Engineering Mechanics
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Module 02
Lecture No 20
Plane trusses II: calculating forces in a simple truss and different types of trusses

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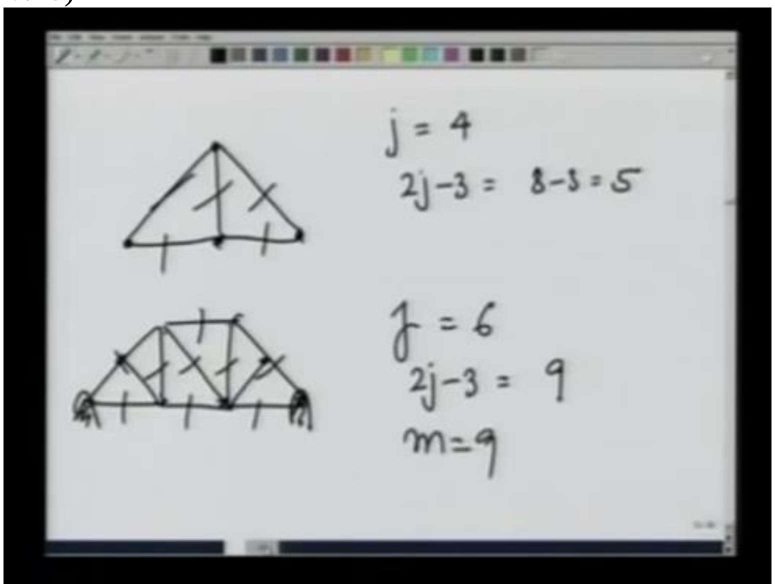

In the previous lecture, you notice that both the ants are put on a fixed point. Actually this make the system indeterminate because the number of external forces is now 4. We could make it determinate by putting the right-hand side of the system on a wheel or on roller. Let us take one example of this. And this is a very particular structure the time taking.

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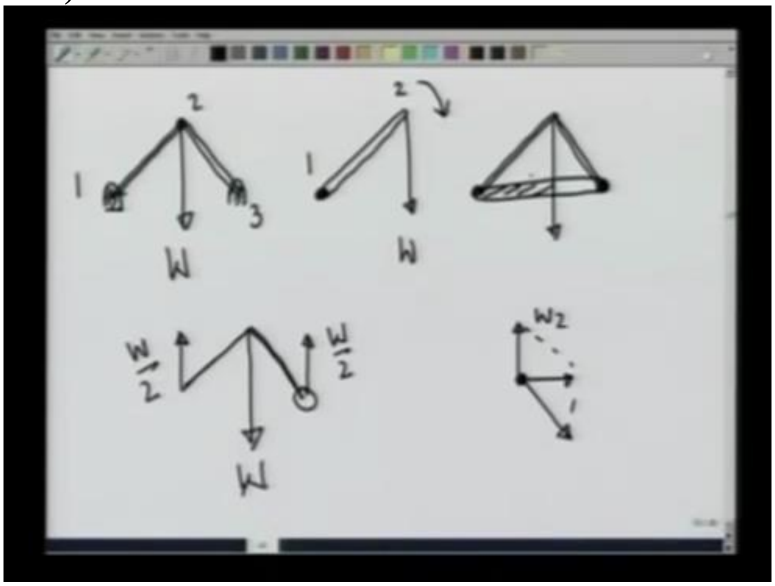

Let us take 20 and I am making it very very carefully which are at a fixed joint here, one joint here and I am loading it right here. This is just to again motivate and play around with forces and things like those in a truss. Now you see, if I start with this rod, let me call this 1, 2, 3. Start with rod 12, put it on a pin joint here and load it. The rod will tend to rotate like this. To stop that, what I do is, I put another rod here so that this is an Isosceles triangle make a fixed joint on the other side also and then load is here.

