Engineering Mechanics

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Statics – 2.6

[Student: Sir I have two questions. Most of the practical trusses if you see, the self-weight will be considered. So in that case how to proceed in analyzing the forces in the member] If the weight of the truss members have to be considered, how will you go about doing that? [Student: suppose one truss will be like this] so let's take [Student: if weight is considered how to proceed for that] good question [Student : this is one question and the second question is like suppose one bar is with self weight as well as it is subjected to external force] hinged on top [Student : hinged on top. So how to proceed for this] it has self-weight also [Student: it has self-weight also] the two questions are actually related. If I answer this question, this question can be answered.

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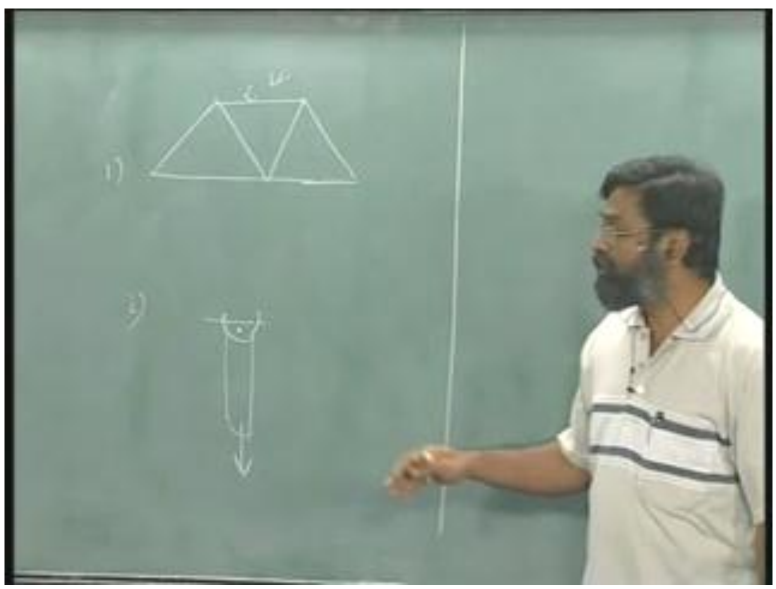

It is usually such that when you design the trusses, the weight of members may not be as negligible. How do I consider the weight of the members also in my analysis and therefore in design? A simple way to go about is supposing I take this particular truss, let's say its total weight is W. Let's say this is A, B, C, D and E let's say. So W_{AB} let us consider and ask the question it is in between, so it will pose a problem. We will assume that the weight is not very high compared to the external loads that are applied.

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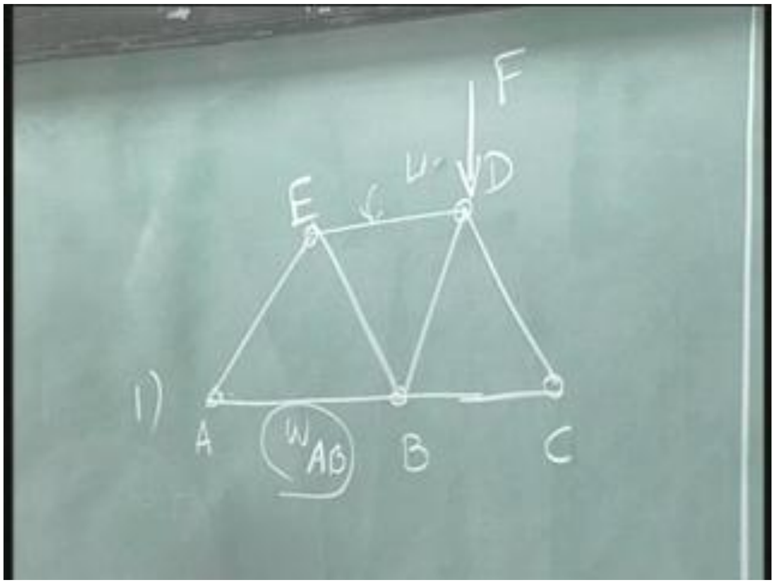

