Structural Analysis II

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Lecture – 09

Good morning. Last time in the last lecture, we saw how to use the force method to solve a truss analysis problem. Just to quickly review that process, if you look at what we looked at, this was the truss example we looked at.

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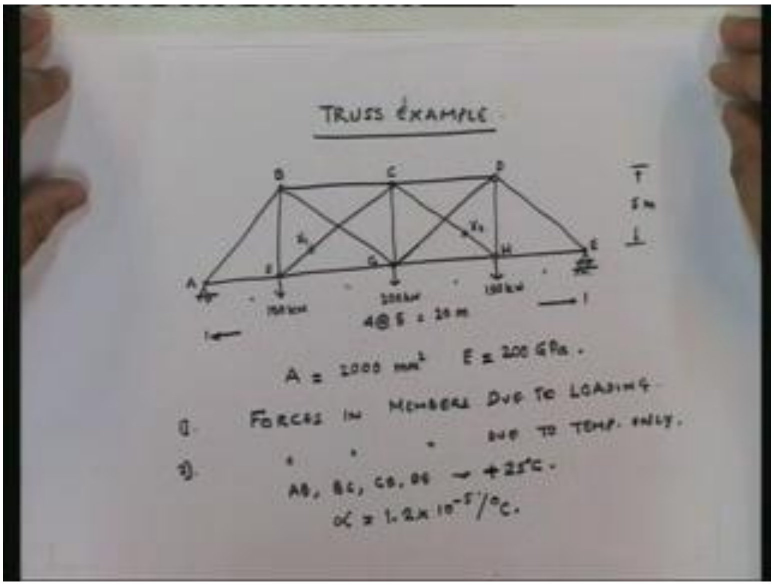

It was a four-panel truss. This was the loading and we calculated the forces in the members due to the loading. For that, we took x_1 and x_2 as the two redundants and then we went ahead and found out the forces in the base structure that is, without these two, both being 0, we found out all the forces in all the members, then we applied x_1 is equal to 1 and x_2 is equal to 0, found out the forces, applied x_2 is equal to 1, x_1 is equal to 0 and found out the forces and after that, we put all of those values that we computed in one table; then, from that table we computed all these various parameters.

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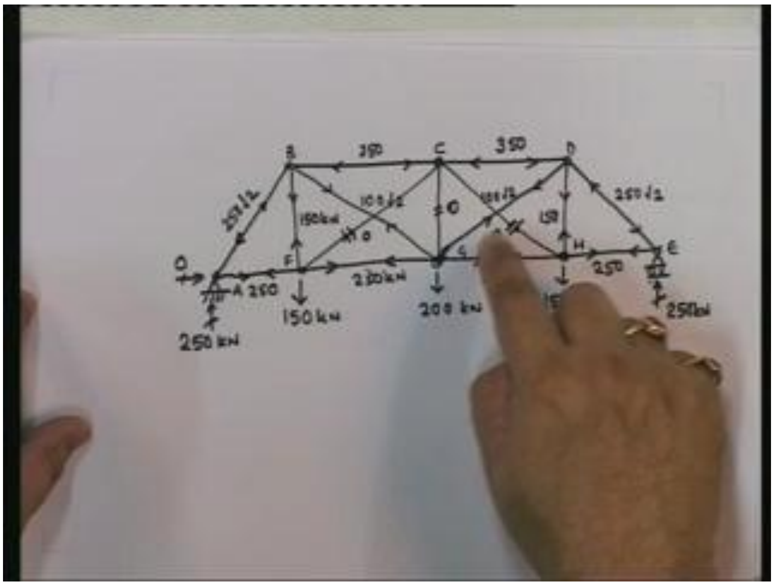

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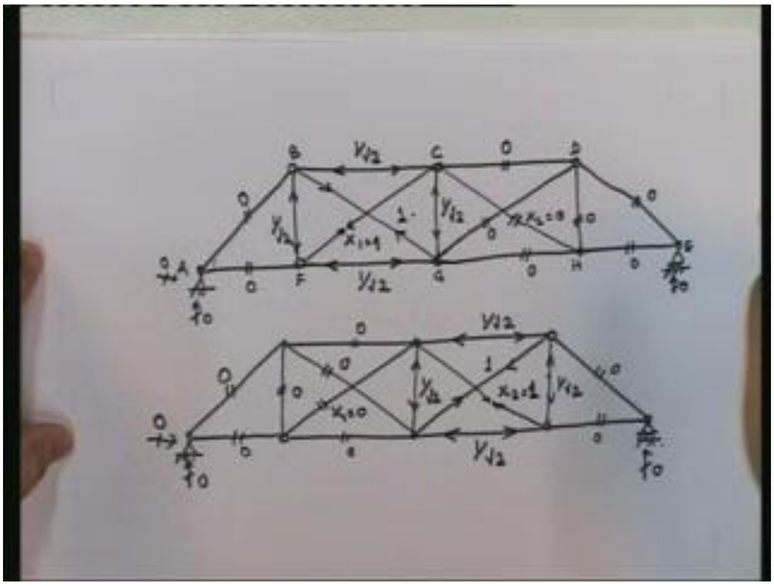

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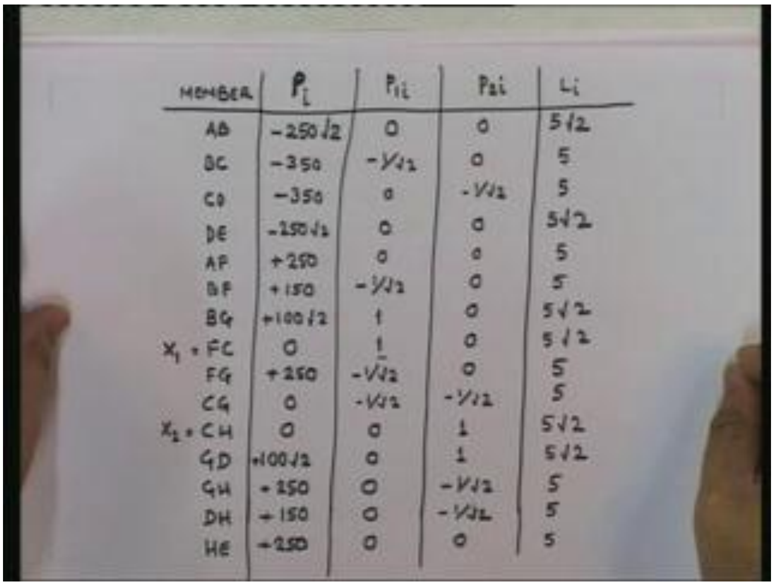

