Mechanics Of Solids
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Lecture - 35
Forces and Moments Transmitted by Slender Members

Welcome come back to the course Mechanics of Solids. So, in the last lecture if you recall we were solving one problem, we started one problem and we could not solve the whole problem in that particular lecture; however, we will try to solve or try to complete that problem in this lecture.

So, there actually we discussed about the mechanical stresses developed due to the mechanical forces right I mean the mechanical strain whatever is getting developed, so because of that you are getting the development of the mechanical stress and that we have calculated. Then we started the calculation of thermal stress and there we just started this thing the geometric compatibility.

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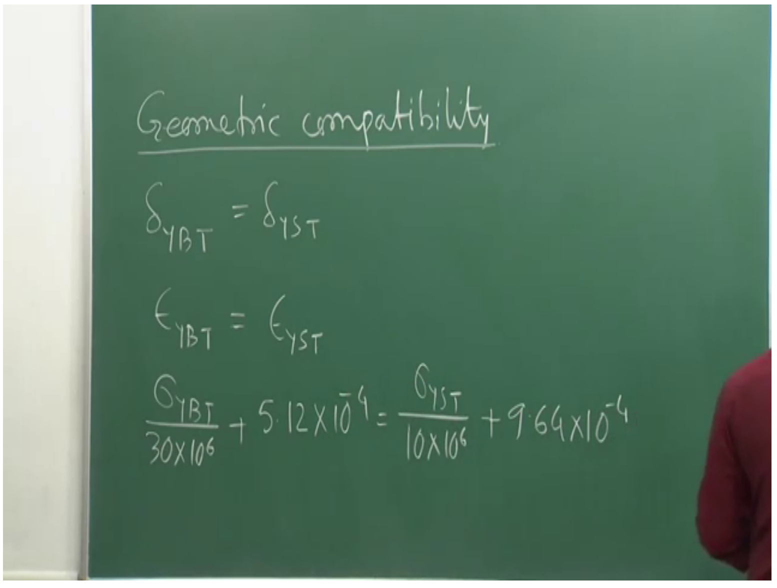

So geometric compatibility if you recall. So, basically there you we will talked about that delta YBT is equal to delta YST right, delta YBT that means, the deformation, the deformation in bolt must be equal to the deformation in the sleeve because we are not expecting or we are not allowing any gap between the bolt and the sleeve the connection. So, therefore, both the things bolt as well as sleeve, both the elements will be elongating by the same amount or if they are contracting they will be contracting by the same amount. So, therefore, the whole assembly will be I mean will be getting enlarged or getting contracted. So, this must be the geometric compatibility for that system under the temperature rise. So, therefore, because this and this is happening due to your the length of the sleeve as well as the length of the bolt both are same, if you look back the problem whatever we defined in the last lecture.

So, what we can write therefore, the strain in bolt in to the thermal that is the thermal strain in the bolt must be equal to the thermal strain in the sleeve and already we have calculated these two things, so you can put those values sigma YBT by 30 into 10 to the power 6 plus 5.12 into 10 to the power minus four equal to sigma YST by 10 into 10 to the power 6 plus 9.64 into 10 to the power minus 4. So, from this we can get the equation sigma YBT minus 3 sigma YST equal to 13.56 into 10 to the power 3 - this is equation 3.

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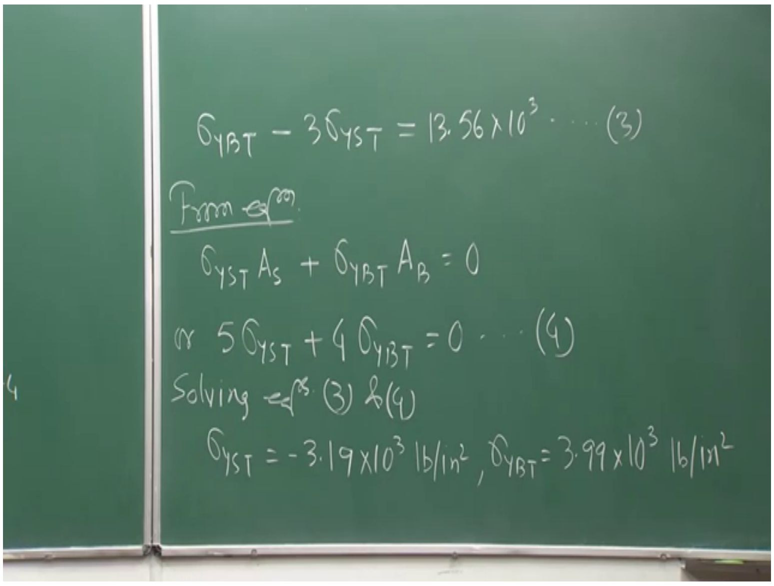

So, this is coming purely based on geometry compatibility of the system under the thermal action.