But the moment I do that, you see if I look at this structure as one, there is a load W. There will be a reaction here and in this case I know because the symmetry is going to be W by 2 here also the reaction is going to be W by 2. And if I look at this pin, pin here, from the support, fixed support outside it is getting a force W by 2 like this and it is being pushed by this rod in this direction. So the net force on this will be in this direction.

It will not be in equilibrium. To bring it to equilibrium, I add another rod here. That makes a stable truss for me. In this particular situation where the this is an Isosceles triangle and I put the load on this joint.

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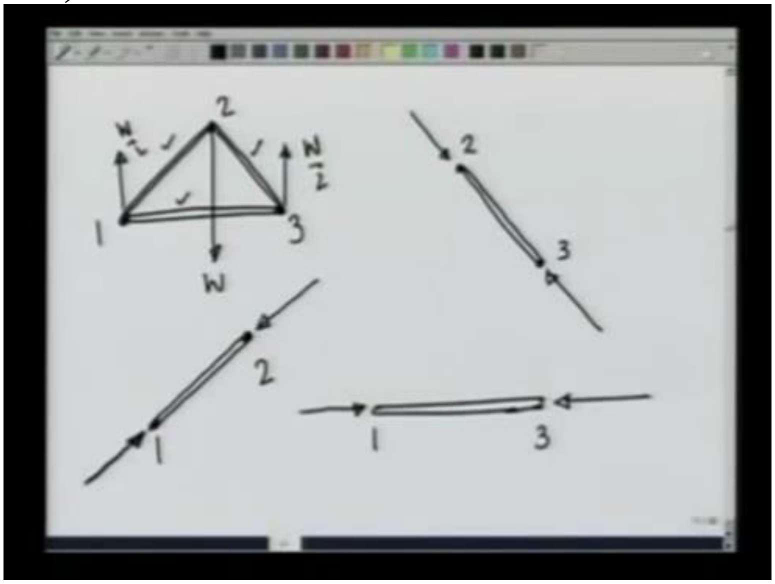

Let us analyse this further. So I have this structure here and I have already argued that I need these 3 rods to bring it, make it a stable structure. If I look at this system, there is a force W by 2, W by 2 acting here and force W acting downwards. What I want to know is what is the forces in these different rods or members of this system? So let us call this 1, 2 and 3. Let us look at rod 12. If I look at rod 12, it is in equilibrium under the forces that are applied on it by this pin here and this pin here, only 2 forces.

And remember what I said in the beginning of the lecture that if a body is in equilibrium under 2 forces, those forces are collinear. So in this case, there will be a force on this acting this way and there will be a force acting on it this way, at these 2 points. This is the only way these 2 forces can act. Otherwise the body will not be in equilibrium. Similarly on rod 2 and 3, there are 2 forces acting due to pin at 2 and pin at 3.

Again, the forces have to be collinear. So the forces have to act in this manner, 2 and 3. And on the rod 1 and 3, again 1 and 3 is in equilibrium or the rod 13 is in equilibrium. So the forces at 1 and 3 have to be collinear. Because if a body is in equilibrium under 2 forces they have to be collinear. So now we know the force directions, let us analyse this further. If all the rods are equal, then all these angles will be 60 degrees.

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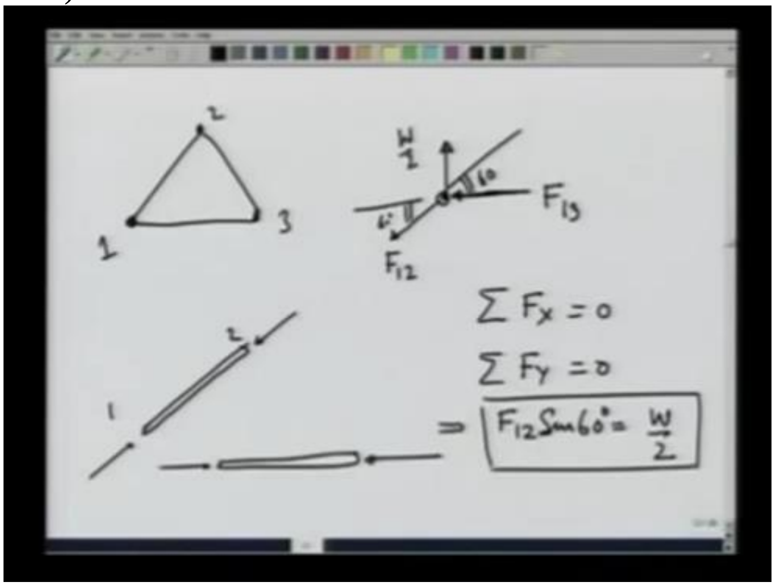

