Aircraft Structure - 1
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Lecture-13
Truss System (Contd.,)

Welcome back to the aircraft structures one course this is Professor Anup Ghosh from aerospace engineering department IIT Kharagpur. We are in the third week of the series. So, we have you are already introduced with the truss system, system you are basically introduced with the plane truss system and a small example two small examples we have done in our last lecture in that in the first example we have seen how the overall equilibrium to consider to find out forces and from separating the members how to prepare the free body diagram, and then to continue for the solution of the total problem.

Then we have already also learned the method of sections which is a very easy and efficient way of finding out a particular member force but that requires some experience unless you are you have solved some problems it is difficult to use that method. With that foundation of plane truss we will move forward for solution of plane truss or similar problem this in; this lecture and in forthcoming lecture we will move forward to three dimensional or space structures sometimes space truss mainly will solve space truss. But this week this lecture this lecture particularly will consider method of joints.

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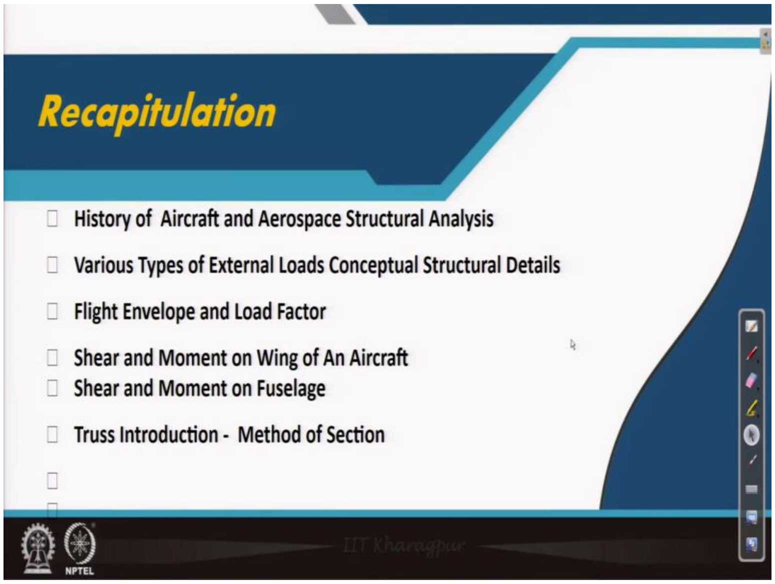

And in this wheel's let us see how do we solve but before that like every other lecture starting we would like to revisit what we have done already. We have seen where from the solid mechanics or structural analysis has started and where we are at present. We have seen how the aircraft has progressed and come to a huge aircraft from a small one from there we have come to loads coming on the aircraft.

We have learned about flight envelope we have learned about load factor, shear and moment on wing of an aircraft we have solved how to find out shear and moment on wing how to solve for shear and moment in coming experienced by a fuselage that is also solved. And then as just now we have talked about introduction to method of sections we have covered and to some extent introduction to truss structures have been covered in the last lecture.

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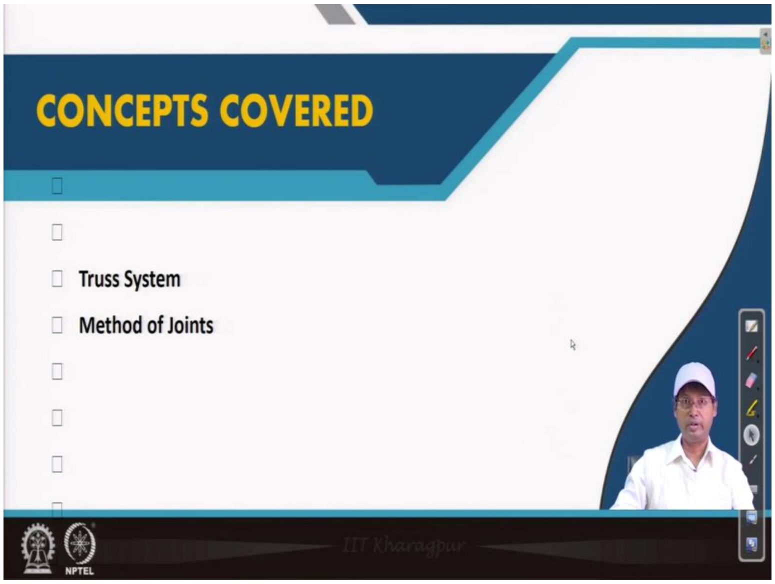

This week the same stress system all you will be doing but method of joints with stress on the method of joints.