In that case what you can do is you can take this weight divide by two and equally divide among the two nodes of the member. For example if this is AB and it has a weight equal to W_{AB}, if these were hinge supports then I will have reactions coming on it and these are equal to each other because the weight is in the middle. Therefore this will be W_{AB} by 2 and W_{AB} by 2. So that when I have to consider this weight, what I will do is I will remove this, distribute them equally among the two nodes A and B as W_{AB} by 2, W_{AB} by 2. You can do this for every member, for example for this member, I will have again W_{BC} by 2 coming in here, there will be a weight here, this is W_{BC} by 2. I will have to add the other two which is W_{BD} by 2 plus W_{BE} by 2 for this particular node.

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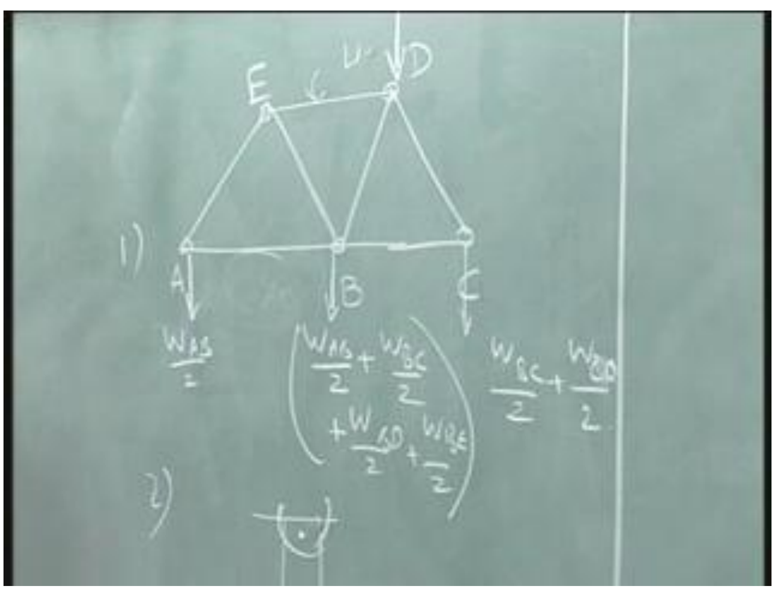

Similarly for C I have two members and therefore the weight of those two members have to be considered. I may just use the notation that I introduced earlier in an alphabetical order. So it is as simple as that. This will give good enough answers in most of the cases. Mind you when you look at this particular truss member, it is no more an axial member. It will also have some bending, so it is a beam but connected through hinges in a way. Coming to the other problem, so once I pushed the values of the weights to the nodes then it is a regular truss problem that I have to solve. Looking at two. Two is also simple, I have something like this, pretty simple.

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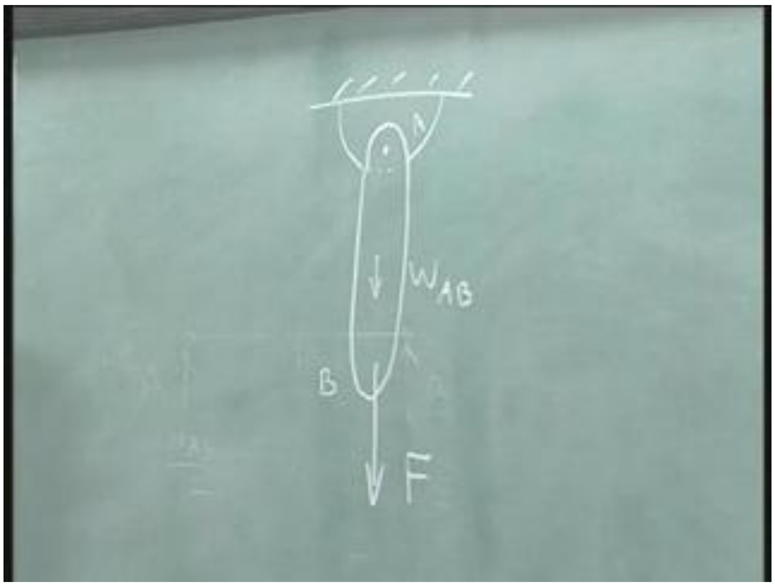