Now I know that pin1 is in equilibrium. Pin1 has a force acting on it which is W by 2. Since for the rod 12, I made forces that are pushing the rod. So the rod would be applying a force the other way on the pin. Similarly, a force on 13 that I made was also pushing the rod. That is, the force is compressive. The force that will be acting on the pin would be in opposite direction.

So let me call this force 13. This is force 12 and this pin is in equilibrium under these forces. Since the forces are acting at one particular point, I do not have to write the torque equation. Only thing I will write is that summation Fx would be equal to 0 and summation FY would also be equal to 0. This gives me that F12, this is 60 degree. So would with this. So have 12 sine of 60 degrees is equal to W over 2. And that gives me F 12.

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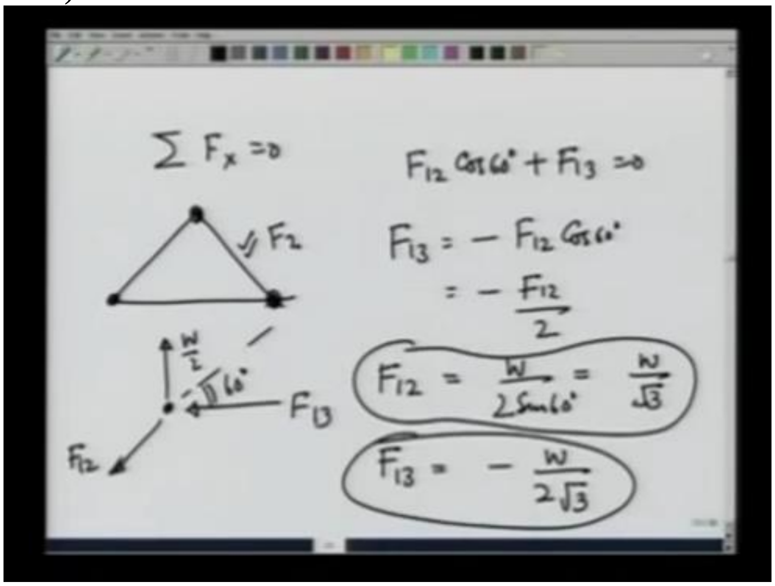

Similarly, summation Fx is equal to 0 I recall that I am talking about this pin. On this pin, there is a force this way, F 13, F 12 and W by 2. This angle is 60 degrees. I am going to have F 12 cosine of 60 degrees + F 13 is equal to 0 or F 13 is equal to - F 12 cosine of 60 degrees which is nothing but - F 12 over 2. F 12 on the other hand we found out is equal to W over 2 sine of 60 degrees which is nothing but W over root 3.

And therefore F 13 is equal to - W over to root 3. I have found the forces on member 13, I have found the force on member 12. To find the force on the 3rd member, that is F 23, I have a choice. Either I can go to this point or this point and consider the equilibrium conditions there.