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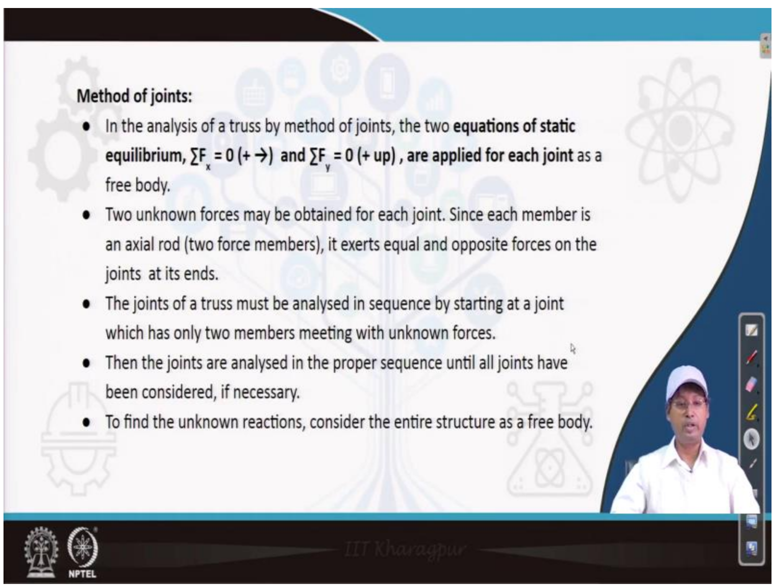

Method of joints if we look at in this analysis of our truss by method of joints the two equations of static equilibrium that is horizontal forces are $\sum F_x = 0\ (+ \rightarrow)$ and vertical forces $\sum F_y = 0$ (+ up) are applied for each joint that is the reason each joint gives us two equilibrium equations. We need to consider the free body and then we need two free body of that particular joint and it reapply these two.

Two unknown forces may be obtained since we have two equations two unknown forces we can find out. Since each member is an axial rod two force members it exerts equal and opposite forces on the joints at its ends. So, while we talk about truss this is very, very important to notice that in most of the cases we for analysis purpose we consider those as two force members and we solve it. The joints of the truss must be analyzed in sequence by starting at a joint which has only two members meeting with unknown forces.

This is quite obvious since if we have more members unknown members then we would not be able to solve the joint or all the forces or at the joint or all the member forces at the joint so that we need to keep it in mind while you are considering joint. Then the joints are analyzed in the proper sequence until all joints have been considered if necessary. To find the unknown reactions consider the entire structure as a free body.

So sometimes this is done before we go for the unknown member forces. So, overall reactions support reactions we can if we can find out that becomes easy to find out the forces in the member.

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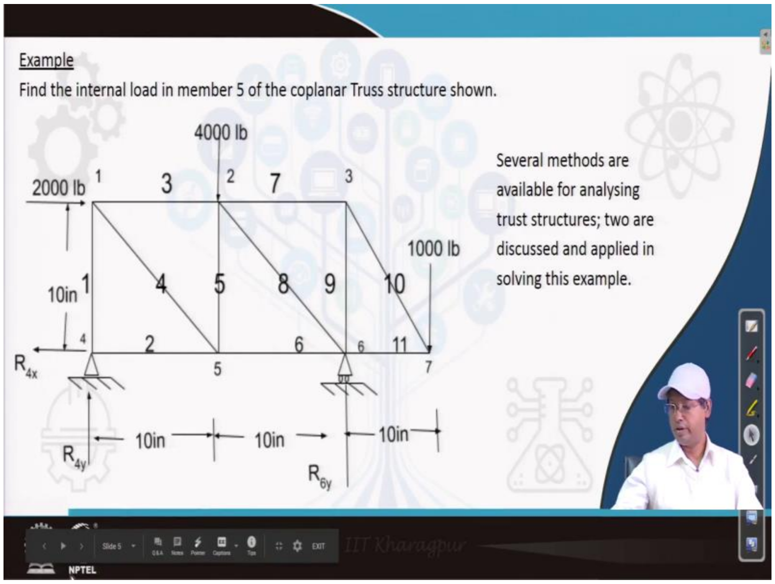

The same example as we have already mentioned in the previous class that this member force 5 this member force 5 is supposed to be found out. In the last week in the last lecture we have considered with one section here and in this example you would not consider section but we see how can we find out the forces using method of joints because method of joints is most more important why we will be solving 3 dimensional trusses that there it helps method of section does not help much.