If I have a force F acting on it, also the self-weight let's say this is AB, self weight is W AB. We can do very similar to what you have done here, in order to consider this like a truss member. Let me just make it a little more complicated and ask this question. This is the pet question of mine. I have to introduce certain doubts in the mind which eventually can be addressed. Let's say I have a link, another link both are attached like this. Let's say I have these two links attached like this and there is a force acting on this. Venket can you make one like this and give me, so that I can demonstrate, 2 members like this. Now this is a very simple problem.

All I need to do is I know this is an axial member and therefore there is a force acting here, force acting here. They have to be equal and opposite because this is like an axial force member or a link member and similarly the other one let me call this as A B C. This is BC and for AB at this node, there is an equal and opposite reaction which means this will be F and this will be F. No problem whatever. So let's look at this particular problem, a little differently. So you just made one like this for just illustration purpose.

There is a force acting at the end BC, so this is A B and C. So if there is a force acting like this downward, then I can resolve like this. What if there is a force acting like this? What really happens is if I hold it like this and pull it like this, you can see that the force automatically moves the member along the line of the force. Let me make it even more difficult. Fine, this is the way it is.

Now instead of a force acting downward like this, there is a force acting upward like this and if I ask the question what is the force in the members. That's not very difficult, I just have to put this force in the opposite direction F, equal and opposite which means it will be acting like this, equal and opposite which means it is acting reverse. Problem done, but if you notice carefully, if I apply that kind of force, it is perfectly all right as long as it is along the axis of both of them. But if I apply a little inclined way, it starts to… You can see it just goes. As long as it is completely axial there is no problem but even a small angle is enough for it to collapse or in other words a small angle is enough for it to become a mechanism.

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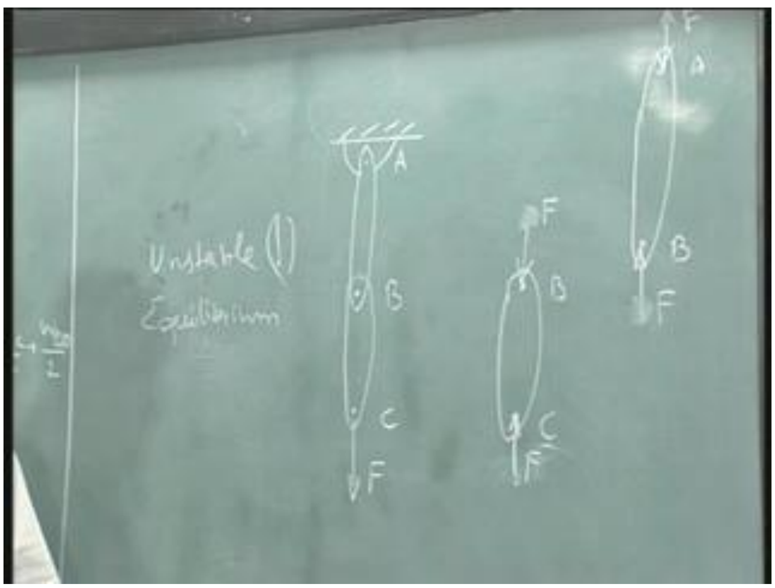

But how is that I am able to solve this problem? Is it in equilibrium? Definitely yes, it is in equilibrium but the problem is it is not in stable equilibrium, it is in unstable equilibrium. Supposing the force is in this direction, there is no problem it is stable equilibrium. The moment the force is in the upward direction, even though I can solve for the equilibrium, please remember if there is a slight movement side ways immediately it will become unstable. Therefore please remember that a problem for equilibrium may be to do with unstable, stable or neutral equilibrium. This is a perfect example of an unstable equilibrium. A ball rolling on the ground is in the state of neutral equilibrium, if this is the mass I will still be able to find out what will be the reaction on that particular rolling ball.