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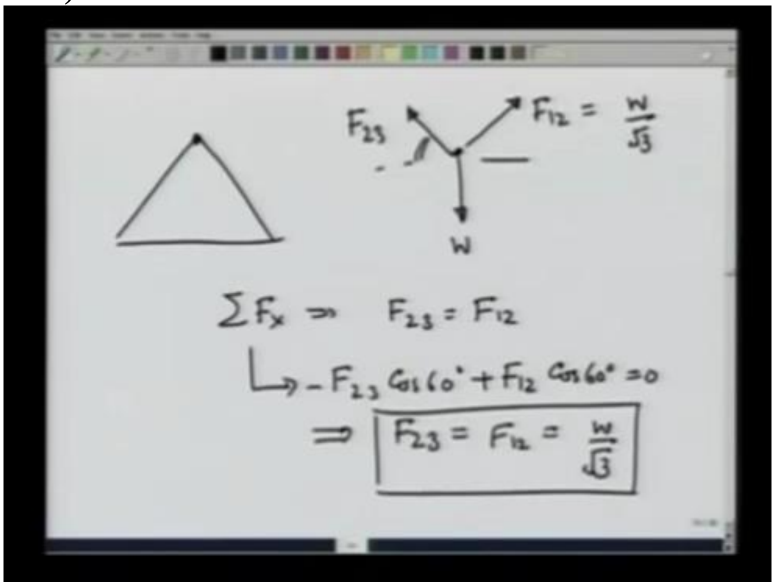

If I go to point here, then according to the way we have made forces, point 2 would be peeling a force this day which is F 23, a force this way which is F 12 which have already determined to be W over root 3 and a force this way which is W. Now summation Fx then gives you that F 23 should be equal to F 12. Of course this comes with F 23, this angle is 60. Cosine of 60 degrees with a - sign + F 12 cosine of 60 degrees is equal to 0.

And this gives you that F 23 equals F 12 equals W over root 3. So we have determined all the forces in the system by looking at equilibrium of each point.

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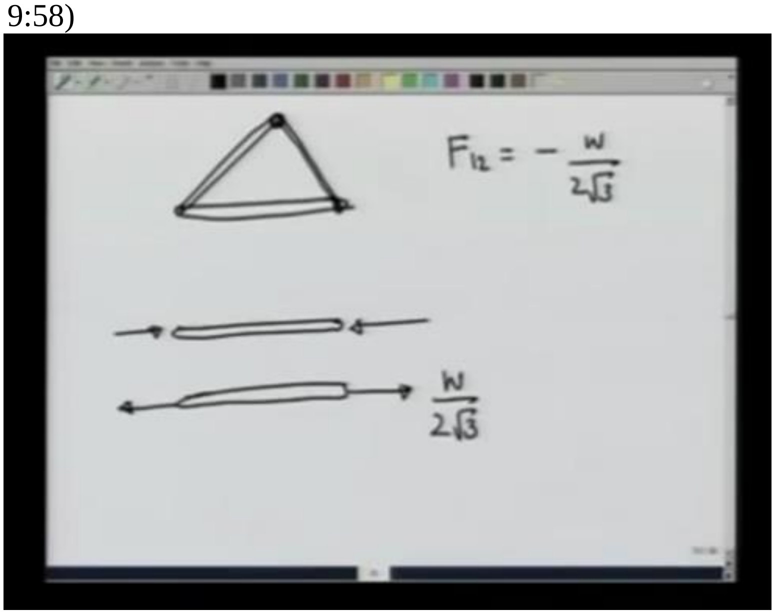

One point I would like to make about F 13 is that F 13 came out to be negative. What that means is that the direction that we had assumed for F 13, that is we had assumed it to be like this, a compressive force is actually not so. It is a tensile force. That is, the rod F 13 is being pulled in this manner with force W over 2 root 3.