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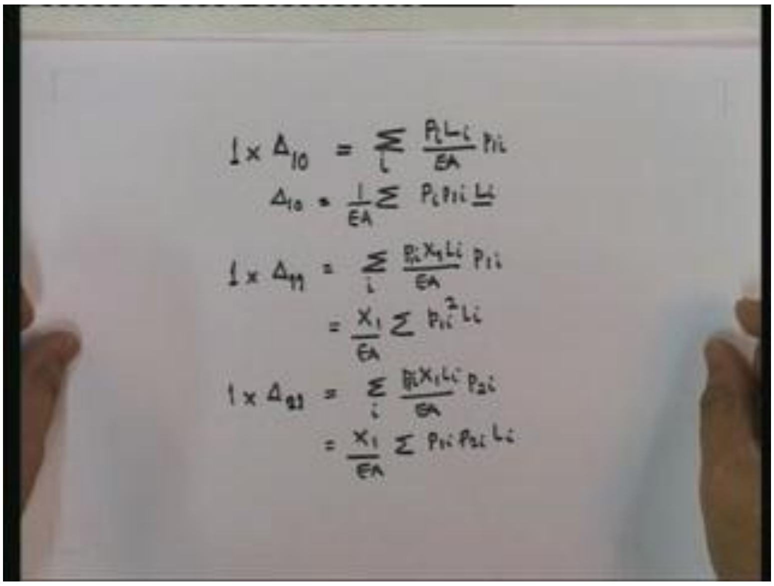

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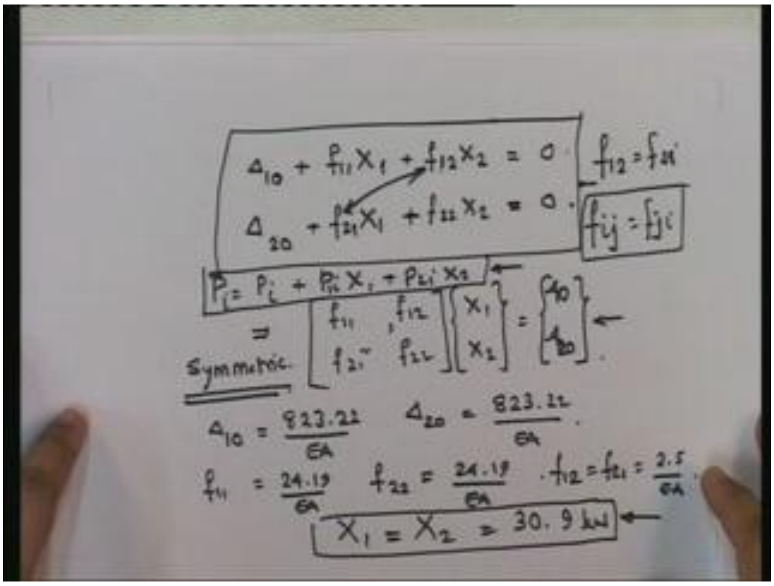

Ultimately, these were the two equations that we got and we solved for X_1 and X_2 and once you solve for X_1 and X_2, then you know what the values are in those parameters and you can find out all the forces.

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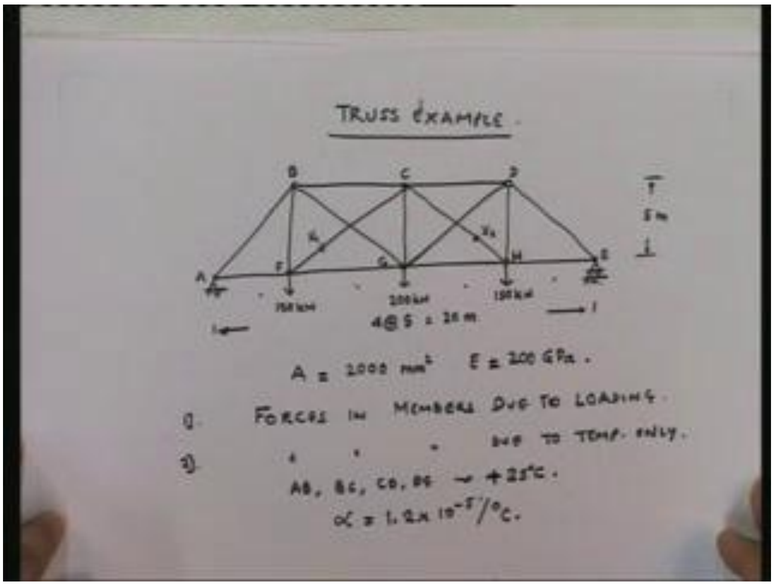

Today, what we are going to be doing is we are going to be looking at the second part of the problem which we did not solve: forces and members due to the temperature only, where AB, BC, CD, DE are subjected to an elevated temperature of 25 degrees where alpha is 1.2 into 10 to the power of minus 5. Today, we are going to be looking at how to do this particular problem.

