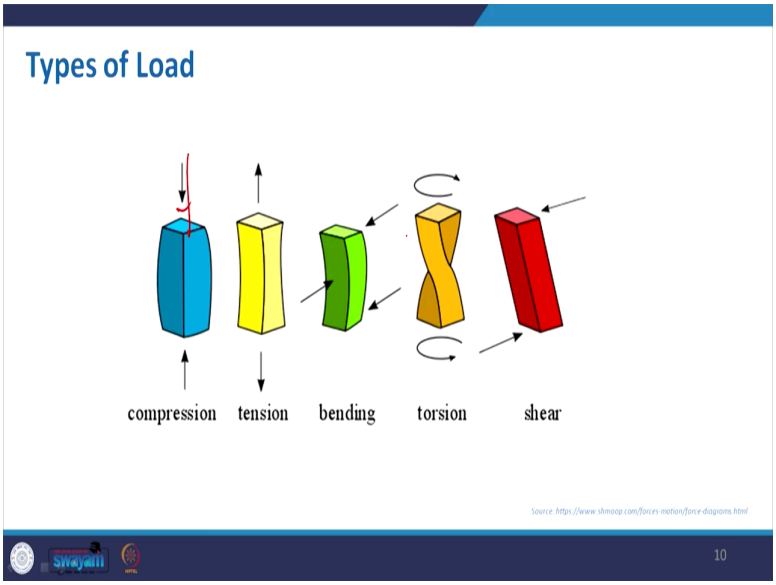

So, when you just put pressure from both the end it will give you compression, when you just pull from both the end then it will give you tension, when you give lateral force in opposite direction. So, maybe wind load and one will give the load to make it in the initial position, then it will be bending and then we will give the moment in the direction, then it will be the torsion and the shear is basically the force acting in opposite direction.

So, before we really go into detail let us understand with this particular example. So, in this case this is the bar and if I just put it there and I put the pressure. So, you can do this exercise and hear it actually got broken because of multiple reasons. So, what happened exactly I have another one to show you. So, when I put the pressure so, it has some strength.

So, first of all it will try to compress and then as because both my finger are not really giving the actual pressure in the same manner. So, it will get different way and that is why something bending happened and after that like as because, like my finger this tends to towards my direction and this is towards your direction so, it also create the shear and it collapsed.

So, collapsing building may occur due to many reasons and the other example that is the tension that if I want to pull it, as because this material is not strong enough or not elastic enough to show that, but I have other you know tool to use it. So, basically I have this weight and this is a elastic material you can see that two yellow color strip is given so this is the distance and when you just float it you can observe that there is some elongation.

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So, elongation and the distance between these two flag applying load and like applying releasing load and then, you know when you apply load like this and when you release load

like this so, this is changing. So, this is one kind of tension that we can face of this and for the twisting again it is the rotation.

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So, I have a strip of cardboard and if I just want to twist in this direction the opposite direction so, then you can see that how it will look like. So, for high rise building it is really a challenge when different kind of you know wind load will come into picture so, that dynamic to be followed up. Now, the compression I have some schematic and by intention I put it to just give you some information to you that compression this is the cycle pump so, manually you have to pump it.

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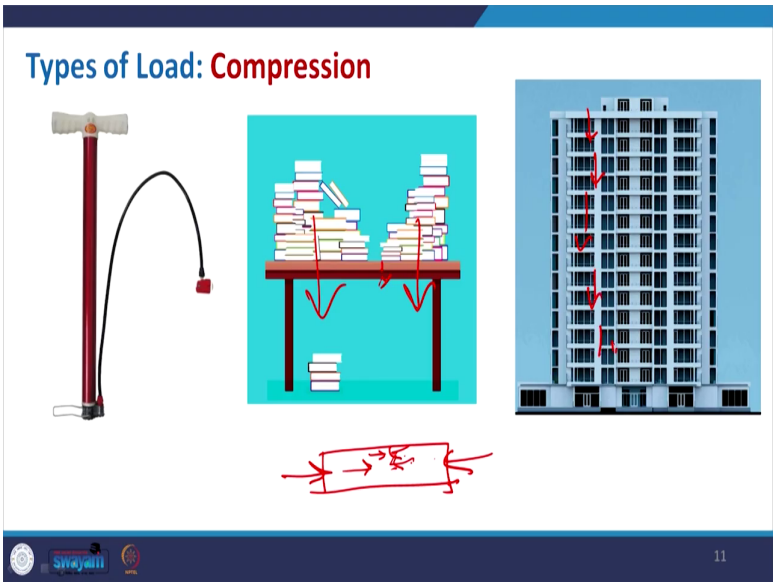