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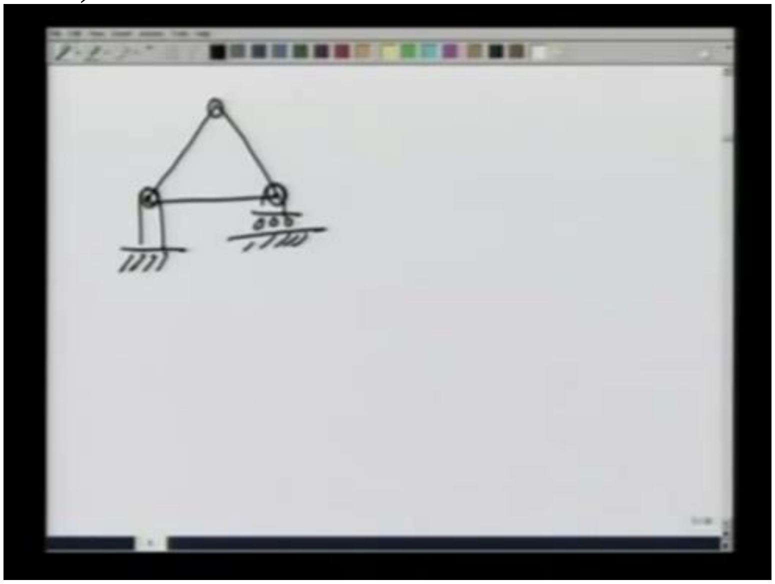

For completeness, I should point out that the triangle that we just made should actually be fixed like this on a fixed pin on the left and on a roller or a wheel on the right. This will make the system statically determinate. Through this, what I have done is, provided you an example of solving for the forces in a truss through method of joints. That is we take each joint, each pin at each joint to be in equilibrium. Now, a few subtle points about trusses.

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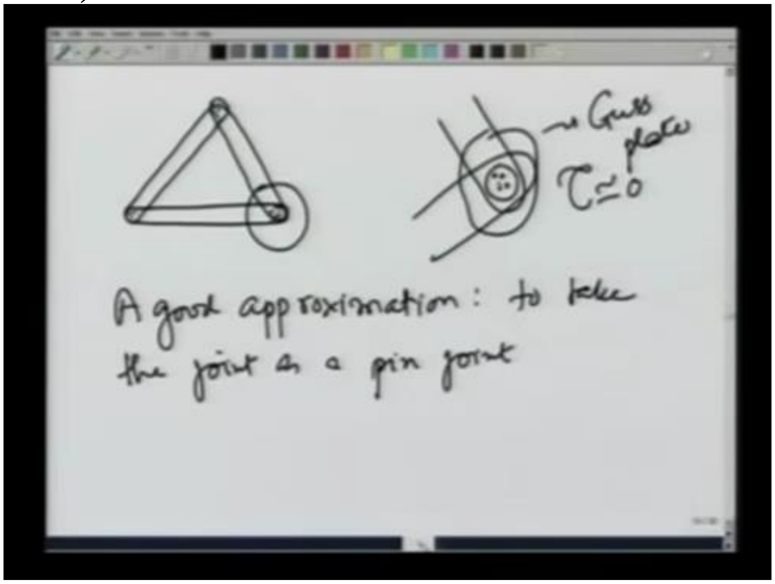

If I take these 3 rods and replace them by slightly wider members with the width of the members being much smaller than their length and instead of applying a pin joint, bolt them here, bolt them here by a plate. That is each joint here looks something like this. And I have put a plate here with bolts here. Even then, it is a good approximation to take this as a pin joint. So a good to take the joint as a pin joint.

Why? Because the width is very small and therefore even there are little forces that are applied by these bolts, the torque produced would be almost 0, negligible compared to the torque that are applied by the external force. And therefore, it is a good approximation. By the way the plate that is put here, you notice it next time when you cross a bridge, is known as the Guss plate.