So, now from equilibrium already we have seen this thing earlier that will be remaining saying from equilibrium your sigma YST multiplied by A S the cross sectional area of sleeve plus sigma YBT cross sectional area of bolt must be equal to 0 because there are no forces acting actually. So, this already we have seen in the last lecture, so that will be remaining same even under temperature rise. So, that gives me 5 sigma YST plus 4 sigma YBT is equal to 0. So, that is equation say 4.

Now, if we solve equation, solving equations 3 and 4 what we can get? We can get I mean if we solve we will get either sigma I mean sigma YST as equal to 3.19 into 10 to the power 3 pound per inch square and sigma YBT is equal to 3.99 into 10 to the power 3 pound per inch square. So, we have got sigma YST and sigma YBT right. So, what we have got earlier we if you recall earlier we had got sigma Y S and sigma Y B right; that means, the stress is developed with the mechanical strain.

Now, we have got stress is developed due to the mechanic thermal strain right. So, therefore, if we add these stresses algebraically we must get the total stress acting on the sleeve as well as on the board. So, let us do that very simple.

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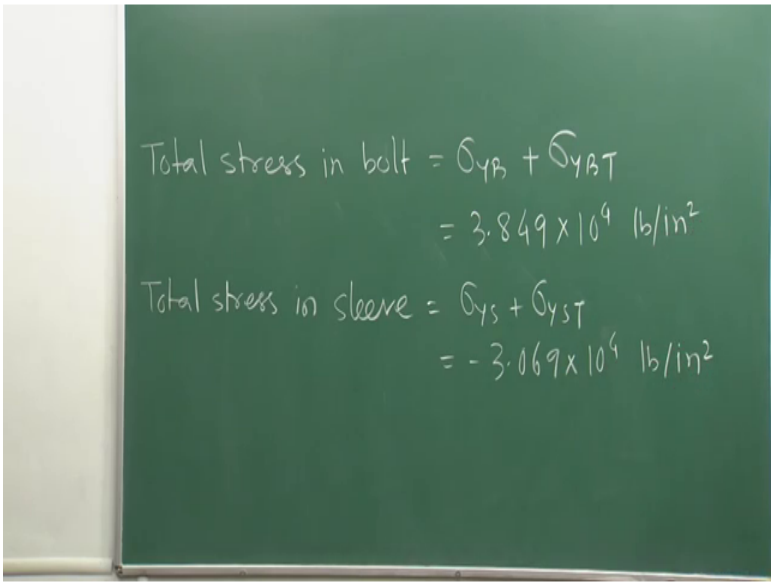

So, the total stress in bolt is equal to your sigma Y B already calculated and now we have got sigma YBT. So, that gives me 3.849 into 10 to the power of 4 pound per inch square whereas, total stress in sleeve is equal to sigma Y S plus sigma YST that is equal to minus 3.069 into 10 to the power minus 10 to the power of four right 10 to the power of 4 pound per inch square. You look at the total stress developed in the bolt that is tends that in nature, so therefore, bolt will be getting extended give the application of the mechanical string as well as your thermal strain whereas, the sleeve will be under compression and this much of compressive stress will be getting developed due to the combined action of thermal strain and mechanical strain well.

So, with this I will conclude the stress strain chapter stress strain thermal temperature relation and we have seen that how we can calculate the thermal strain and how we can find out the stresses developed due to the thermal strain.

Well, now, will start or will proceed to the next chapter that is the forces and moments transmitted by slender members, forces and moments transmitted by slender members.