So, three unknown reactions this is one arrow has to be put here this is a reaction R_{6y} this is roller support that is why only one reaction there are two reaction because it is pin joint support then we have horizontal forces so there must be some reactions at 4 in the horizontal direction. Several methods are available for analyze truss structure two are discussed and applied in solving this example two means one we have done already other we will be doing now.

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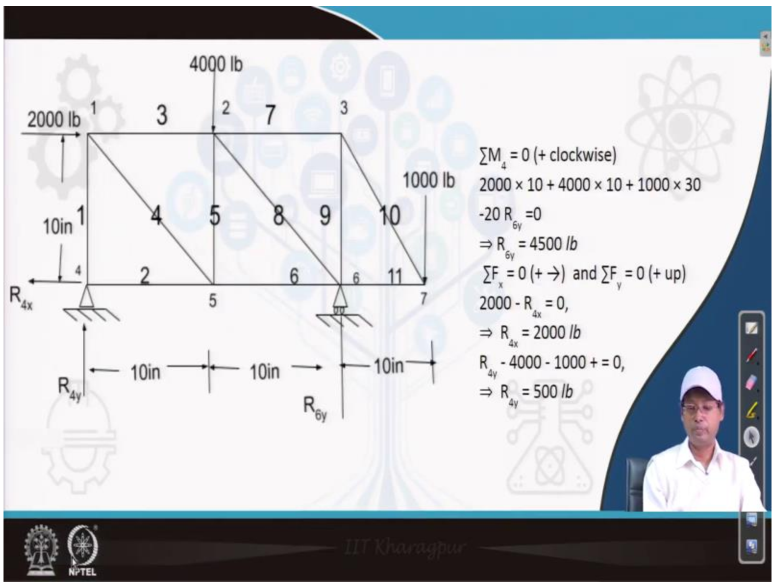

So here we find out the overall reactions of the structures from the support as we have already discussed sometimes it helps a lot for using method of joints that is what is done. So, in this case it is considered that these supports are removed and there are two reactions here at this point and one reaction here is acting in this point. And a summation of M_4 equals to 0 ($\sum M_4 = 0$) that means we are considering moment about point 4 is equals to 0.

So that is what is done 2000 multiplied by 10, 4000 multiplied by 10 this way this way this way it is acting and 1000 multiplied by 30, 10 10 10 acting this way all are in the same direction -20 R_{6y} this is acting the other way as it is which is better to put a an arrow on this. So, this is acting in the other direction so that is the reason the equation is form this way and if we solve this equation we will easily get that the vertical reaction is 4500 pound.

Once we have found out the vertical reaction what at joint 6 what we are doing is that we are considering sum of horizontal forces equals to 0 and sum of sum of vertical forces equals to 0. The sum of horizontal forces will give us these are known force because there is no unknown no more unknown remaining and the sum of vertical forces will give us this unknown reaction because this is already known.

So accordingly what we get we get R_{4x} is equal to 2000 pound it is quite apparent from the structure also that it is supposed to balance force is supposed to be balanced by this because there is no other horizontal force in overall weight acting on the system. And for Y is equals to if we consider the vertical equilibrium I think there is a typographical mistake, so what is the mistake is this R_{4y} acting upward -two are acting downwards.

So this should not be there, this should be R_{6y} equals to 0. So, R_{6y} is already known so from that there we can easily find out R_{4y} as equals to 500 pound.

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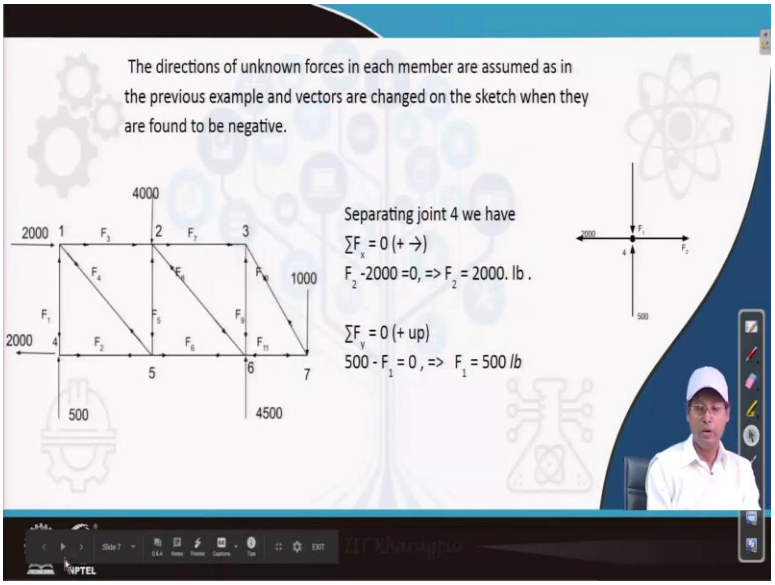