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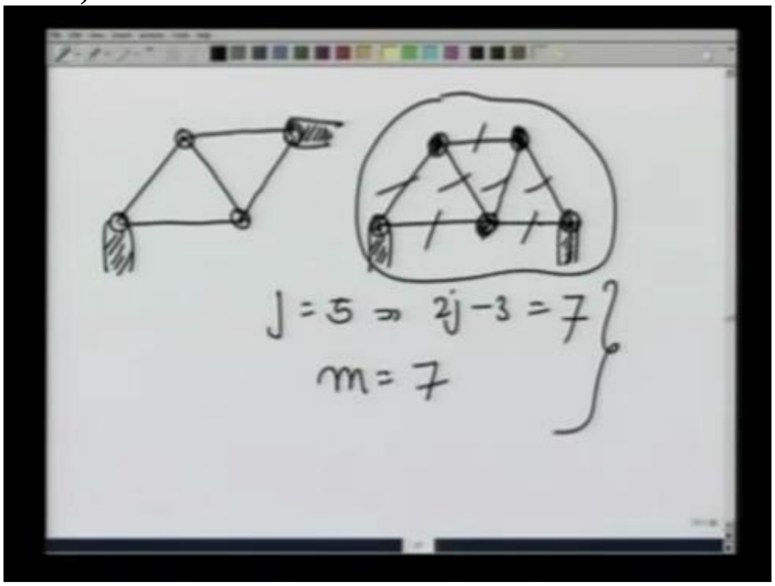

So let us see now given a basic truss like this which I just solved for, how can I make a bigger truss? Let us see, if I want to extend this further, I would apply or put a member here and give a joint here. This joint now has 3 members that can provide equilibrium. Then this point, suppose I do not want to provide a support here, I have to provide one more member and I could provide a fixed support here, a fixed support here.

That is one possible truss. Another way is I have this basic truss which is fixed here, fixed here. I do not want to fix it here now. I provide one more member so that this point now has 3 members that can provide equilibrium to it. This is a fixed point. And suppose I want to put this on to the fixed point. Then this member has one post coming from the fixed support, one from from this member.

So I have to provide one more member so that there are 3 forces acting on it. But this gives a loose end here. I could fix this loose end by putting 2 members here. Now you see, each joint has a minimum of 3 members so that this becomes a statically determinate structure. Let us see if it is. Number of joints in this case is 1, 2, 3, 4, 5. So J equals 5 implies 2J - 3 is 7. And 1, 2, 3, 4, 5, 6, 7 members.

And therefore M which is 7 provides that this is a statically determinate structure. This is capable therefore of remaining in equilibrium when loaded.

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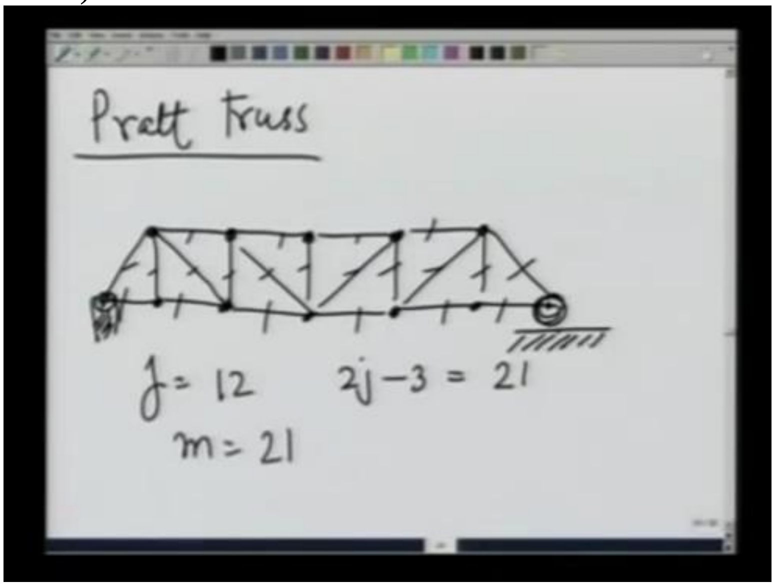

Several examples of trusses that you see in everyday life are example, Pratt truss which you see. Pratt truss which is like this. This put on the supports here and these are joints. Let us see the number of joints here are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. 12. So 2J - 3 is 21. Number of members is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21. So this is a statically determinate truss and capable of remaining in equilibrium.

These points can be fixed. On the other side either I can have a fixed pin or usually you put it on a wheel. I will comment on this a little later. Let us look at some other trusses in the meantime.