So, what exactly it does it like whatever they air it compress and then you can feel the pressure that when you just give this thing and this is a table where pile of books are being placed so, load is being transferred. So, it is giving pressure so, so that there will be you know like if we consider a material so, the particles each particles, due to compression they will come to close each other.

So, this is something we can say the compression, this is for the load again it will give some pressure on that the compression is being put on that. Now, here it is the tension already I have mentioned with the spring. So, with this material even it is steel.

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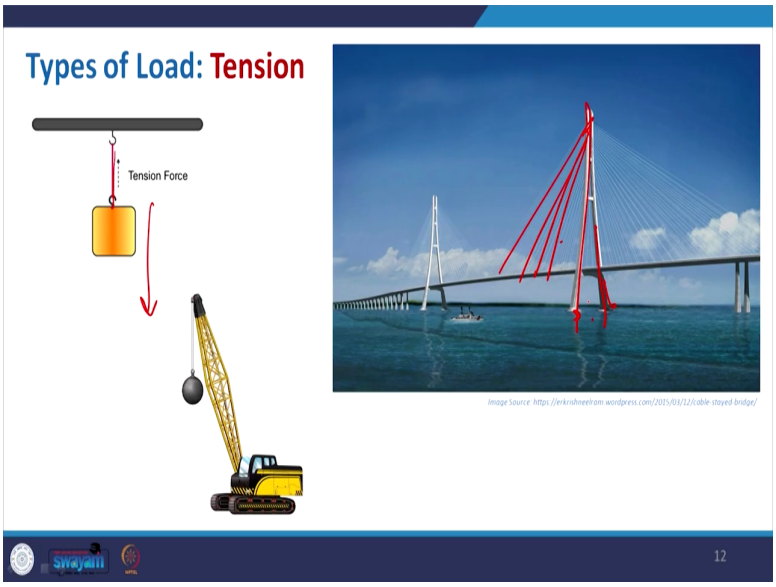

So, there will be some deformation of the certain you know yield stress, will come to that also this is the crane and here basically all these cables they are putting in tension and these are the compression. So, they are balancing each other to maintain the equilibrium. The shear already I have shown with the thermocol the way it got broken. So, this is the same thing and that to be honest also like when you tear a paper.

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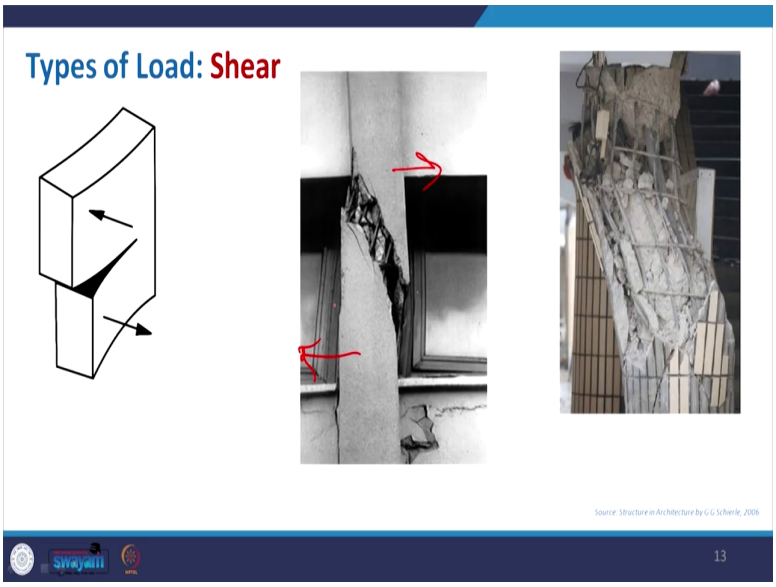

So, that we put pressure in the different direction and then it got the results. So, here two pictures that you can see this is again a failure of column due to shear. So, it is moving this direction and this direction and it also depends on the rigidity or stiffness of the property will come into the later stage to discuss it.