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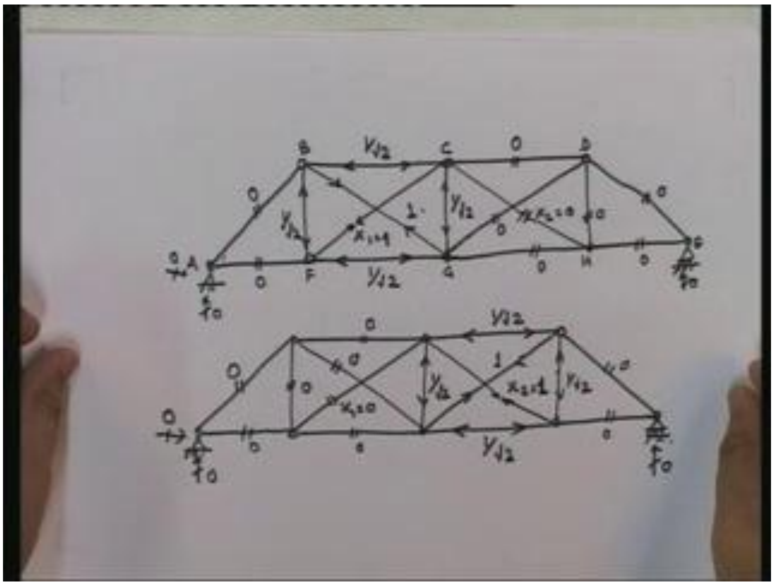

Note that this remains as our x_1 is equal to 1 and x_2 is equal to 1. These are still our virtual force and real force system depending on how you are going to be using them; I have already talked about them last time, I am not going to repeat that.

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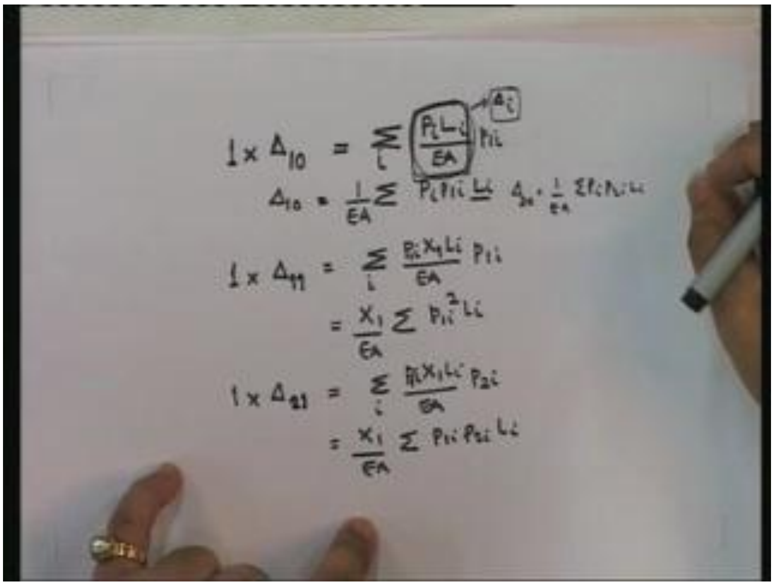

The only thing that happens differently is that these equations…. There is also another equation here, which I did not write down that day. That is 1 upon EA sigma P_i P_{2i} L_i. What is this term? This term is nothing but the real deformation in member i because of the loading. In the case where we have the temperature problem, all that happens is you calculate the deformation in the member directly; you do not calculate forces, you calculate the deformation directly and your problem statement becomes this way.

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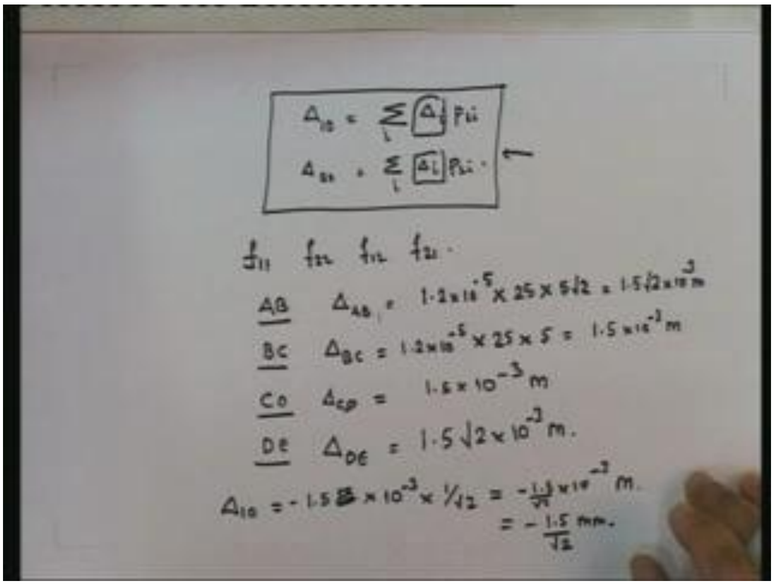

$Delta_{10}$ is equal to summation over all the members $delta_i$ into P_{1i} and $delta_{20}$ is equal to i $delta_i$ P_{2i}. These come from your virtual force equations; I do not want to go into that all over again. This is the only difference.

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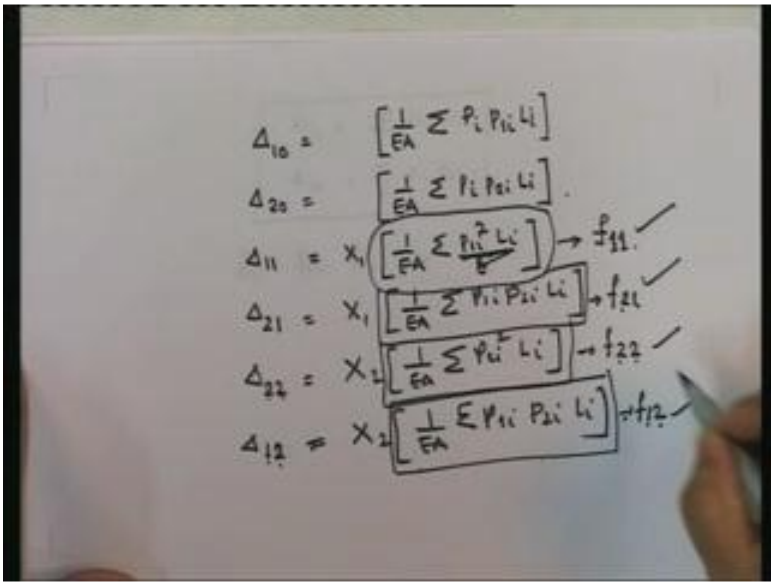

If you look at it, these remain the same. Only this and this for loading is this; when you have temperature, this is different and this is given by these (Refer Slide Time: 06:14), where these are the temperature deformations that you get in every member. Let us look at it. We have only member AB, member BC, member CD and member DE. These are the only members that are subjected to the elevated temperature, so let us find out $delta_{AB}$ due to the elevated temperature. How will you find that out? Alpha is 1.2 into 10 to the power of minus 5 into $delta_t$ ($delta_t$ is 25 degrees) into L.

