Aircraft Structure - 1

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Lecture-12
Truss System

Welcome back to aircraft structures one course this is Professor Anup Ghosh from aerospace engineering department IIT Kharagpur. We are at the beginning of week 3 lectures, lecture number 12 truss system will get introduced to truss system. We will see how determinate truss is and predominantly in concentrate in these weekly lectures with determinate truss, plane truss as well as space truss.

Space truss is our 3 dimensional stress is more popular in aircraft structures but to get introduced we will spend some time in truss structures plane stress structures and then we will proceed further.

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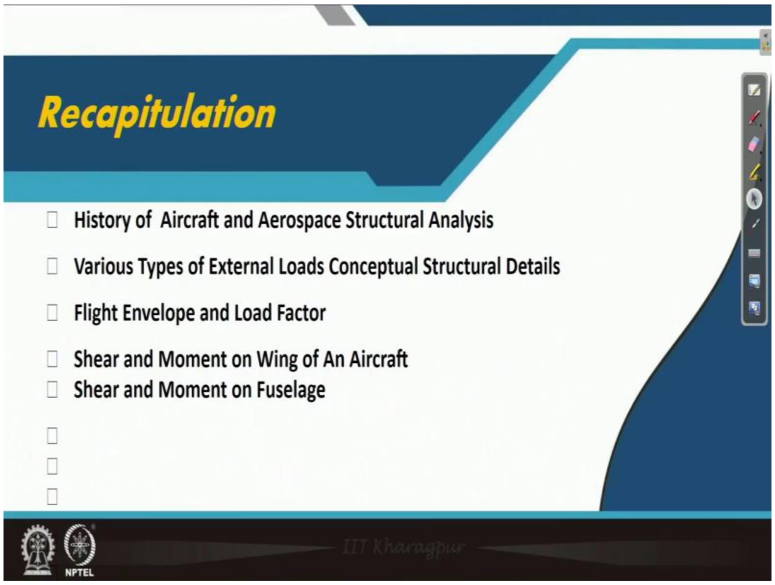

So as we have seen this is history of aircraft engineering we have seen, we have in the last week what we have seen is mentioned at the bottom the shear and moment on fuselage and shear and moment on wing.

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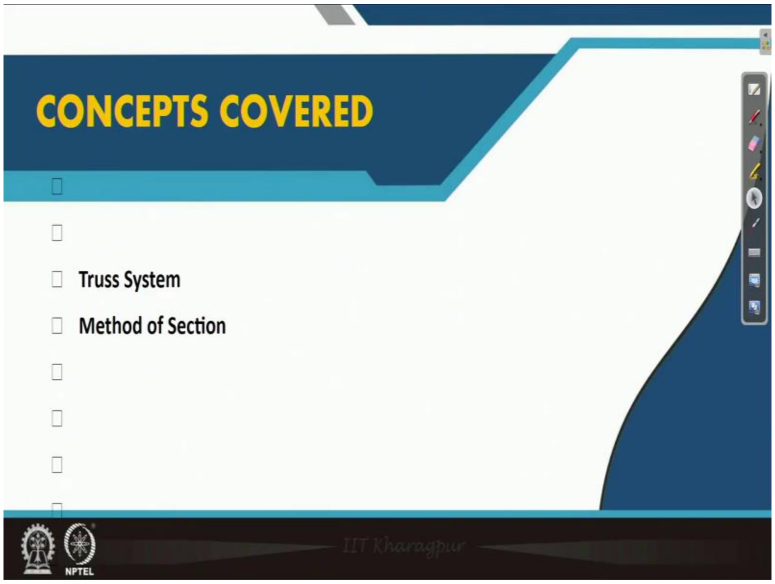

Also we have seen so with that we will get introduced this week with two the truss system method of section.