Another interesting example is this which is a wheel. This is a wheel and let's say it is rotating with an angular velocity omega. At this point can I find out the force acting on this if this is an axle. For example, I am just going to make it a little easy to realize. Let's say it is hinged on an axis and this is rotating with an angular velocity omega.

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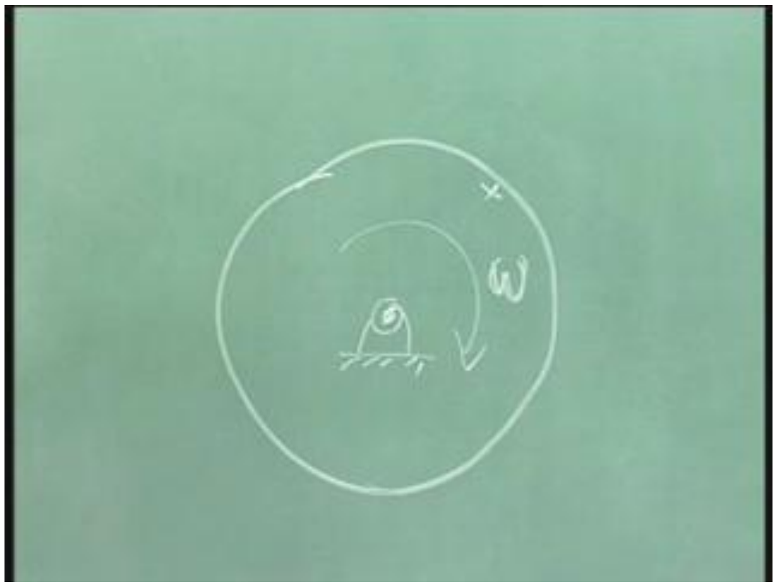

Since it is rotating at an angular velocity omega and this is a point on which the support is existing. Can I solve this like a static's problem? The answer is yes but please notice that any other point that you take apart from the centre will undergo an acceleration. You have m omega square r that comes into picture. Await, there is an equal and opposite reaction goes by the body and therefore this particular particle is in equilibrium of the body or in other words if I take any other point on this, it is actually accelerating. But this is a problem where I could simply solve like a static problem and if this is very similar to the rolling bar that we have introduced over here. Please remember that it can be a stable equilibrium, unstable equilibrium, neutral equilibrium. As long as there is an equilibrium or in other words there is a statical notion that I am able to bring, it is possible to solve for the forces.

Another important thing to note is how do I know it is stable or not? It is like asking the question how do I know a person is sleeping? What do I do? I go find out whether he is responding to it or just tap a little bit, checkup. So we disturb the person to a certain extent to find out whether the person is sleeping. Very similarly here I will disturb this a little bit, just move the force this way, that way. Find out if it is coming back to the configuration that I have. If it is so, it is in static equilibrium. If it is not, but still it is holding in place, it is in neutral equilibrium or if it is applied upwards as you have already found out in this particular example, slight change and if I push it becomes a mechanism or in other words it is no more in static equilibrium. We have a truss like this, if you look at it quite a few members are there.