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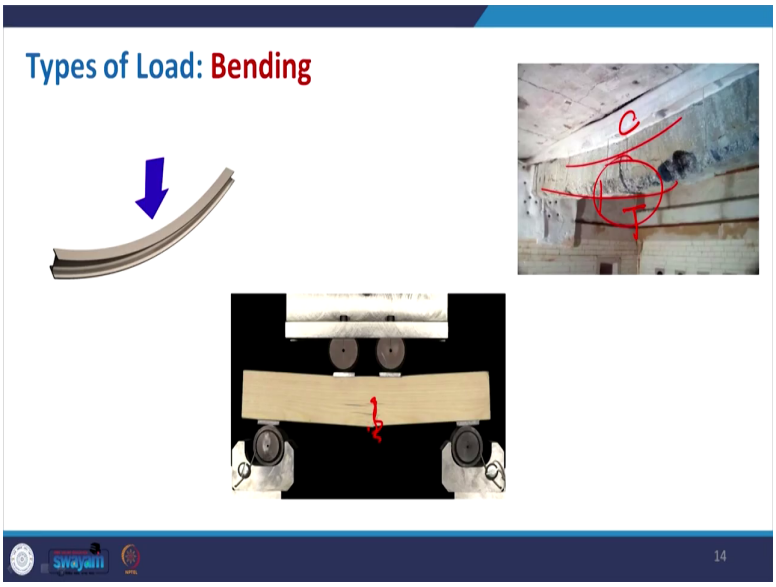

The bending again it is very clear and this is you know laboratory tests where load being applied on a wooden beam and you can see the deformation and cracks developed here. Now in this case again let us understand this with this is the bar and we put pressure from that. So, it will have a sag. So, sagging moment been created, but interesting fact is that, so at the top portion of that ok. So, it is shortened so, as bending said that one end elongate and one end shortened.

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So, this is the shortened. So, compression takes place here the upper end is got elongated. So, in this case it is the bottom one is in tension so, compression and tension. So, this is very useful information will again come back to this for designing the reinforcement for the pivot column and this is again a real photograph where like excessive bending you can observe the deformation. So, this part is basically tension and this is the compression.

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Now, the torsion the very good example that in daily basis when we just squeeze or twist our towel to you know remove the water into it during washing our cloth or towel. So, this is basically the torsion we giving pressure in the opposite direction and it will give the twisting form, applying this though this building is very stable giving this twisting form to just have this. So, this is again very much important specially for the high rise building, where the lateral load will play a crucial fact.

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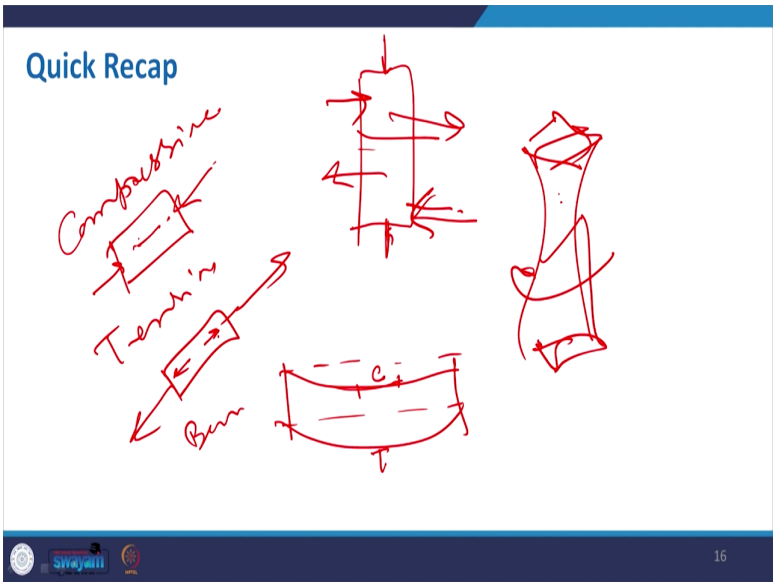

So, in quick recap what we have understood, one is your compression when we press it. So, that is basically you know the particles they come closer to each other and then, we got the tension where we just pull it and the particles they go away from each other, then we have bending. So, in bending what happen? So, applying load this was original position so, this portion shorted so, it is compression like this and the bottom part it tension it is there and the shear is basically, the force applied on no excessive force applied to it in opposite direction the lateral force so, it will develop a slide.