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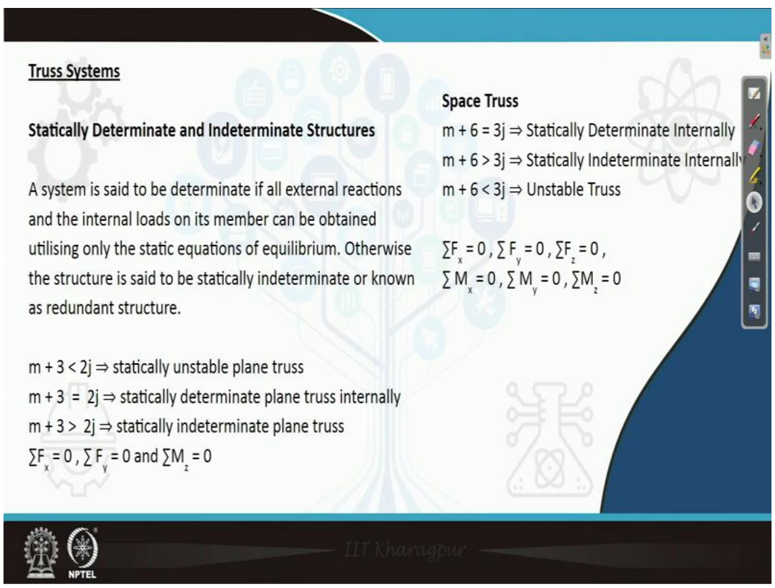

So, what we do a truss system statically determinate and indeterminate structures in this terminology determinate and indeterminate structures. This is very frequent in case of truss structures. So, it is easy to determine which is determinate which is not inter determinate or indeterminate. A system is said to be determinate in all external if all the external reactions and internal loads on its members can be obtained utilizing only the static equations of equilibrium.

See here we mention internally and externally, internal loads and external reactions otherwise the structure is said to be statically indeterminate or as redundant structures. In case of planes truss we usually have three equations equilibrium equation that is the reason and number of unknowns are in, so total number of unknowns are m + 3. And we have number of equations as number joints multiplied by 2 if it is less than that it is unstable plane truss we say if it is more equal then it is statically determinant.

Plane truss internally we say internally because if the number of reaction is more than it is externally indeterminacy it is 3 if it is internal indeterminacy. So, if it is more it is indeterminate plane truss. So, the three equations of equilibrium as we have seen many of you are already introduced so we are not going to spend much time on it. If you are interested about it please refer to many mechanics books many books are available to show it.

Similarly for space truss the number of equations has 6 as it is described at the bottom 3 equations of force and 3 equations of moments and similar way it is internally determinate it is indeterminate and if it is less than it is unstable that means the truss is not supposed to be our load it is to collapse.

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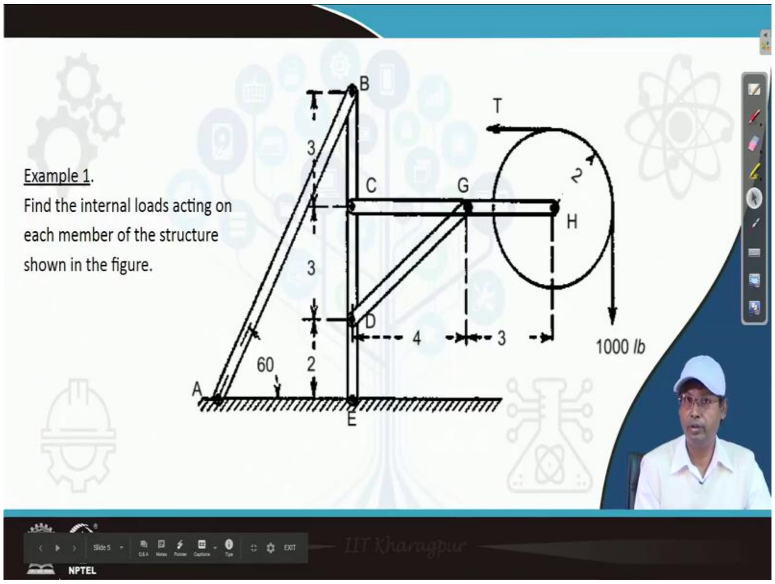

So, it is always desirable to study a truss structure with example method of joints type of we will study this week. Two examples who will do this is one example it's a very famous example we have a consider the requirement are to be found out is internal loads. Internal loads acting on each member of the structure shown in the figure. So, somehow there are loads T equals to this is acting one hundred pound is acting on it this is freely rotating disc attached at the end of the this horizontal bar CH and there is one more system which is supported here.

And one more link bar is there that is say that another two Force member is there what is to force member also we will see.