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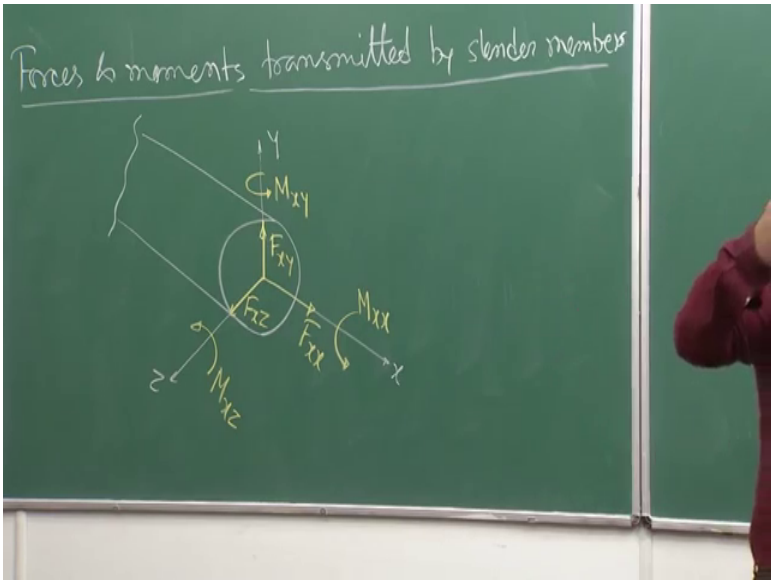

The first thing we should know what is slender member. So, slender member is nothing, but a member for which the length of the member is much more higher than either of its cross sectional dimension. The length is much more higher than the with or your breath that is a land b if you consider if you considered a rectangular cross section or if you consider a square cross section. So, any one of the I mean either of the literal or the cross sectional dimension will be much more lower than the length.

Now, generally I mean we defined that it should be at least 5 times the length should be at least 5 times more than the cross sectional dimension. So, the classical example of the slender member is nothing, but your beam whatever you generally see in the building, then column and then you can you can think of the shaft, the shaft which is rotating in the in some mechanical machines that is very slender member. So, these are all slender members. Now you can think of the aircraft the wing that is also the slender member. So, these members the length in the length direction it is much more higher as compared to the cross sectional dimension.

Now, for that particular type of member the slender member the behavior, I mean what if I apply some force or moments how that force and externally applied forces and moments will try to develop some internal forces as well as moments we will see that. So, this chapter will be dedicated to solve what to analyze this kind of slender member.

Now, before that let us draw one slender member. So, this is one typical say slender remember all right it is a circular cross section. So, this is your say x axis this is your say y axis and this say your z axes now this is one slender member. So, in the length direction it is much more higher than the diameter of the cross section. So, now, some under the action of different external forces and moments if I consider this is my some cut section internal section this is this is nothing, but your x plan right if we see this cross section this cross section is nothing, but the x plan or the x cross section right because this spring is normal to the x axis as per our previous definition.

So, therefore what are the forces are acting. So, let us draw that first one is this force this force will be defined as F xx on explain along x direction fine then you have F x plane y direction F xy then x plan z direction F xz these are these are probable forces acting on this plane fine. Apart from that some internal moment will be getting develop, so that moment is nothing, but say we are following right hand thumb rule. So, this will be M xx on x cross section you are having moment with respect to x axis similarly on x plan or x cross section you are having the moment with respect to y axis that will be M xy similarly M xz. So, these are 3 force components and moment components will be acting on this plan, there is no issue.

Now as per our definition if the force is acting on positive plane along positive coordinate direction or the axis direction then that force will be defined or represented as positive force. Now as per our definition all the force components like F xx F xy and F xz all force components whatever are shown in this particular figure all are positive in nature right. Now for moment we will consider the right hand thumb rule; that means, you know that right if this is axis direction. So, if I point to the thumb towards the axis direction then whatever rotation will be getting in the moment that rotation or that moment will be positive. So, as far as that definition all moments I have shown as positive. So, this is our sign convention will be following.

Similarly, if the forces are acting along the negative plan; that means, negative x plan if you consider if the forces are acting along the negative along the negative coordinator axis then those forces again will be positive. So, positive plane positive direction will be positive negative plane negative direction will be positive if they are reverse; that means, positive plane negative direction or negative plane positive direction they will be negative as per our definition. Already we have seen or we have defined that thing in the stress chapter when we are discussing about the concept of stress we are not going to repeat that thing again in detail.

So, now this forces if you look at these forces will try to impart some kind of special behaviour on the slender member now what is that. Now if I consider the first F xx this if you look at this F xx this is your x plan, this axes of the slender member is coinciding with the x axes. So, this F axes is nothing, but your axial force and this component tends to elongate or compress the member and often and is often given as simple F x.