What is L AB? L AB is equal to 5 into root 2. What does this become? This becomes 1.2 into 25 is 30, 30 into 5 is 150, so this becomes 1.5 into root 2 into 10 to the power of minus 3 meters. Similarly, $delta_{BC}$ is 1.2 into 10 to the power of minus 5 into 25 into its length, which is 5. So, this is equal to 1.5 into 10 to the power of minus 3 meters. Similarly, $delta_{CD}$ will turn out to be 1.5 into 10 to the power of minus 3 meters and $delta_{DE}$ will turn out to be 1.5 into root 2 into 10 to the power of minus 3 meters. We have computed these; these are the only ones (Refer Slide Time: 08:23). Here, all that will happen is $delta_{10}$ will only have $delta_{AB}$ into the P_1 of AB. P_1 of AB.

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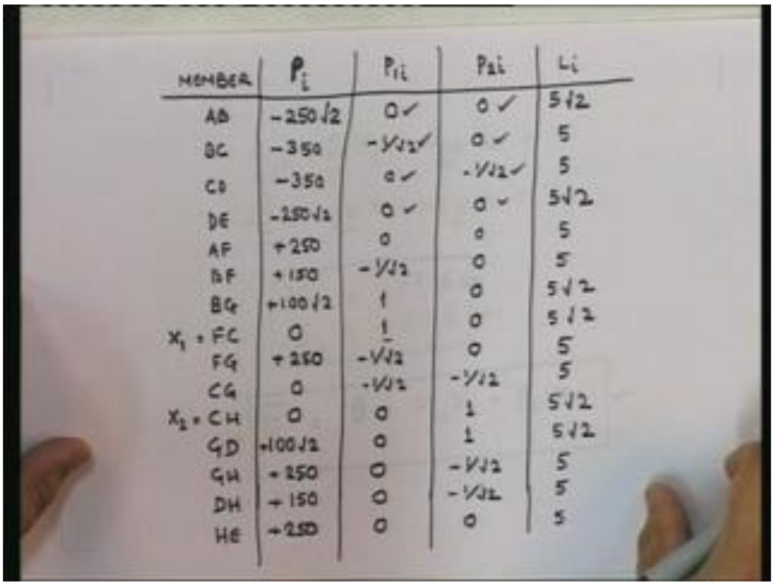

MEMBER	P_i	P_{1i}	P_{2i}	L_i
AB	$-250\sqrt{2}$	0 ✓	0 ✓	$5\sqrt{2}$
BC	−350	$-1/\sqrt{2}$ ✓	0 ✓	5
CD	−350	0 ✓	$-1/\sqrt{2}$ ✓	5
DE	$-250\sqrt{2}$	0 ✓	0 ✓	$5\sqrt{2}$
AF	+250	0	0	5
BF	+150	$-1/\sqrt{2}$	0	5
BG	$+100\sqrt{2}$	1	0	$5\sqrt{2}$
X_1 = FC	0	1	0	$5\sqrt{2}$
FG	+250	$-1/\sqrt{2}$	0	5
CG	0	$-1/\sqrt{2}$	$-1/\sqrt{2}$	5
X_2 = CH	0	0	1	$5\sqrt{2}$
GD	$+100\sqrt{2}$	0	1	$5\sqrt{2}$
GH	+250	0	$-1/\sqrt{2}$	5
DH	+150	0	$-1/\sqrt{2}$	5
HE	+250	0	0	5

P_1 of AB is 0. Then, we have $delta_{BC}$, which is 1.5 into P_1 BC, $delta_{CD}$ is P_1 AC and $delta_{DE}$ is this into this. If you look at the entire procedure, since P_1 AB, P_1 CD and P_1 DE are all 0, the only thing that contributes is BC. So, $delta_{10}$ will turn out to be equal to minus (1.5 into root 2 into 10 to the power of minus 3 multiplied by 1 by root 2), because it is minus 1 over root 2. $Delta_1$ becomes minus 1.5 into 10 to the power of minus 3 meters, which is minus 1.5 millimeter. Similarly, we can compute…. Here again, for P_{2i}, you will see that only CD comes in and CD has exactly the same concept. Therefore, if you look at it, you will see…. Sorry, I have made a mistake here (Refer Slide Time: 10:03). $delta_{BC}$ is not 1.5 into root 2, it is…. You basically have minus (1.5 over root 2), so minus (1.5 over root 2), that is approximately 1 millimeter.

Similarly, $delta_{20}$ also turns out to be exactly the same. By computing in that case, $delta_{CD}$ will be 1.5 into 10 to the power of minus 3 multiplied by minus (1 over root 2), it becomes minus 1 over 1/2. Essentially, once we have computed $delta_{10}$ and $delta_{20}$, we substitute the same equations that you have which is $delta_{10}$ plus f_{11} X_1 plus f_{12} X_2 is equal to 0 and $delta_{20}$ plus f_{21} X_1 plus f_{22} X_2 is equal to 0.