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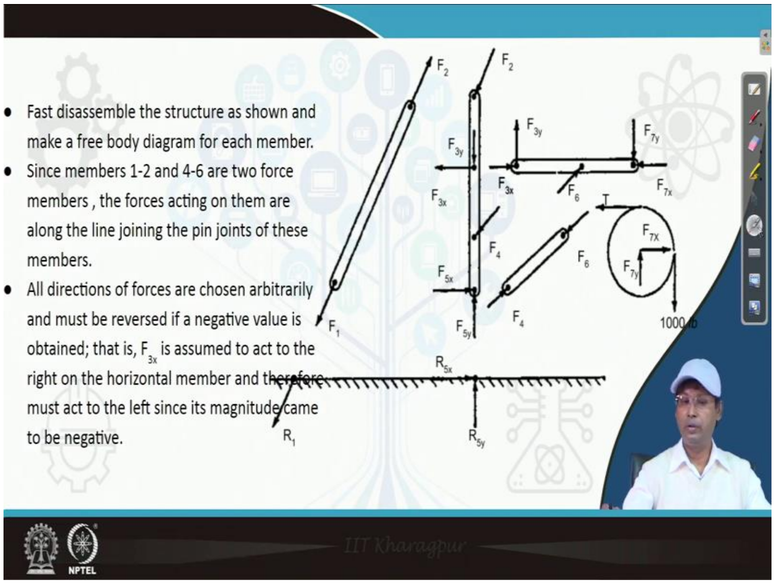

So, fast disassemble the structure as shown we have disassembled it or in more better way we say it is a free body diagram. They make a free body diagram for each member since member one two and four six this is four six, this is one two. Are two force members the forces acting on them are along the line joining the pin joints of the members Since these members are only joined at the two ends and there is no other force in between this if we are able to find out one.

It is a two force member so if one is known the other is automatically known so that that is the way the free body diagram is shown here and that way it reduces to 3 reaction this one this one and this one. So, we need to find out external reactions and also we need to find out the internal loads developed in the member. All directions of forces are chosen arbitrarily and most must be reversed if a negative value is obtained that is F_{3x} is assumed to act to the right on the horizontal member this way and this way

And therefore must act to the left since its magnitude to be negative. So, this will come later so we will see if it is required we may need to reverse or considering the same direction putting the negative value we can easily solve that problem. So, all the forces here two components are there from this point as it is you see F_{7x} is acting this way here. The other way it is acting here F_{7x}, F_{7y} is acting this way upward it is acting downward here and at this point.

Similar way F_{3x} is acting this way there is a reason it is acting this way we are assuming all these joints are pin joints that means the it is free to rotate and it can have since there here we have two components it has two components here only we have one component that is why it is two force member. Here also only one member that is why it is a two force member.

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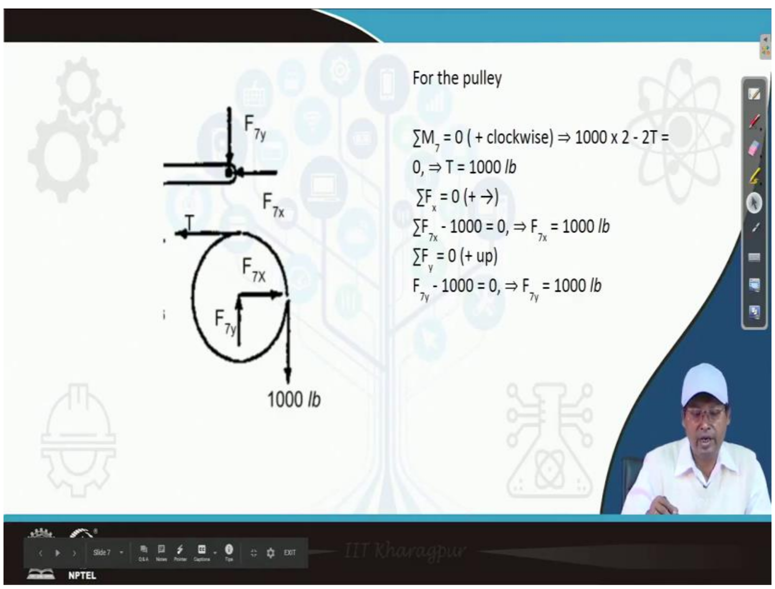

So, we have a consider the free body diagram for solving from one side that is the general approach of solving with method of joints. What we have done we have separated out the disc and let us see from one to other equation how do we solve the problem. For the pulley summation of moment we have considered about this point clockwise is considered positive.