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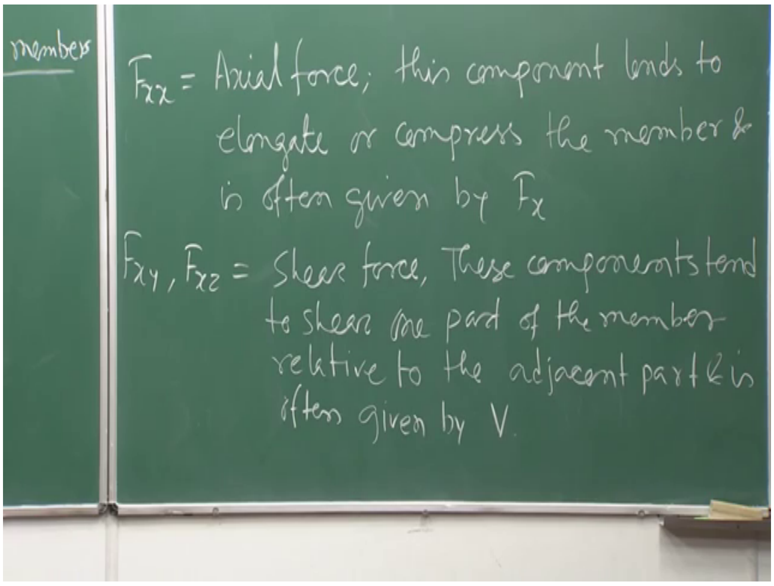

As I told you right generally we do not write sigma xx sigma yy sigma zz something instead of that we generally write sigma x sigma y sigma z because we know that normal stress always will be acting on that plane on which the out one normal is along the along that particular coordinate axes. So, therefore, F xx instead of writing F xx because it is quite understood that axial force will be always defined as only one subscript that is F xx. So, if I get F x so that means, it is the axial force along x direction and of course, it will be it should because if this is the axial force and then that should act on that particular plane that is x plane.

Then coming to F xy and F xz what is the kind of say behaviour you will be getting from these forces. So, these forces are nothing shear force right shear force. So, these components tend to shear one part of the member relative to the adjacent part and is often given by V. So, subsequently we will be using this term V. So, whenever we will I think V is capital V is nothing, but the shear force.

Now what it does actually this shear force is basically it will it will try to shear one part, say suppose if I have two parts suppose something like this if you consider. So, this it is like it is say some segments of the slender member slender member is like this or shear will try to move one part related to the other part. So, you will be getting the share on this screen right this is the shear force will be acting like that.

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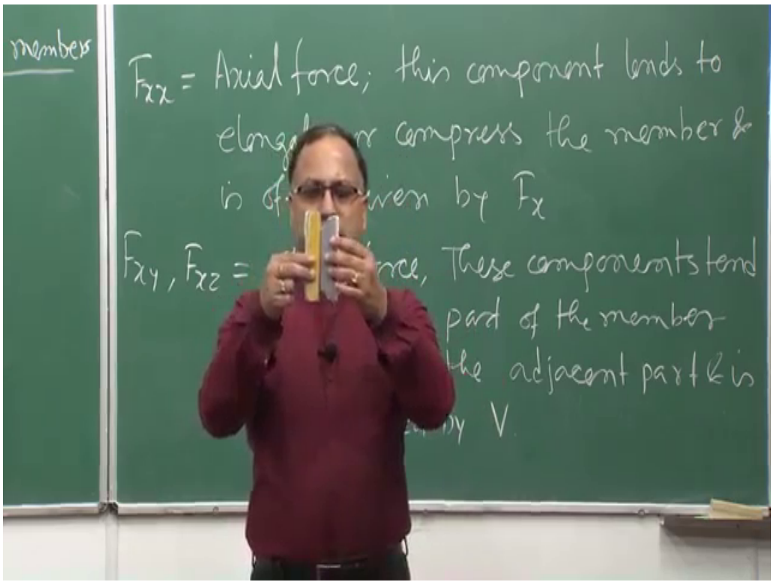

So, this is very much see very much present in the slender member when it will be under some externally applied forces as well as moments that we will see later on and this will create or this will give or this will tell you that some kind of say adjustment or say some kind of say if you design some concrete beam you need to put some sheared enforcement for that to take care of that particular shear. So, if you know the shear force then basically based on that shear force you can find out the shear stress and to take care of the shear stress you can modify or revise your design. So, that the shear force should be taken care, so this knowing this shear force is very very important in case of slender member.

Then coming to the next part that is a M xx if you say the nature of this moment what kind of say behaviour it produces in the slender member M xx.