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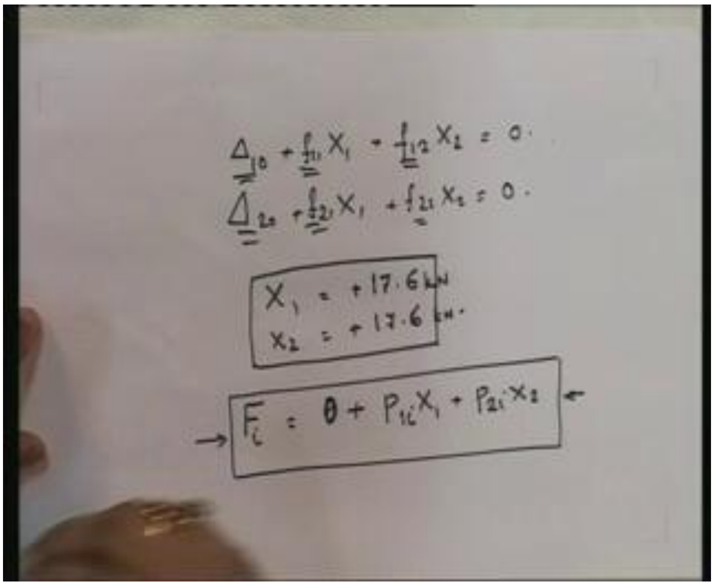

Since we know these, these, these, these, these and these, we can solve for X_1 and X_2; the value of X_1 and X_2 turn out to be equal to plus17.6 Kilonewtons and so is X_2. Once you know this thing, the force in the member is going to be equal to P. In this case, what is P? P is the load due to the temperature alone, so this is 0. You are going to have P_{1i}, which is the force in the member, into X_1 plus P_{2i} into X_2. This becomes the force in all the members due to temperature where we have already got P_{1i} and P_{2i}, you know X_1 and X_2 and you can obtain the forces. In essence, these are the forces that you find out in your truss for temperature. Now what we want to do is to go ahead and look at a frame problem. We have already looked at how to tackle a realistic truss problem and today what I am going to be doing is I am going to be looking at how to treat a frame problem. I will take an actual problem and go through all the numbers, so that at the end of it all, it helps you to be able to solve a frame problem.

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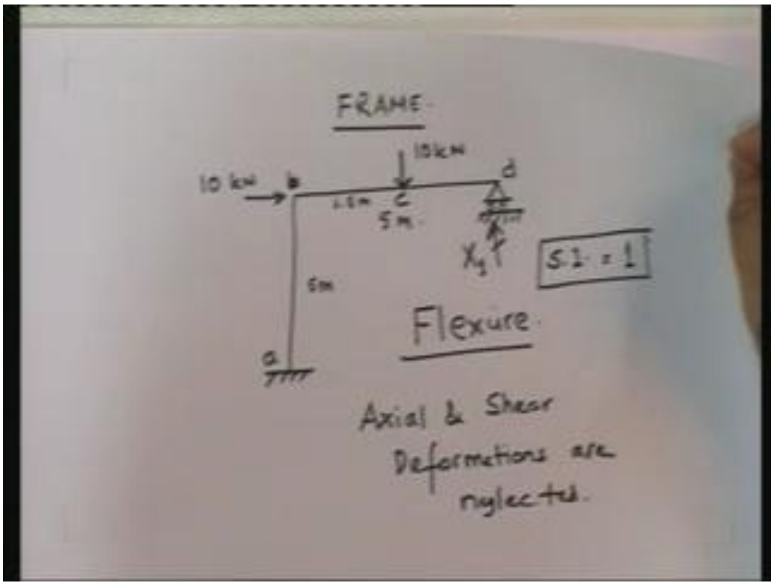

Let us take a frame; I am going to take a simple frame. Essentially, if you understand the concepts with a simple frame, you should be able to use it to solve any problem. I will go through all the details so that you know how to tackle the problem. Let us take a situation where we have this as 5 meters, this as 5 meters and let me call this a, b, c and d. These are the loads on the structure (Refer Slide Time: 14:16). This is acting at the center span, so it is 2.5 meters; this is acting at b, the lateral load. This is a typical kind of load you would have: a gravity load and a lateral load due to wind or it may be even earthquake, does not matter. So, this is the load. We have to draw the bending moment diagram for this particular structure. Remember I am going to explicitly state that we only consider flexure; in other words, both axial and shear deformations are neglected. This is the problem.

How many degrees of static indeterminacy? I will leave it up to you to go through your steps; using my procedure, you will see that the starting indeterminacy is 1. I am going to take this reaction as my X_1; so, this is the problem statement. What is the first step? The first step is to take the base structure where X_1 is equal to 0, find out all the forces in the members and find out the deformations, then put X_1 is equal to 1 and find out the bending moment diagram. Once you get the bending moment diagram, you can then go through the process. Let us go through this particular process.

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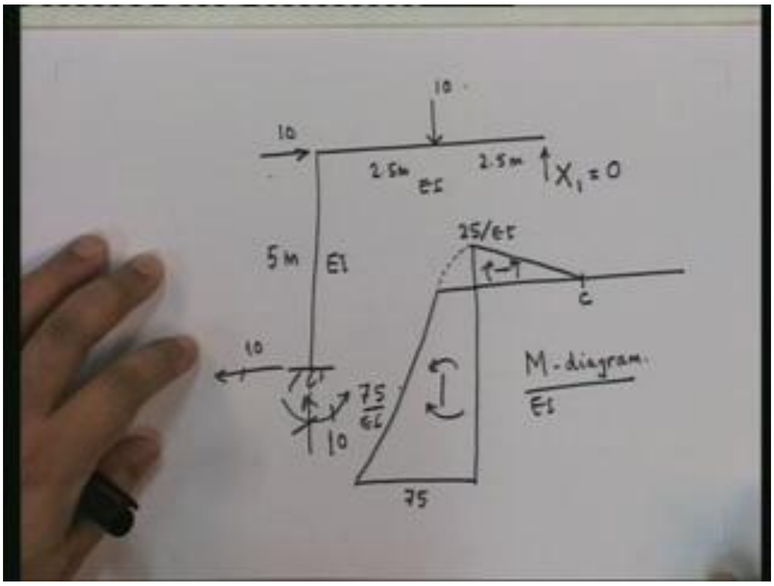

The first part is where X_1 is equal to 0; let me put it explicitly: X_1 is equal to 0. This is the loading, this is 10, 10. What will be the reactions at this point? The reaction over here will be 10, horizontal reaction will be 10 and you will see that this gives rise…. This is 5 meters and this is 2.5 meters, 2.5 meters. If you look at this 5 into 10, if I take moments about this point 5 into 10 plus 2.5 into 10 that is the net moment that has to be resisted here. So, you have a resisting moment here equal to 75.