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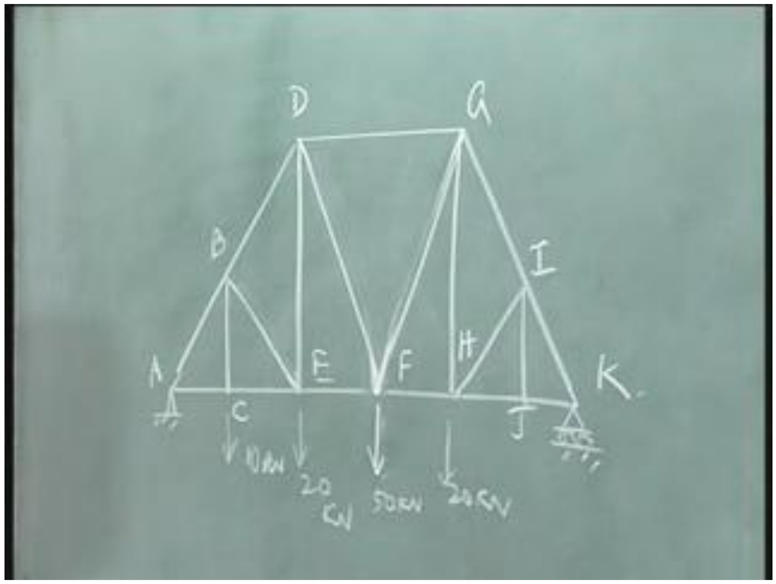

This is a truss in which you have small members like this connected to these bars and there are some forces acting on that. I have just numbered all the joints. All the joints are pin joints. Now if I ask the question, are there any members in this which are members with no force at all. We call those members as zero force members. Let's examine and find out whether we have zero force members. We notice here 10 kilo Newton force acting at C and you have a bar over here and 2 bars over here. Let's examine this particular node. If I had taken a section of this joint, I would have revealed the member forces. I mean just write them down, this is JK, HJ, IJ.

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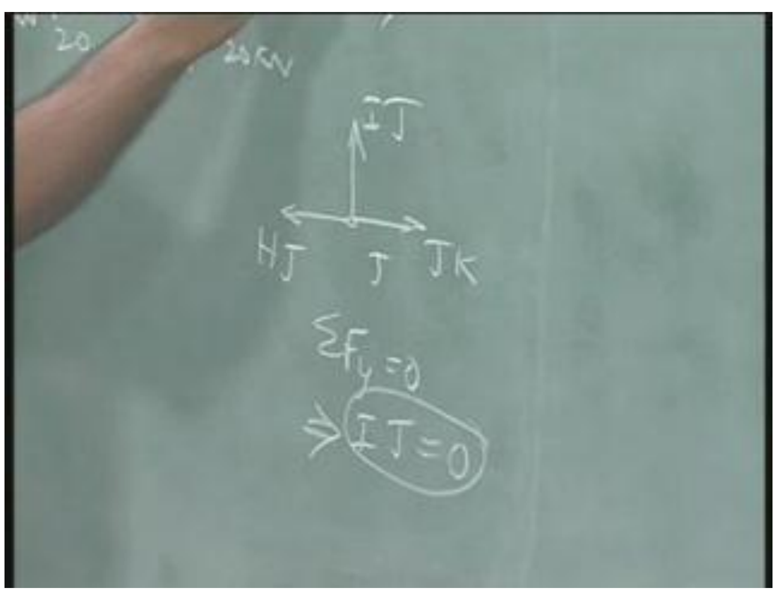

Upon examining this, immediately one would find that vertical equilibrium will involve only the member IJ. There is no external force acting on it. If I take sigma F_y equals zero for this, immediately this will give me an answer that IJ is equal to zero. So this is a zero force member. Let's say this is connected in such a way that this is perpendicular. Is this a zero force member? If I had found that IJ is a zero force member and this is perpendicular to this particular set of members K I J and if I draw the free body of this particular joint I, I have 1, 2, 3 and 4 forces revealed. Mind you I am always drawing in such a way that all the forces emanate from this joint. Now I just have to number, this is IK, IJ, HI and GI.