Dimensions are not given here also this is the two 2 feet three 3 feet 4 feet and these are also in feet changing. So, that is the reason to was coming there and while what we see that 1000 multiplied by 2 is equals to minus of 2t again 2 multiplied by, so tension in the cable is 1000 pound you will consider summation in x-direction we get the F_{7x} this equation I guess it is a typographical mistake I hope you will get it F_{7x} - 1000 is equals to 0 if I cut this then F_{7x} - 1000 is equals to 0 here.

Similar way we get there F_{7y} the component in y direction is equals to 1000. So, once we know this we will take these forces here and we will go on solving the other components.

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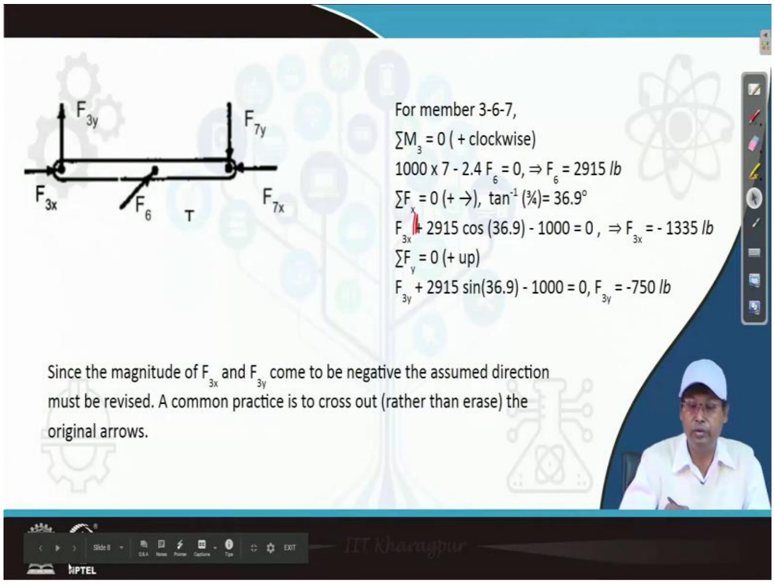

So, that is the reason the free body diagram has come in this slide. So, in this slide as we have considered that two force member F_6 is acting here in this direction but one thing we need to know is about the angle that is solved here tan inverse 3 by 4 is equals to 36.9 degree. This 3 by 4 is from the geometry is already in taken. So, first to consider moment about 3 about this point we are considering moment and this 2.4 is already calculated.

The distance between this length so 1000 is 7 is this distance is 7 and then this is passing through this point these two are also passing through this point so the no component of these three forces are coming only F_{7y} acting downward this is acting this way the perpendicular distance is 2.4. And accordingly if we solve the equation we get the F_6 equals to 2915 pound. So, similarly if we consider the equilibrium equation in the x direction this 2915 pound of F_6 whatever we have got that cost component of this, this is the angle.

Whatever we have found out if F_{3x} this direction plus this is also acting in this direction minus this F_{7x} this 1000 is considered so this gives us the equilibrium equation in the X direction and we get that F_{3x} value ad as minus 1335 this is what was mentioned in the first slide it is negative. So, either we may continue solving considering the arrow otherwise other direction or with the help considering this as a negative force keeping the direction same we can continue solving it.

In the Y direction similarly if we get the sine component will come of the same force and we get the vertical direction force as F_{3y} is equals to minus 750 pound. Since the magnitude of F_{3x} and F_{3y} comes to be negative the assumed direction must be revised. A common practice is to cross out rather than erase the original arrow this is that is what we I mentioned just now we may keep the arrow same with keeping the force in the other direction or we can change the arrow.

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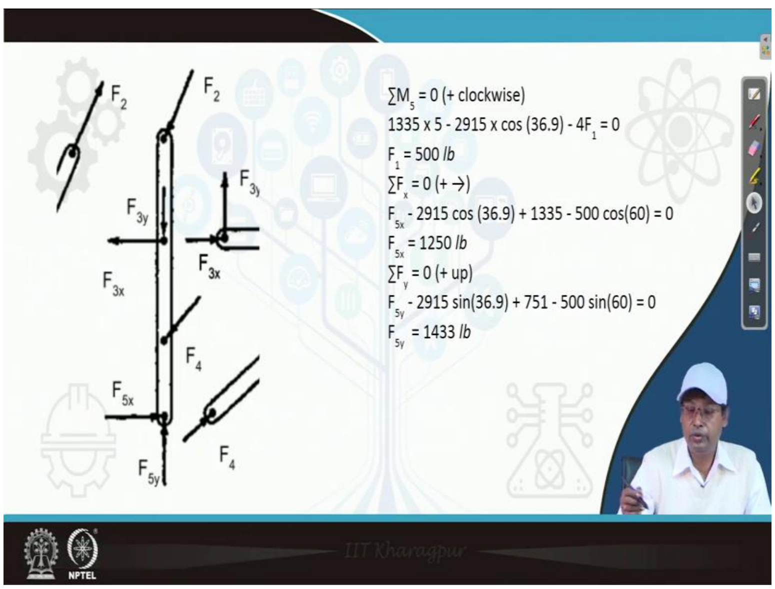