So, it may move this side this may move side for normal beam to the high rise, this is another problem we have to really take into consideration and the other one that we have seen that is the torsion. So, when we twist a building like this ok. So, give a motion to that with the

example. So, these are overall you know property of the structure that we are you need to understand.

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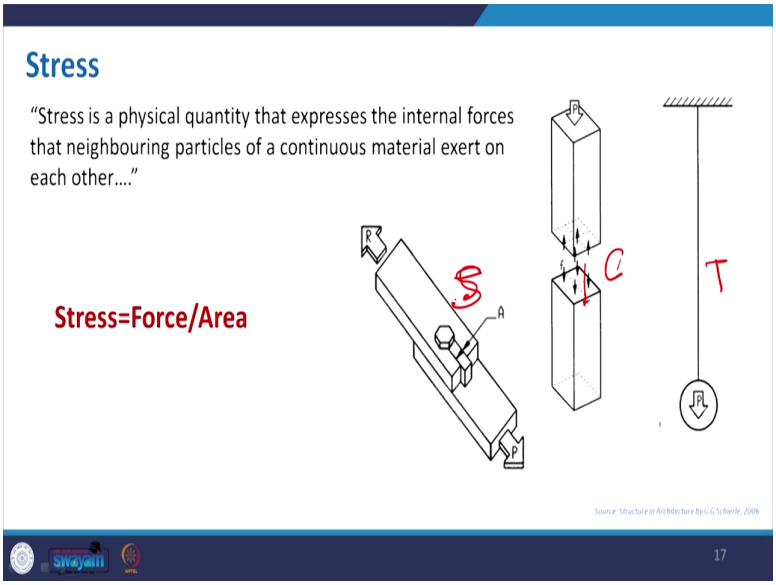

Now, come to the stress in this case stress is normally defined as the force per unit area and wind that is being created by compression it is called compressive stress when it is due to tension; it is tensile stress, when it is due to shear it is shear stress. So, in this case it is tensile hear it is putting pressure on that compressive and here it is basically shear.

So, compression tension and shear we repeatedly we will be using these terms in our upcoming lectures to know the different structural property. Now, the strain is like you can see through the GIF image what is happening here and also the same thing like with this particular model. So, like in this case it is as because I have used a rubber. So, it is giving you

some motion up and down and you can see the distance between this when we do not apply any force. So, it is short and now get elongated.

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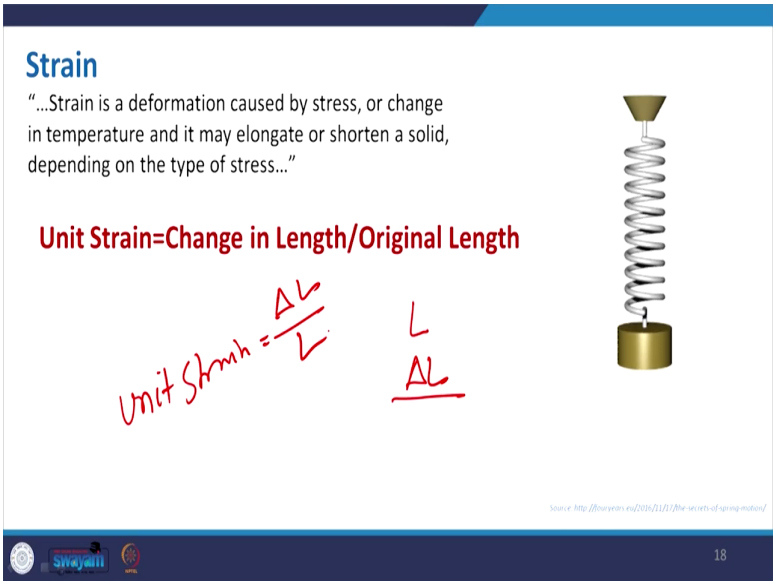

So, there is some deformation. So, that deformation is basically if it is L and the deformation is delta L. So, this is basically the strain and along with that the unit strain is calculated by your change in length by l. So, this is very important and it act depending on that you have some ultimate you know strain and stress and when you compare when we develop the relationship between stress and strain we get elastic modulus.