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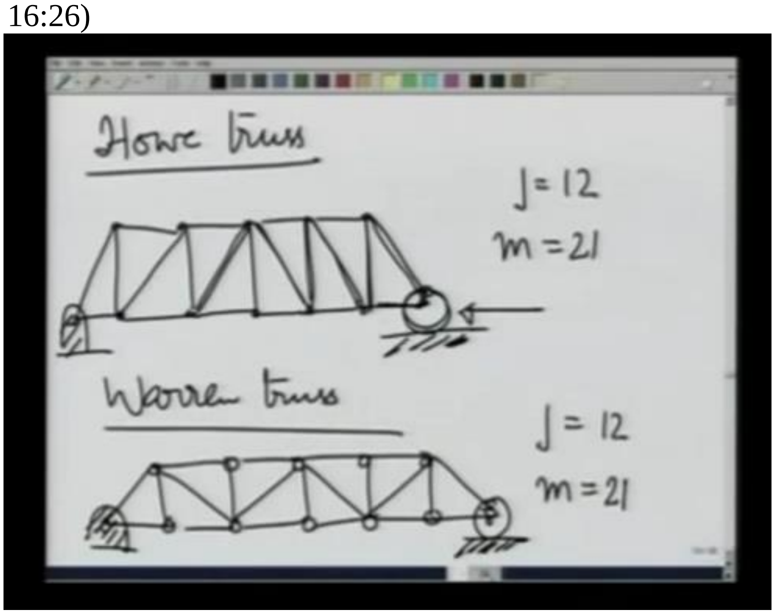

The other one is Howe truss which is like the Pratt truss except that the fixtures are other way. Again you can count the number of joints and number of members. They are consistent for it to be statically determinate truss. 3rd one is a Warren truss which is like this. So these are different variations on the way the members and joints are fixed on a truss. And this side again I put it on a roller and this side is fixed.

Again, J equals 12 and M equals 21. So they are consistent. J equals 12 and M equals 21. So they are also consistent for them to be statically determinate trusses. Why we put a wheel here or a roller here is because what we have assumed in all this is that these members are rigid members. However, in reality, they deform. And when they deform, the distances may change and to accommodate for that, we put a roller here rather than putting it on a fixed pin joint so that the stresses are not developed in these members.

Notice that even when the wheel is put instead of a fixed joint, the truss is capable of remaining in equilibrium since there was a redundant constraint on the system to start with.

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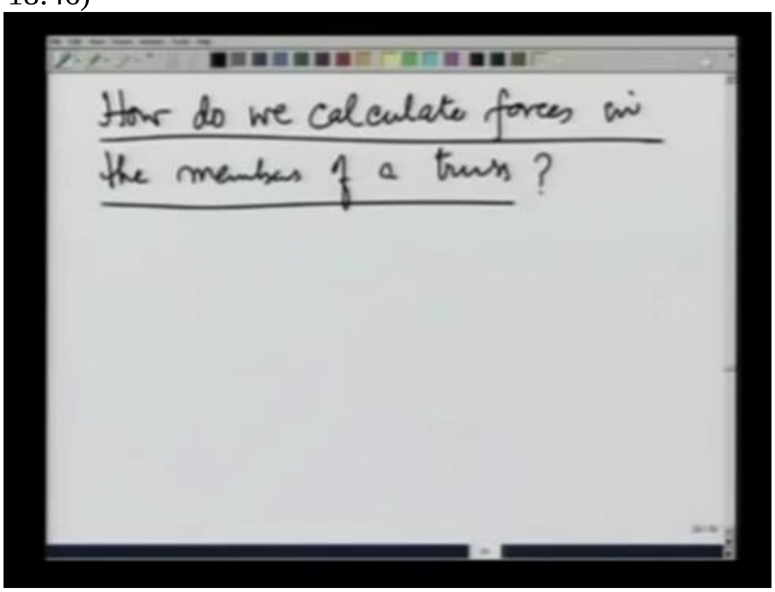

So the question that we want to answer is how do we calculate forces in the members of a truss? And that will be analysing the trusses.