So if we come here in the next vertical member forces equilibrium of that process this F_6 ; F_4 and F_6 are same since there are two joints that is why at two points this is named in this way so F_{3x} you see is considered in the same direction so we are supposed to put the negative value. So, we are considering moment about 5 this point so what are the forces will come. This forces are known this force is known this is the force only unknown forces this F_2 .

Again this F_2 here it is written F_1 actually this F_1 and F_2 are same because it is a two force member. So, it may be written either as F_2 or it may be written as F_1, so from there considering that same equation what do we get is that if F_1 is equals to 500 pound. Now considering the summation of forces in the horizontal directions please keep in and keep it in mind in our drawing it was mentioned that this angle is 30 degree and the other angle if we complete this, this angle is 60 degree.

So considering the X Direction force equilibrium what we are going to get is that a F_{5x} the reaction here we write the equation this way a F_{5x} - 2915 cos 36.9 + 1335 - 500 cos 60 = 0, so see this is positive, though it is on the other direction positive is put because of the negative force found and accordingly we get the value of the 5 reaction 1 of the reaction F_{5x} which is 1250 power.

Similarly if we consider the equilibrium in the Y direction same manner the sine component comes and sine component of this force comes and the seven people the other two forces components of what are coming. And we get the value of F_{5y} is goes to 1433 pound. As I was made I have mentioned previously now you see that this is to force member that is why F_1 is equals to F_2 , F_4 is equals to F_6 .

Now all internal loads have been obtained without the use of internal structure as a free body. The solution is checked by applying the three equations of equilibrium to the internal structure. So, considering the entire structure as a whole these three reactions can be found out so that is what is done. It is said that instead of finding out the equilibrium equations for the whole structure is found its calculated and it sums up to equals to 0.

In the Y direction also if we consider this also comes as 0. And if we consider a moment about this point that also comes as equals to 0. The equilibrium check should be made wherever possible to detect any error that might have occurred during the analysis. So, this is a simplified very simple example to get introduced with the method of joints sorry yes method of joints. The next example what we will be solving is a introduction to the method of section.

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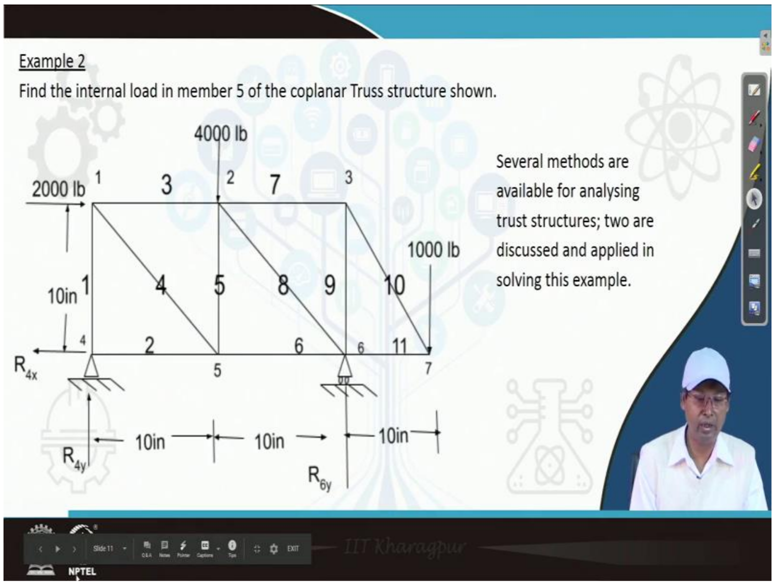

So, and let us see how do we solve? This is one example this all these are liquid spaced 10 inch distance this is a truss member all these joints are pin joints we always assume sometimes we show sometimes we do not show. So, this is pin joint that is why there are two reactions this is roller join that is why there is only one reaction. This is acting upward and we need to find out member forces you please keep it in mind these small scripts are the right numbers 1, 2, 3, 4, 5, 6, 7 and this big font number whatever is there this one these are the member number this number is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11.