So, the direction of unknown forces in each member are assumed as in the previous example and vectors are changed on the sketch when they are found to be negative. So, this is a general convention we do and that way it is it is shown here. So, what we are doing first is the joint 4 is separated out first this is the joint 4, disjoint method of joints. The other way if we look at it is something like this here is a section cut out and this joint is kept aside. So, if we draw a free body diagram for this particular joint and as we have already discussed horizontal force summation equals to 0 particle for summation is equals to 0.

And that is what is applied here and that gives us F_2 is equals to 2000 pound and F_1 is equals to 500 pound. So, this method is really easy but it is this kind of tedious method we need to follow step by step the joints and we need to find out the forces.

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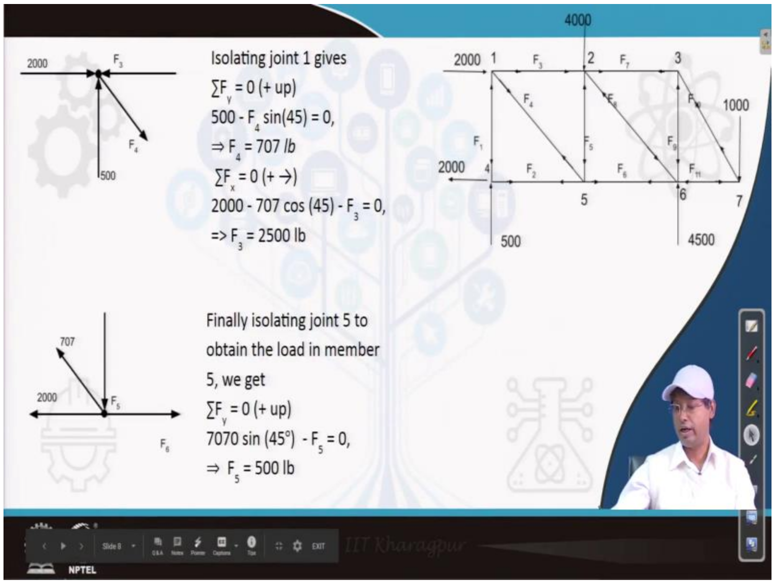

So, once we have found out the joint 4 see this member force is already known. So, if we consider this joint here the unknown forces are this and this. So, we have two equations easily we can find out these two member forces that is what is done here in this the joint F_3 is taken as a kept aside free body diagram of that joint 3 is prepared 500 is the F_1 force is applied here external force 2000 pound is applied there.

Then it is simple its vertical moment equilibrium is considered sorry vertical force equilibrium is considered 45 degree and if for sine 45 degrees it goes to 0. And then it gives us that F_4 is a goes to 707 pound and similarly if we consider the horizontal force equilibrium, so 707 cos 45 comes here and F_3 we can find out as 2500 pound. So, there is I do not think much things to explain only we can see where to move to find out the member force unknown member force F_5.

So if we claim this at present after solving this member forces is forces known this member forces known this member force is known. And if we come here in the last slide we have found out this member force also. So, considering this joint this is not known this is not known so only two unknowns are there so if we attempt this joint we can easily find out the F_5. Whereas if we attempt this joint here we do not have two or less unknown so we have three unknowns here.

So better not to attempt this joint it is better to attempt this joint and accordingly to find out the member force. And since our aim is to find out the F_5 here we have only our only two. We have a considered if vertical equilibrium only F_y in the Y Direction equilibrium only and accordingly we get I think this is another mistake 7070, 45 degree is not correct this is 707 only this is not there. So, with that we get that F_5 is equals to 500 pound.