So, in this case, what exactly it is? It is very simple this is basically, stress by strain of the material. So, for this you can calculate it and this is also known as the Young modulus like developed by Young. So, that is why also like we can select the material which can have the

higher modulus or something which will depending on the load applied the deformation and all.

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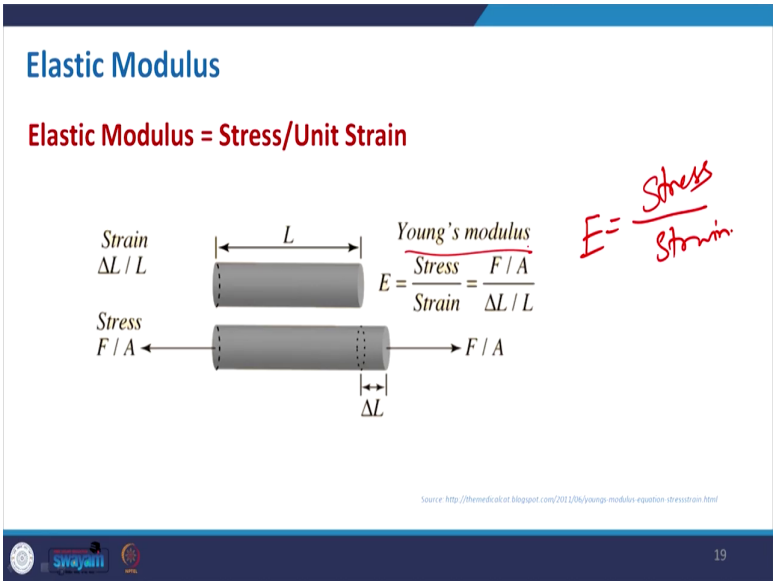

Now, the other one is related to the you know Poisson Ratio. So, it is the ratio between lateral strain by axial strain. So, if we just take a you know elastic material or something. So, here you can see that earlier shape was like this as square one and when you take it. So, there will be deformation there will be increase in length. But as well as there will be you know decrease in the thickness. So, in this case you can see that a cylinder when we pulled off.

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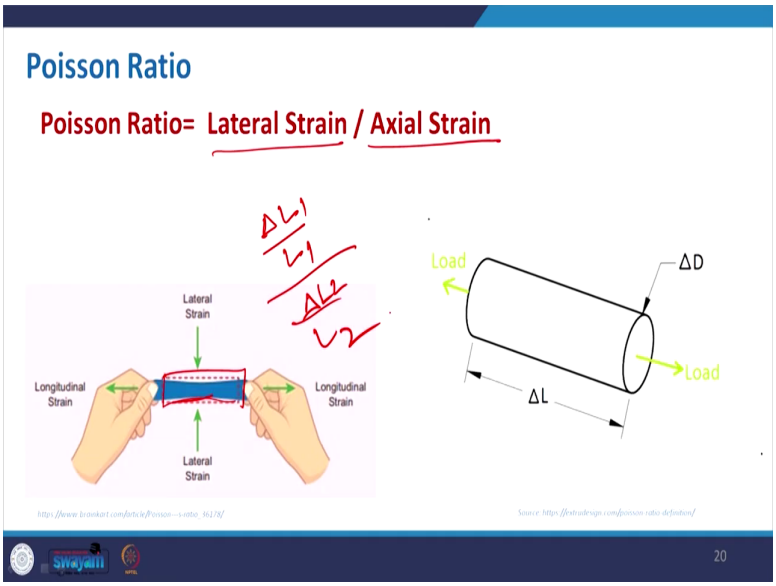

So, what is happening the length is increasing, but the radius it is getting deformed you can practice with some you know having thickness some tube. So, you can just try to pull it so, you can see. So, that particular lateral strain so, lateral strain means the deformation. So, earlier whatever the size and then you have delta L by say L and then the this distance maybe this is L 1. So, this is again you get the increase the change in the you know longitudinal strain or axial strain and get it the ratio.