This is even 10-inch there is a horizontal force acting here on this joint 200 pound, 2000 pound one vertically downward force is acting. Here at joint two as for four thousand pound and at joint 7 there is a there is a load acting as 1000 pound what we need to find out we need to find out member force this, find the internal load in the member 5 of the coplanar truss structure shown. So, that is what we have already discussed that we will be solving mainly the plane trusses or the coplanar truss structures which does not have any other any member away from the plane of the other members so considering that we will solve this problem.

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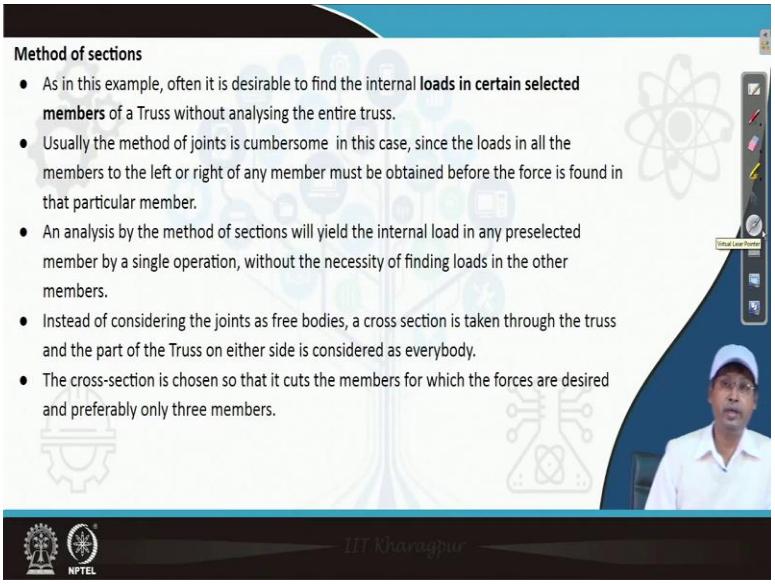

Method of sections as it is said here as in this example often it is desirable to find the internal loads in certain selected members that is why the method of section is more popular. While we do not need to find out all the member forces in those situations method of method of session is much more popular of a truss without analyzing the entire truss. Usually the method of joints is cumbersome in this case.

Since the loads in all the members to the left or right of any member must be obtained before the force is found in that particular member. In method of joints if we follow we need to need to find out all the member forces, previous to the member force what we want to find out that is the reason this is more popular. An analysis by the method of section will yield the internal load in any pre-selected member by single operation without the necessity of finding loads in the other members.

Instead of considering the joints as free bodies a cross-section is taken through the truss and the part of the truss on there on either side is considered as free body. So, this is the key we need to choose a section that section is not a desirably a straight line it can have can be a curved section also but the either side as a free body. This is free body considered as a free body the cross section is chosen.

So that it cuts the member for which the forces are desired and preferably only three members are cut. So, this is a trick to cut only three members but many times it is not possible to do and such examples if time permits we will follow.

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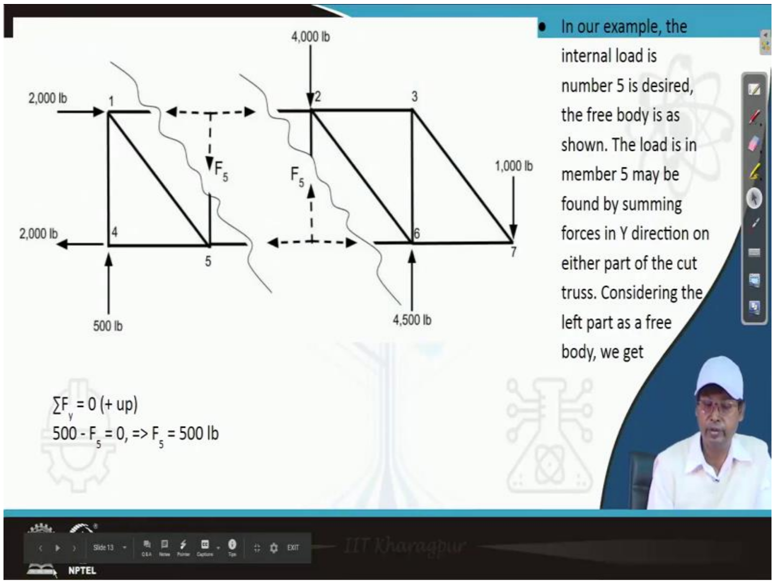