Once you have that, you can draw the bending moment diagram. Let us see how I will draw the bending moment diagram. The bending moment diagram over here would land up starting from c. The value over here would be 25 that would be the same value here and then this becomes 75, the sense of the bending is this way and the sense of the bending over here is this way (Refer Slide Time: 17:45). This is your bending moment diagram, M diagram. This is the M diagram for X_1 is equal to 0; so, this is the base structure bending moment diagram. Note that I have also made the assumption that this EI and this EI are the same; so, if I just divide by EI and EI would give me the M by EI diagram. What is M by EI? This is the curvature. So, it directly gives the curvature diagram for the real curvatures under the loads. What is the next step? The next step is for X_1 is equal to 1.

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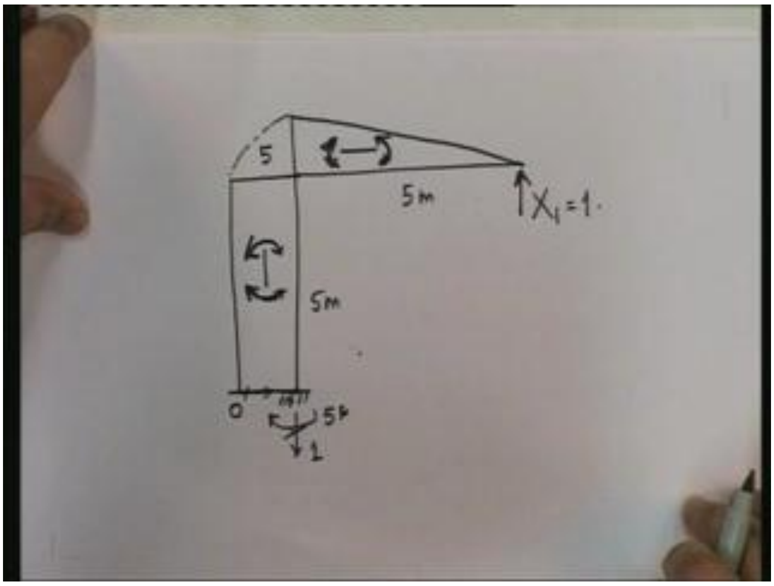

Let us find out what the reactions at this point are. The reaction at this point is going to be 1, this is going to be 0 and what is the moment going to be equal to? This is 5 and this is 5. If you take moments about this point, this gives rise to this, so you are going to have a moment in this direction, which is equal to 5. I am not going to write Kilonewton because this is just a unit, there is no force; so, this is the moment 5. How will the bending moment diagram look? Note: I do not care which direction I draw the diagram as long as I show the sense. I am drawing it in the same direction as that, but note that here, the bending is hogging; in other words, tension at the bottom, compression at the top.

Here it is sagging, so it is going to be tension at the bottom and this is going to be hogging; so, although I have drawn it on the same side, you can draw it on the other side, it does not really matter, you can draw it. However, you have been asked to draw…. So, I think as long as you are consistent…. This is the point that I always make: as long as you are consistent, it does not matter. This value is equal to 5 and you will see that at this point, it is going to give rise to a sagging moment. It is actually this way and that is correct; if you look at this, you will get it over here; here, it is actually the opposite way.

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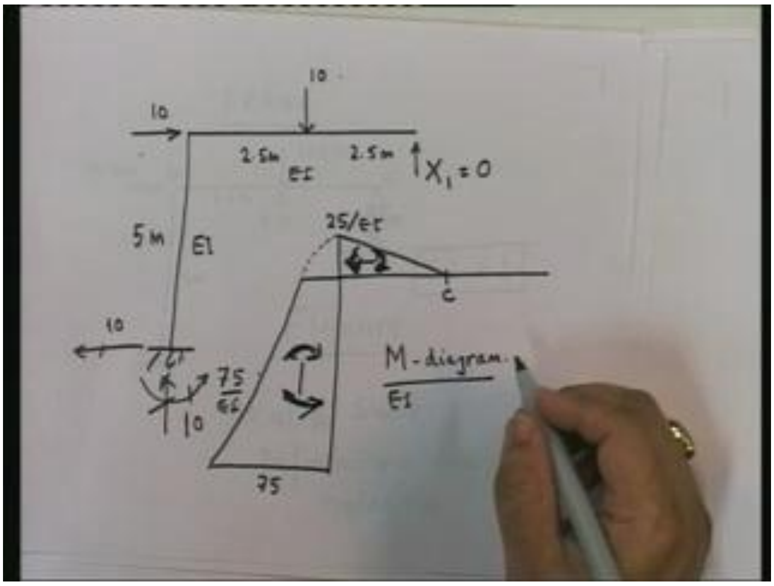

If you look at this, this is this way, this way and this way; this is the opposite way. I am so sorry, I made a mistake here. Please ensure that you understand. This is hogging because this creates a curvature in this direction and that is what you are doing here and this also is this way. Over here, you have it as sagging; this is sagging. So, what do we have? Let me just put it together in the other one.