So, it is also important to know this aspect of the structural property. Now, come to the thermal load so, apart from that also due to the excessive you know heat gain either from some friction or through sunlight. So, there will be expansion. So, depending on that there will be thermal expansion. So, for that reason also from our childhood we used to know that why this gap being created.

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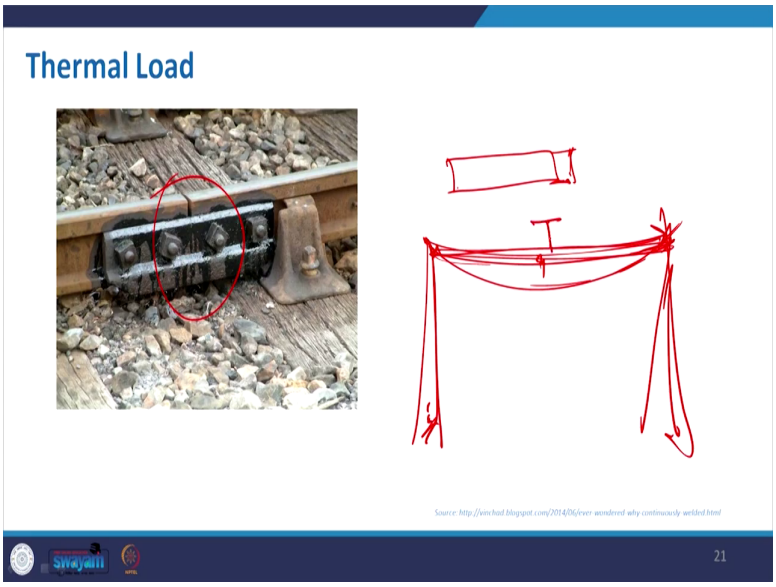

So, this expansion gap is being created in the railway track, as well as you know building where the thermal you know for a huge building where the material is really you know the material used can get effected with the excessive heat it can change in cold climate or something. So, as true with the you know the tower electrical tower, where you know in winter we have almost this kind of arrangement, but during the summer days during cold time it is being little bit tight when it is in summer so, it expands.

So, we get a sagging to this. So, we have to encounter this you cannot take this length as universal. So, that like it will have developed some strains sometimes you know it will be developing tension. So, it may collapse. So, thermal load is another important thing and along with that everything should satisfy the 4's of the structure that we already discuss that is your Strength, Stiffness, Stability and Synergy.

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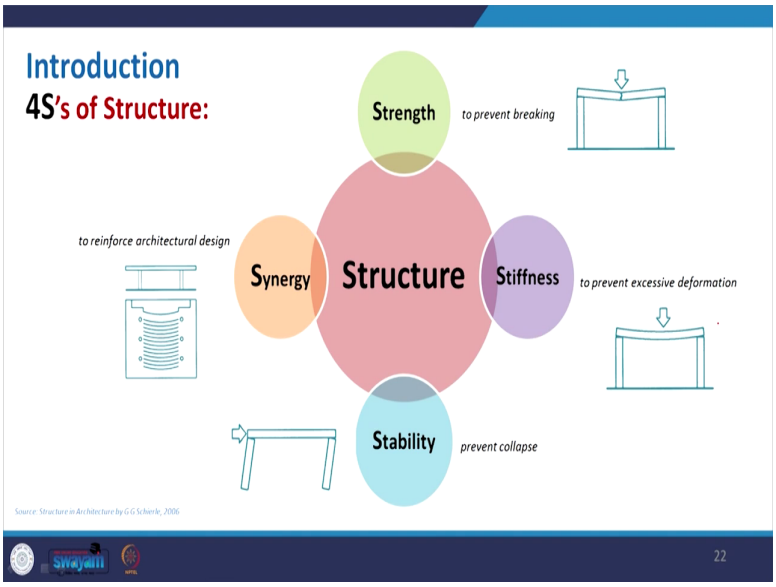

Where strength will prevent your structure from breaking stiffness will prevent it from the deformation then the stability deformation means it may be the horizontal or the buckling is basically when you have this vertical structure and put the load and this particular building. And then the synergy is overall arrangement or everything in order to give the final outcome.