So the truss section what we have considered here is this one as it is said preferably three members to cut that is what is cut here if we look at this member this member and this member are cut. And what we have we have we need to find out the external forces before we come to the method of section. Finding out external forces we need to solve the equation that you may do as a homework or maybe why we will be solving the same problem using method of joints there you can you can learn how to find out the forces.

Considering the whole structure as a free body and then considering moment about this point if we consider then we can easily find out this vertical force. And the other way if we consider the other two equations once this is known if we consider equilibrium in the vertical direction that will give us this reaction force. If we consider equilibrium in the horizontal direction that will give us this reaction force.

So once we come to know these reaction forces we can easily apply the method of section and continue. In our example the internal load in the member 5 is desired, the free body is as shown. The load is load in member 5 they may be found by summing forces in y direction on either part of the cut truss. Considering the left side as everybody we get so this side is considered we are considering the equilibrium in the vertical direction so if we consider this way the unknown force this is acting in this direction, this is acting in this direction. So, if we are considering this equilibrium what we get is that these two are horizontal components.

So if we simply consider the equilibrium in the vertical direction the Y direction that gives us as the solution F_5 is equals to 500 pound. So, it is that easy to find out using method of section. But in our next lecture we will see how difficult how time-consuming it is to find out using method of joints. But method we need to learn both the fast process to do because we some these method of sections sometimes is not very good in case of 3 dimensional truss.

Having a section in 3 dimensional truss is very, very difficult and in those cases method of joint more useful and we need to follow this that method of joints more vivid way and we that will be covered in our next lecture.

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So, with this consideration let us end today's lecture and with this lecture there are standard references what we have already seen earlier also. Applied elasticity by one analysis of your cuff structure and introduction by Donaldson analysis of design a flight structure by Bruhn by

Ravello theory, Theory analysis of flight structure the aircraft structure for engineering student might mention Peery and Azar aircraft structure Wesley Peery and Azar aircraft structure but amongst these books the most popular and most useful books are this Bruhn.

This Megson this Peery and sometimes we have also considered this Bruhn, later classes we will consider Donaldson also you have used to some extent and any book of aircraft structure is always useful for learning.

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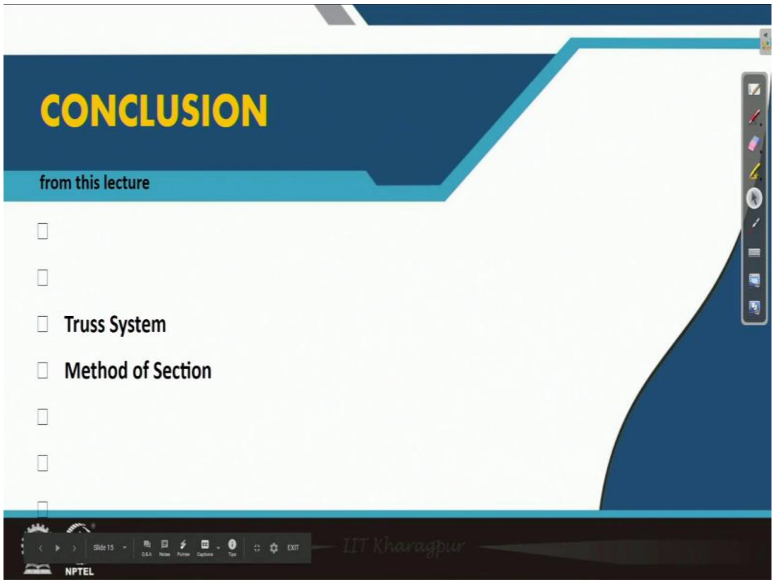

So, what we have done in this with more stress is the method of section and we have seen that we if we choose a section in a very wise manner. With experience we can easily find out any member force without much difficulty without much effort putting on it. So, this is a very intelligent way of finding out but it requires experience to do. So, with this lecture thank you for attending this lecture and we end today's lecture you please come back in our next class with method of more detail of method of truss, thank you.