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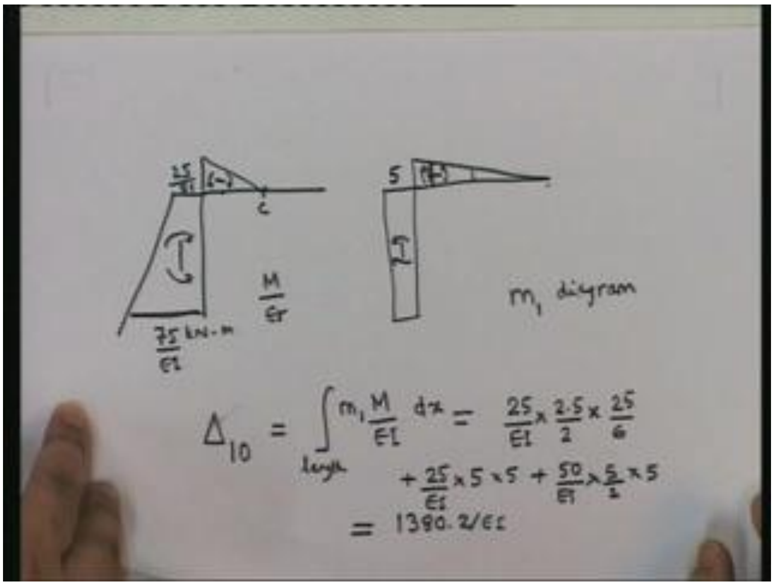

I will draw it small so that I have both of them. The actual M by EI diagram is starting from c. This is hogging, hogging 25, 75; these are Kilonewton meters because the loading is Kilonewton and the forces are meter. These are 25 by EI and 75 by EI. Note that if you have two different EIs, then the moment diagram and the M by EI diagram would not be the same. But in this case, I have taken them to be same and this is the small m_1 diagram. The m_1 diagram I have shown it on the same side, but this one is opposite (Refer Slide Time: 22:53). This is the M by EI diagram, this is the m_1 diagram.

Now, what do we do? Note that, if I want to find out the displacement at this point then my equation becomes $delta_{10}$ is equal to integral over the whole length m_1 into M upon EI dx over the entire length of the frame. That is $delta_{10}$. If you look at this particular situation, all you have to do is take this area and at its centroid find out this value, take this area and the centroid, find out this value.

I will go through the steps. Let us look at what you will get over here. In this particular one, what is the area under the curve? 25 upon EI multiplied by 2.5 by 2 – that is the area under this curve. Now let us look at this; which point would this be? This point would be 2.5 by 3 from this end, which is actually 5 by 6. If you look at this, since this is 5, this is 5 by 6 from this point. If you take that, you will see that this the value at that particular point, the centroid of this graph, is going to be equal to 25 by 6; this is going to be the value at that particular point. Is that clear? It is going to be equal to 25 upon EI multiplied by 2.5 by 2, which is the area of this curve, multiplied by 25.6, which is the value at the centroid of this. This is the integral of this area, the integration over this length.

Then, we look at it over this length. This can be broken up into two parts, one a rectangle of 25 by EI. So, you are going to have plus25 upon EI into 5 (that is the area under this curve) multiplied by the value at…. that is going to be 5 because it is a constant; it does not matter where the centroid is, it is going to be the same. The next one is going to be the difference, which is 50 upon EI. So, 50 upon EI multiplied by 5 divided by 2 (the area of this triangle) multiplied by 5, which is the centroid at this point. What we get is 1380 by 2EI. This is the value of $delta_{10}$. Then, we need to find out the deflection due to X_1 is equal to 1. What is the deflection due to X_1 is equal to 1? That is my f_{11} that is my flexibility.

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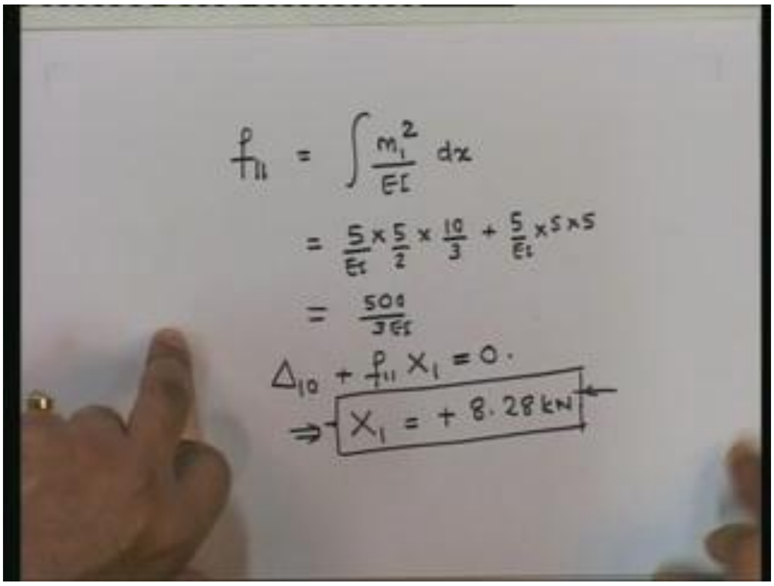

Displacement at one due to unit load at one and that is equal to m_1 squared upon EI dx. What is the flexibility? Flexibility is displacement at one due to X_1 is equal to 1. What is going to be the actual displacement due to X_1? It is going to be f_{11} into X_1. I am introducing the concept of flexibility which I have introduced with the truss; I am doing the same thing over here. If you look at this, if I draw this, this will then be this integral with itself upon EI (Refer Slide Time: 27:41). If you look at this, this is going to be equal to 5 into 5 by 2 (that is the area under the curve) multiplied by 10 by 3 (that is the value at the centroid). Sorry, this is going to be 5 upon EI because this is the real part. Then, plus 5 upon EI multiplied by 5 multiplied by 5. What are these? This is the integral of m_1 square dx over this length and this part is the integral over this length. This is going to be equal to 500 by 3 EI; this is my f_{11}.

What is my compatibility condition? Delta$_{10}$ plus f_{11} X_1 is equal to 0. Since this is only one redundant, this is the only additional equation that I require. From this, by plugging in the value of delta$_{10}$ and f_{11}, I get X_1 is equal to minus…. I am sorry, I have made a mistake. I just wanted to make a point here: since this and these are opposite, the delta$_{10}$ turns out to be minus 1382, so here, X_1 is equal to 8.28 Kilonewton. I have got the value of the reaction at the support d that we have. Once I have got that, what is the next step?