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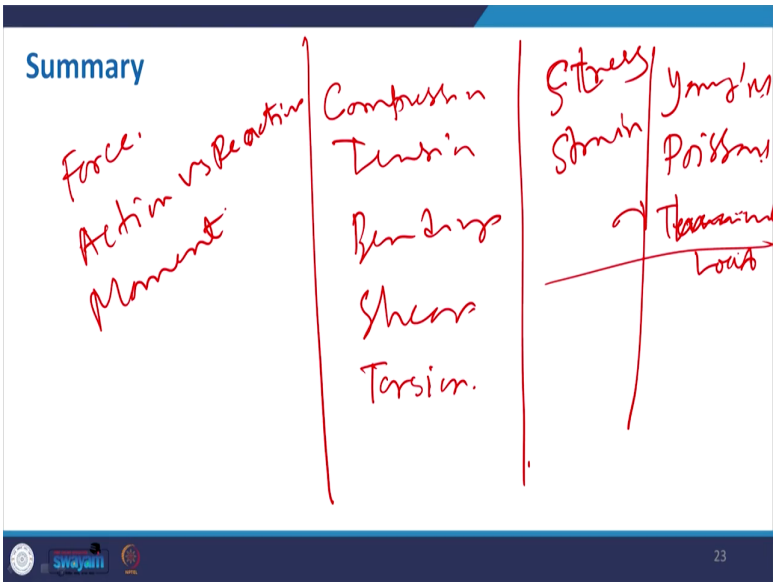

So, in this what we have learned? So, we started with force, then we know this action versus reaction and you know in this also we have studied that force always act in pair and in opposite direction, then we come to moment and different kind of result of momentum, and then along with that we also studied the compression, then tension then your bending, then shear ah, then you have the torsion ok.

And along with that we also studied the stress the you know stress, and then strain, and their different relationship with the young modulus, and then you also know the Poisson's ratio, for the lateral strain and axial strain then along with that also we know that thermal you know thermal load and, then basically we got some basic property of the structure by which we will be able to select the right material for right resistance.

So, that overall your building will be stable ah, it will have the enough stiffness enough stability for the arrangement and overall synergy between them to your building more you know safe from any other you know externalities any other applied force and it will be you know proper resistance to all these external forces. So, with that I conclude here I have included some books where you can find it is a basic books of structural mechanics, normally in you know engineering we used to study it.

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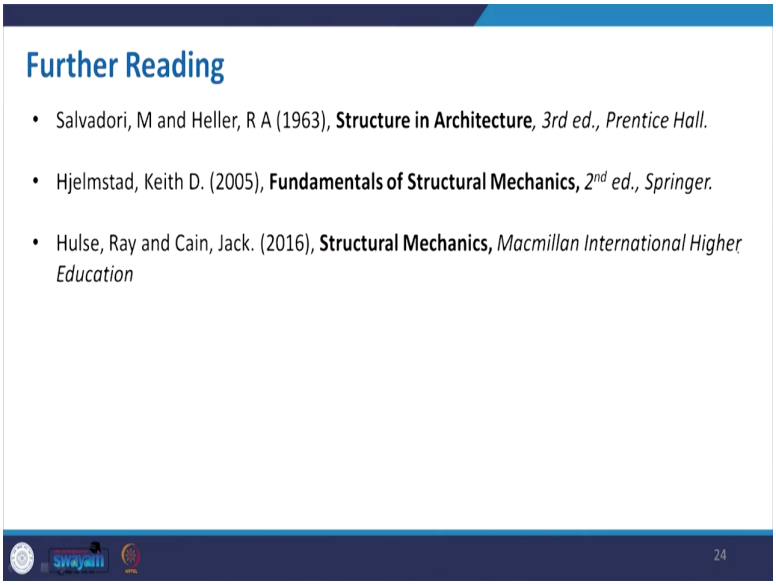

So, you can go through it and the next what we will discuss is basically the structural requirement and again with that I thank you all for attending this course and hopefully I have really covered something and then we will move forward to the requirement of structure.

Thank you.