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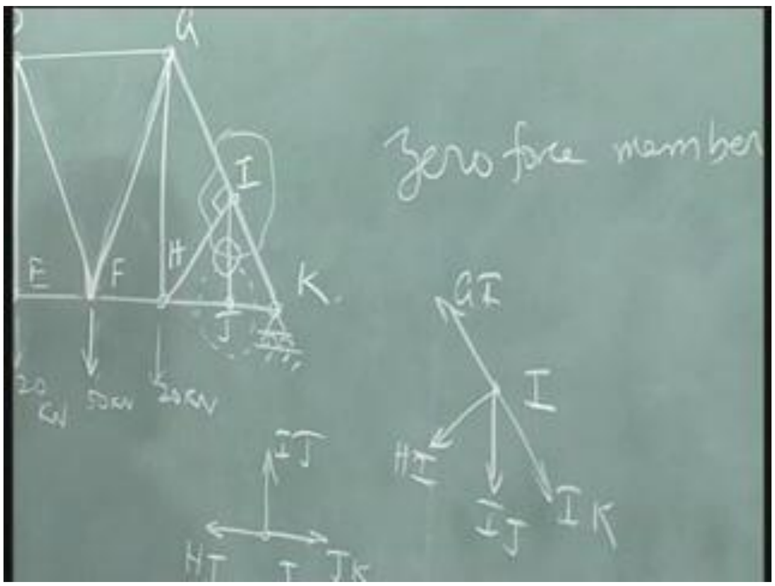

What did they do earlier? I looked at this particular joint and found that member I J is a zero force member. This is a zero force member. Let me just erase for the sake of understanding and what is this angle? This is perpendicular and if I take this as lets say y prime and this as x prime and find out sigma F_y prime equal to zero. There is only one force that will take part in it. There is no external force also. This immediately tells me that member force H I is equal to zero.

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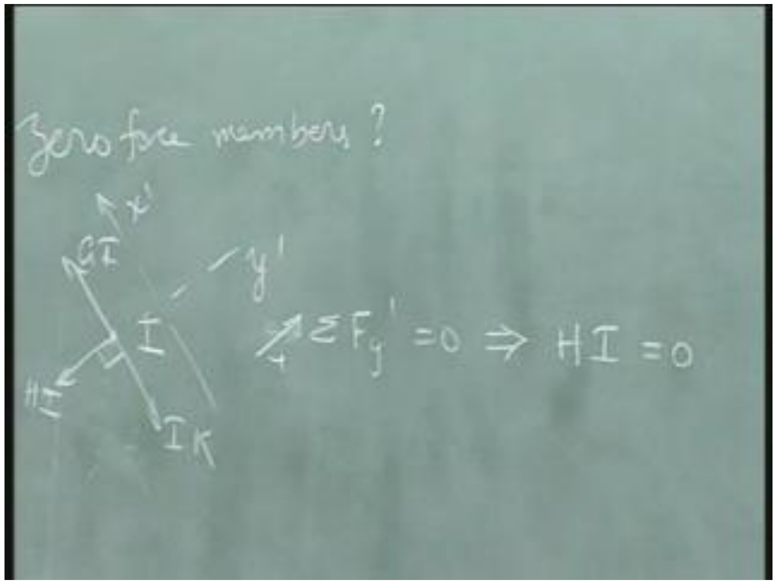

Let me use another color here to indicate, this is equal to zero. If these two are equal to zero, how about these two? Can I say anything about it? I will be tempted to say that IK and GI are equal to zero. Do not do that mistake. Remember GI and IK are equal which is a good answer. Therefore another point to note here is GI equal to IK is the other equation that I get out of this particular joint I. Like that I can proceed if this were zero, HI were zero there is a force acting on this particular node. If I take vertical equilibrium, GH will immediately be equal to 20 kilo Newton. So it is possible to solve for this which means this is a non-zero force member. Let me just put a cross to indicate that this it is non-zero force member.