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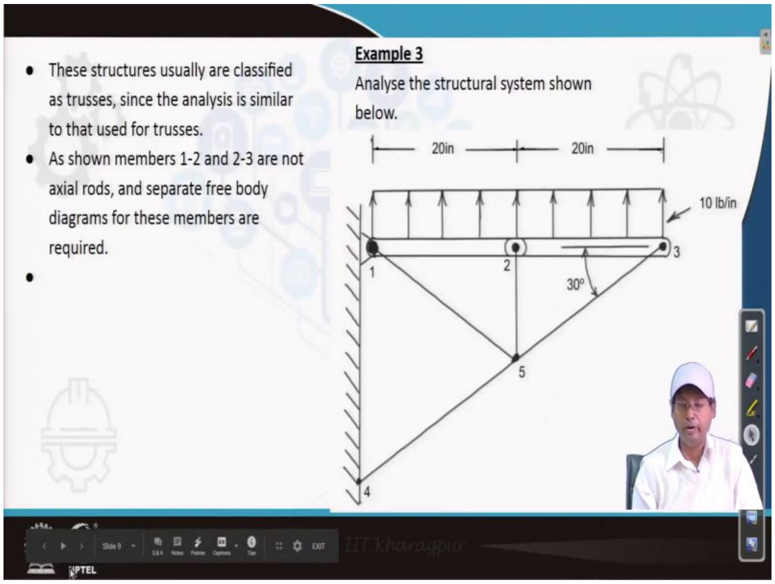

So we will have solved two problems, two problems one in one method the other one in two methods and this one is not exactly our principally truss but we can solve this problem considering truss concept and let us see how do we do. Because in general the truss members are not loaded transverse to its axis. So, but in this particular case this member and this member is loaded transverse to the this axis in the upward direction.

So principally this is not a truss but this type of problem can be solved using concept of truss. Let us see this structure usually are classified as trusses because of the reasons as I told you since the analysis is similar to that used for trusses. As shown in member 1 2 and 2 3 are not axial rods and separate free body diagram for these members are required. So, as I told you we need to consider these two members as a separate free body and we need to do. Let us see how do we solve this problem.

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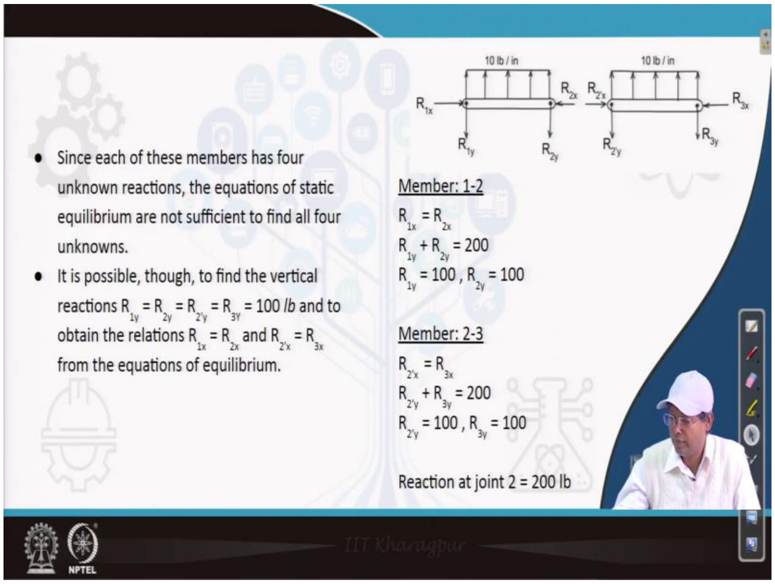

Since each of these members has 4 unknown reactions 2 at this end 2 at this end. The equations of static equilibrium are not sufficient to find all 4 unknowns. It is possible though to find the vertical reactions R_{1y} , R_{2y} , $R_{2'y}$, R_{3y} equals to 100 pound and to obtain the reactions R_{1x} equals to R_{2x} and $R_{2'x}$ equals to R_{3x} from the equation of equilibrium. So, this is more on like a equations of equilibrium is applied and from the symmetry of the structure we can find out that.

Since dimension I do not remember I need to go back this is 20 inch this is 30 degrees, so this dimension is not required. So, that is total 200 pound is acting here it is completely symmetric one and it is shared by these two that is the reason it is said all these forces are equals to 100 pound and this is in the transverse completely transverse direction it is acting. And these 2 has to be equal otherwise equilibrium are to be maintained that is the reason we say that R_{1x} is equal to R_{2x} and $R_{2'x}$ equals to R_{3x}.