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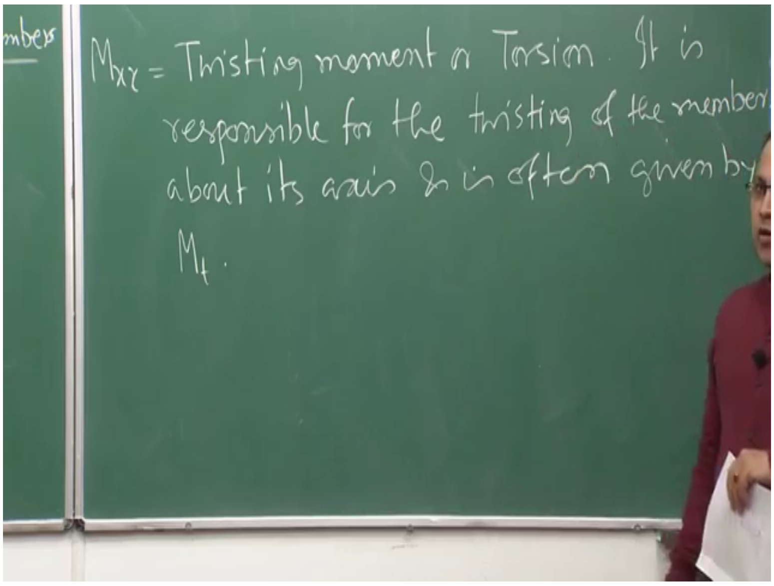

What does it do? Now this is a slender member say suppose this is this my hand is a slender member and I am applying that M xx moving like that. So, what it gives it gives twist right. So, there for M xx is defined as twisting moment, twisting moment or torsion popularly known as torsion, it is responsible for the twisting of the member about its axis and is often given by M t.

So, the next chapter next topic will be covering this torsion part. So, in this chapter will not be talking about torsion, but; however, depending on the action right M xx will be giving you the twisting in the slender member the slender member will try to twist because of this kind of moment that is M xx. Now what about this M xy and M xz what kind of behaviour it provides in the slender member M xy and M x z?

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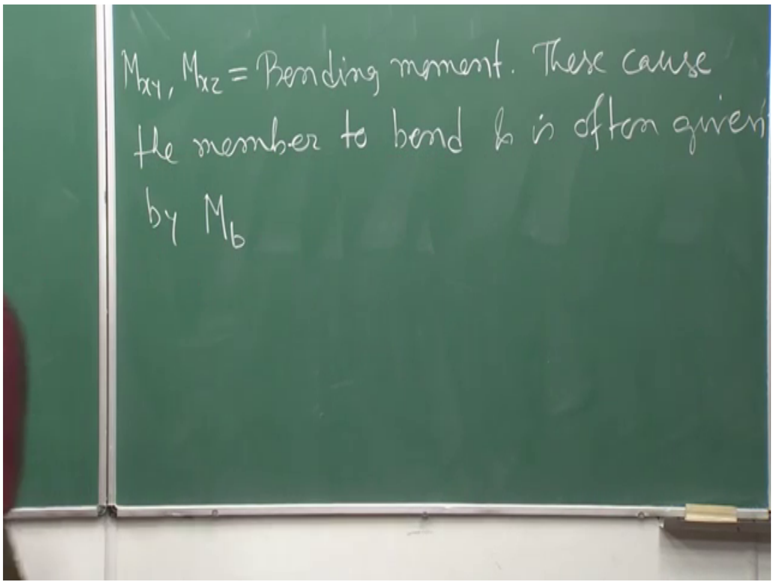

If you look at M xy and M xz what does it do suppose this is a slender member, if I consider M xx M xz is there or this side or this side whatever if I consider this is my positive express. So, M xz as shown, so this will be doing like that right, so this is my M xz. So, that will provide some bending in the member. So, that is why this is known as bending moment, bending moment these cause the member to bend and is often given by M b. So, what are the things we have learnt? Axial force shear force twisting moment or the torsion and bending moment right, so these 3 this 4 types of force forces as well as moments will be coming on a particular slender member if I consider any particular section right.

So, now as I told you, these components will be positive in the force and I mean force or moment compress acts on a positive phase along the positive axial direction. So, that remains same the sign convention. Now we are going to define the sign convention for shear force for axial force there is no problem right, axial force as per our definition on the positive plane along positive direction suppose if I say this is one member this is the positive phase, so on the positive phase this is my positive phase say if this is my x direction and say the negative phase is something like this, so this is my negative.