Now let's look at any other particular joint that will give a zero force. If I look at this particular joint, I have equilibrium in the horizontal direction involving these two, vertical will involve these two which means this need not be zero, this need not be zero. If this is not zero, this will have a component in the horizontal and vertical directions. So unless I get something out of this, I may not be able to say anything. This is not a zero force because there is a 10 kilo newton acting. If this is not a zero, this is not a zero force and naturally if this is not a zero, this is not a zero, this is not a zero force and so on.

I can easily find out what are the zero force members. Simple but then supposing I ask this question. In a particular construction let's say these are the loads that are applied. Why would I want zero force members? This is an important question that many people fail to ask or answer. That is when you need to understand the stability of these particular numbers. For example can you give me a long strip. You can come over here. This is a long strip, let's say this is under compression. If this is under compression it easily buckles we call this as buckles. Just hold at the centre and I am going to press. When I press you find that I need to apply more force in order to get this member to be buckled or in other words, if I have to improve the strength under compression, under buckling I would want to insert a member over here that which will act to give stability to this.

A simple example that I can give is the same thing that we did earlier. Supposing I have something like this and a force is acting like this. It is already in equilibrium but it is in neutral equilibrium. In order to make sure that it is fine in this particular manner, if I have to make sure that it supports the force in a stable manner I mean probably take one more member like this and connect it to a support. A horizontal member like this, connect it to a support. If you look at this particular problem this is stable.

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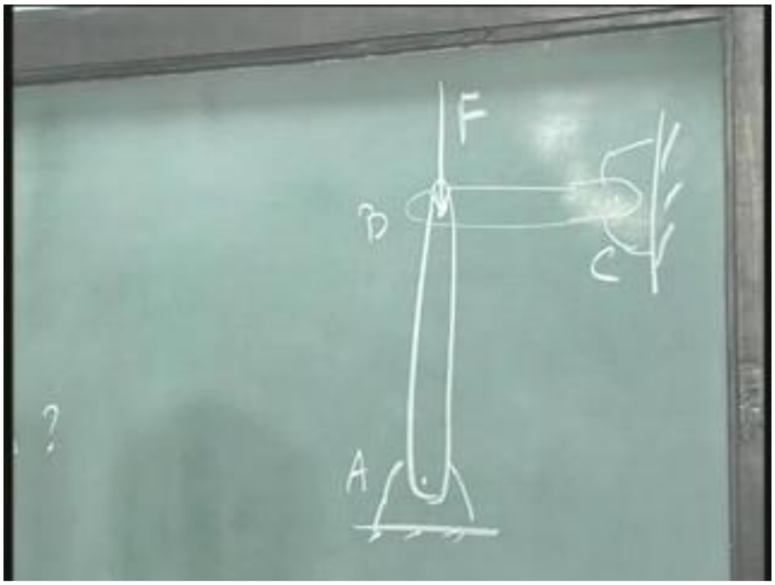

Even though the member supposing I name them as A B C, even though member force BC is zero, in this particular case its very simple to analyze just like what we did in the previous truss. If I take a particular direction equilibrium at B, for example horizontal equilibrium immediately I will know BC member force is zero. This member force is zero and this member force is minus F or in another words it's under compression. What is the action of this? The action of this is to give stability else it will just freely rotate. Many of the times in trusses you will find for certain set of forces, there will be zero force members. Most of the time these zero force members are used in order to reduce the effective length or to give stability to this particular truss. In this case I could have had a straight member like this without this.

Since these two are zero if I remove them, I could have had something like this. But remember this has become longer and if there were in compression, for example if there is a force acting on this, in fact this particular force will push it. If you analyze for the problem that is given already, you will find that this member is under compression and therefore likely this buckling is more so I would want to support it like this to a particular nearby point and this particular member I, this is joint H, I H. H I member is primarily to support the member G K.

Similarly you will find that this is under compression. I will introduce another member like this. This increases support for this particular member as well as this particular member and that's the reason why you still have zero force members in the truss and it is useful for the construction. Main reason for that is in order to introduce stability to the truss.
Thank you.