So member 1 2 if we look at horizontal equilibrium gives these two and vertical equilibrium gives these two and from symmetry since the two are two symmetric we can easily consider that these are 100 pounds. This already I have discussed so this is we can skip now.

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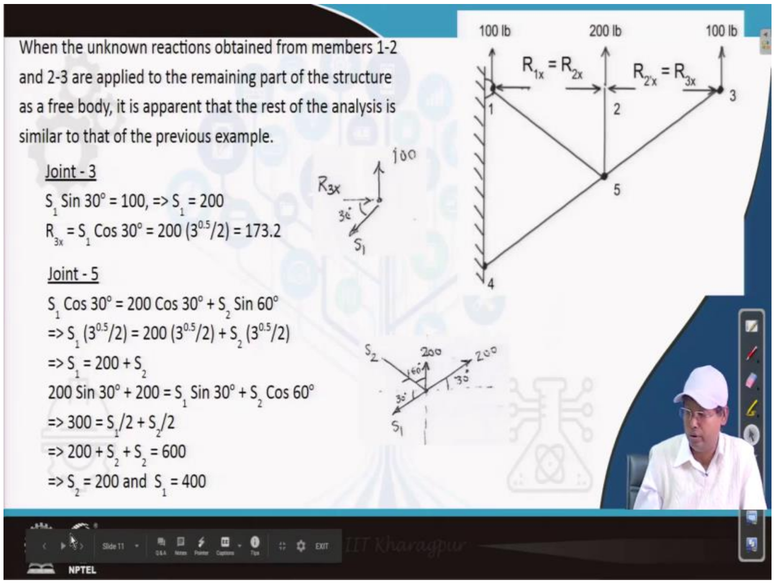

When the unknown reactions obtained from member 1 2 and 2 3 are applied to the remaining part of the structure as a free body. It is apparent that the rest of the analysis is similar to that of previous example. So, it is almost similar to the previous example as it is said those forces are applied here as shown here and then considering joints one after another we can easily find out the forces. So, first this joint is considered so S_1 we are keeping the name here as S_1.

Here also we say S_1 so it please do not get confused with this S_1 and this S_1 better in this course let us make it this is a $S_{1_{35}}$ so this is $S_{1_{35}}$ sine 30 is equals to 100 from this vertical equilibrium equation we can get and $S_{1_{35}}$ is 200 that is what we get so this is $S_{1_{35}}$ this is 3 5 and corresponding way the R_{3x} what we get the horizontal that we have got that those are equal these two are equal but what is the amount or how much pound it is that we did not find out so this is the value of that force.

So this joint is known we move to that second joint R 5, so in this what we can say that this S_1 is it actually is $S_{1_{45}}$ this is 4 5 and it goes on this is 4 5. So, please consider that this is 4 5 so what do we do in this how many unknowns we have this 200 is already known from the previous example from this joint there is no other forces acting. So, this is 200 about this joint if we look at what the forces are acting in the transverse direction from simple equilibrium we get that this force is 200.

So from there if we look at this is 30 degree yes here it is written this is also 30 degree so this is cos component acting in this direction 200 cos 30 this is acting in this direction this one. And this S_2 sine this is also acting in this direction. So, this makes us the summation of F X equals to 0 and remaining part I think only to put the numerical values and we can find out we get the equation of S_1 and S_2. So, if we go for the vertical equilibrium direction.

So this 200 sine 30 this is this component is coming here and then 200 it is being added this one this is the 200 and this vertical component is this is coming here and along with that this is also coming this S_2 is coming as cos 60 so that gives us another equation with S_1 and S_2 this is second equation. And if we solve these two equations we get S_2 equals to 200 and $S_{1_{45}}$ is equals to 400. So, well this is explaining is much easier but while we solve problem we do sometimes small mistakes be careful while you solve problems.

And in this joint we have found out at this point of time this is known this is known this is found out and this is also found out. Let us move to the next slide.