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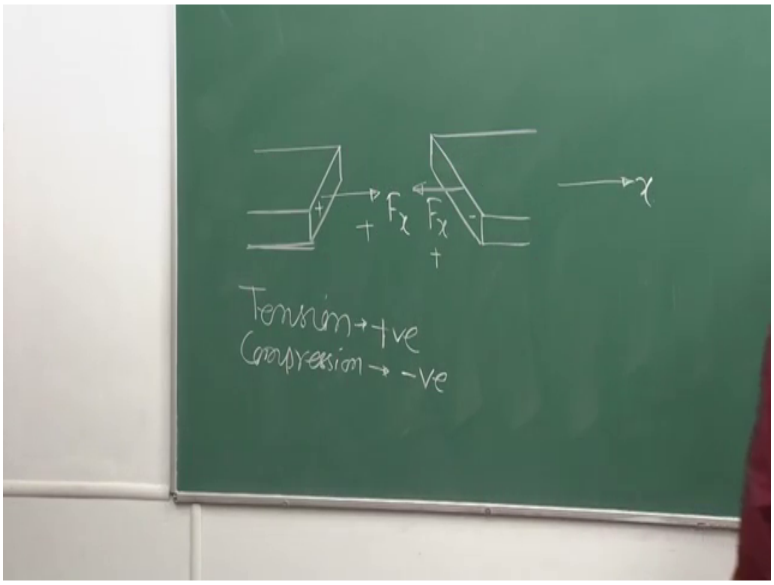

So, on positive phase this is my positive phase positive x phase on positive x phase along positive x direction this F x is positive. Similarly, on the negative x phase the F x is acting in the negative x direction therefore, it is also positive. So, what kind of behaviour or what is the nature of this force which will talk about the behaviour of the member. So, I will what kind of say behaviour we can expect from this kind of force either elongation or compression. So, therefore, if I say the positive force; that means, the tensile force is positive similarly compression is negative as from definition.

Now, what about the shear force? For shear force, now onwards I will be talking shear force as SF and bending moment as BM.

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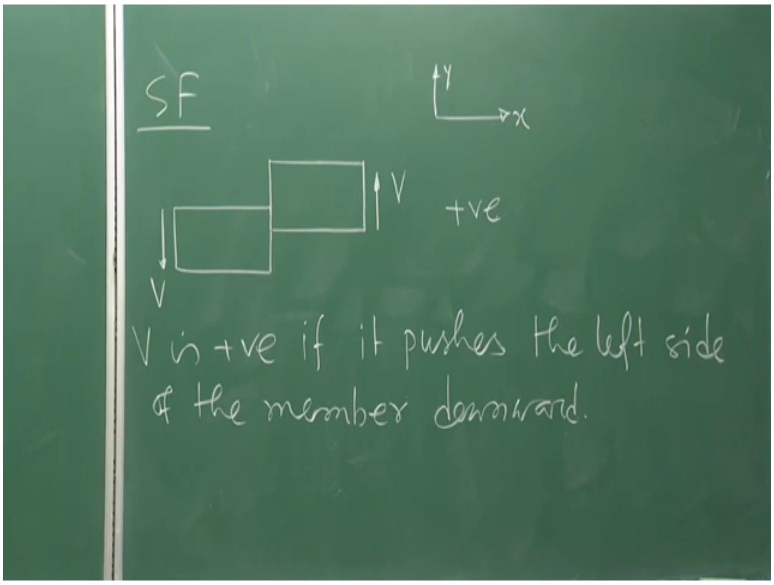

So, shear force suppose this is as I told you the one part will be moving related to the other part of the member and say this is the direction of shear force and this direction is positive. Now why it is positive say if I say this is this is a this is my x direction this is my say y direction this is why positive x direction this is my positive x plane on positive x plane along positive y direction the shear force is acting right the direction of this force is along y direction. So, therefore, this shear force must be positive.

Similarly, you try you can verify this thing on the negative plane what is happening. In the negative plane basically this V is acting on the negative plan V is acting along the negative y direction. So, therefore that is also positive. So, this configuration is positive; that means, this configuration of the shear force is positive. So, we can write what - so V is positive if it pushes the left side of the member downward, so V is positive if it pushes the left side of the member downward. So, left side of the member is this. So, this is coming down, so therefore, this shear force will be positive this configuration right if you see this configuration it will positive if it goes reverse then it will be negative fine.

So, similarly we can define the sign convention for the bending moment as well. So, I will stop here today. So, in the next lecture we will be defining the sign convention for the bending moment and we will take one small example by which you can find out the shear force and bending moment.

Thank you very much.