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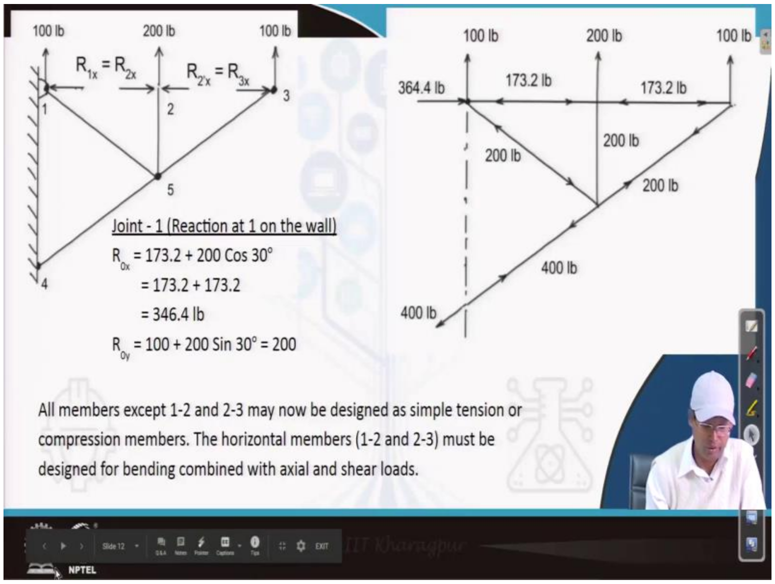

This slide is about joint one reactions at one on wall we need to find out here this 400 pound is already known because this is pin joint and it is a two Force member this is already known one the reaction here we need to find out reaction at one that is the reason it is stated reaction at one on the wall. So, R OX or 0X sometimes we say, reaction is we are considering this as 1732 is that this member force already you have found out, those are equal.

And we have got that and this 200 cos 30 is coming from this member this is also 30 degree so that is the sorry, this is 30 degree so that is the reason we have the cos component here and that gives us the horizontal force as 346.4 pound. And the vertical equilibrium condition if we consider from same this member force sine component is coming and that gives us 200 pound as the vertical force.

Here one important point better to note down with that point we will conclude. All members except 1 2 and 2 3 may be designed as simple tension or compression members. The horizontal members 1 2 and 2 3 must be designed for bending combined with axial and shear loads. This is what I try to tell you inform you at the beginning of the solution of this problem. So, these two members are not designed completely as axially loaded members.

These are designed for shear loads as well if the member the force is much more bending moment is also much more then we sometimes need to design it for bending moment also. With this let us conclude today's lecture.

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References are as usual I do not find any point to repeat.

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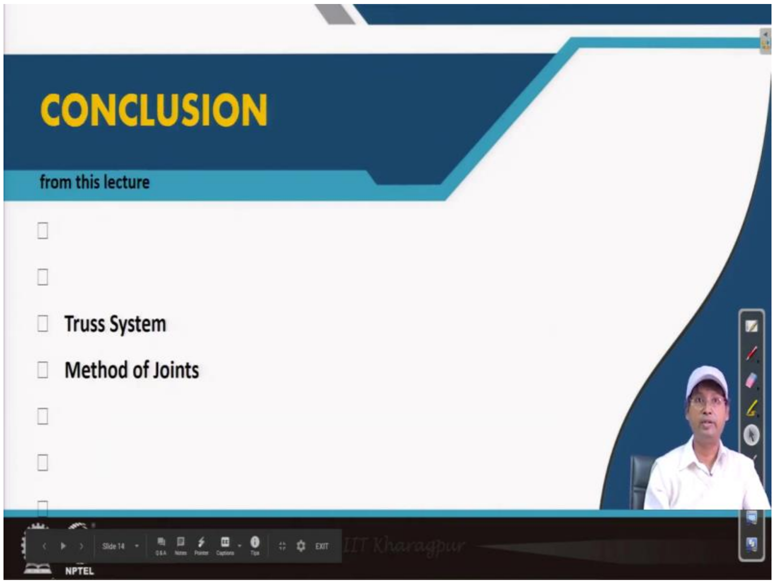

What we have learned is that truss structure mainly three examples who have done on truss structure plane truss structures and in the next lecture we will move to the three-3 dimensional structures basically the 3 dimensional trusses which are very, very popular in aircraft structures. Big example is, if you if you look at the tail boom of helicopter those are 3 dimensional trusses not only that those are still being used you can find many small helicopters use that three dimensional truss tail boom of helicopter.

Not only they are in many other places most important the basic analysis of any landing gear is considered as a 3 dimensional truss structure and the primary analysis of the landing gear is generally done you considering those as it truss structures. And then more fine analysis more detailed analysis is carried out while we have other forces found out and we continue that way. So, with that thank you for attending this lecture we will come back with 3 dimensional truss next in our next lecture, thank you.