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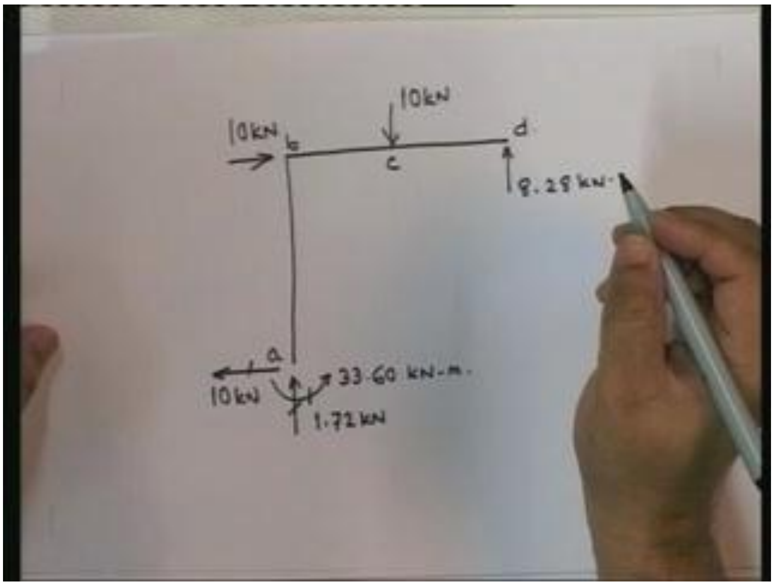

The next step here is to actually draw the bending moment diagram. However, before drawing the bending moment diagram, let me draw the…, this is my loading. I know this value, this reaction; so, this is a, this is b, this is c and d. I have found out this reaction and this reaction value is 8.28 Kilonewtons. Once I know this, I can actually find out the reactions at this point; this reaction is going to be 1.72 Kilonewtons, this is going to remain 10 Kilonewtons and what I get is this: if I find out that the moment over here is 10 into 5 plus 2.5 into 10 that is 75 minus 8.28 into 5. This is going to give me a moment in this direction whose value is going to be equal to 33.60 Kilonewton meter.

Once I have found out the reactions, I can proceed to finding out the forces in the bending moment diagram. Let me just see how I will draw the bending moment diagram. Let me go piece by piece in this particular case. I will take bcd, I will separate out bcd and ab separately. If I separate out, then what are the things that I generate if I take out bcd?

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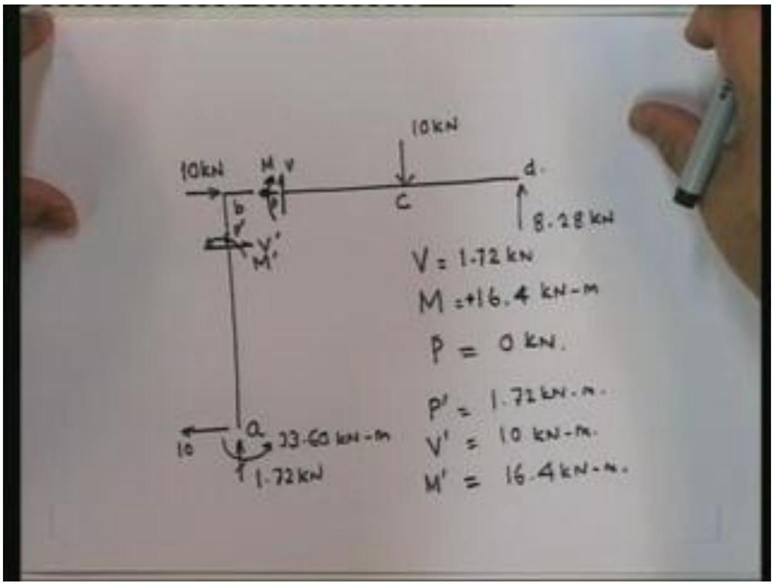

This is 8.28, this is 10. Note that I am going to isolate the joint and then I am going to have the member. This is a, b, c and d. The only difference is that this cut that I have made is actually infinitesimally small; it is just so that I can isolate the joint b and look at it separately. When I make a cut here, what are the forces that I generate over here? The forces that I generate over here are a shear, the shear is going to be in this direction, then a moment; let us just take positive moment right now, so the positive moment will be in this direction and what else? There could be an actual force too. Note that you do not have to consider shear deformations and actual deformations but the forces are still going to be there.

This is going to be M, this is going to be V, this is going to be P and can I find out these values? Sure, because I have this; here, I know this is roller support, so moment is going to be equal to 0. What is V going to be equal to in this particular case? V is going to be equal to 1.72 because you take sigma f_y, you will see that is equal to 1.72 Kilonewton. What is the moment over here? Let us take the moment about this point; this is going to give you 10 into 2.5 this way and this going to give you 8.28 into 5 the other way. This is going to give you 41.4 minus 25. What is that going to be equal to? It is going to be equal to 16.4. Which direction is it going to be? Actually, if you look at it, this is going to be this way, this is going to be this way, so the net moment is actually going to be… if I am showing it this way, it is going to be minus 16.4 Kilonewton meter.

What can we say about P? Take sigma f_x is equal to 0, you will see it is 0 Kilonewton. I have found out the forces here. Once I find out the forces here, just the opposite ones are going to be coming here. Let me take this one. This one, I know all the reactions that are coming here, 1.72, this is going to be 10 and you have already found this out as 33.60 Kilonewton meter. If you look at this particular case, how do I find out the …? When I make a cut here, I am going to get reaction V here, I am going to get a moment here and I am going to get an axial force b here.

Let me just see, I will make them separate so that the P prime…. What will be P prime equal to? Sigma f_y equal to 0 gives me that P prime is equal to 1.72 Kilonewton meter. What is V prime going to be equal to? If you look at this, sigma f_x is equal to 0 will give me 10 Kilonewton meter. What is M prime going to be equal to? Let us see. 10 into 50 is going to be in this way, 33.6 is in this way, so what is it going to be equal to? If you look at this, this is going to be giving this way. If you look at your moment, it is going to remain…. This moment is going to be equal to 50 minus 33.60, so that is going to be 16.4 Kilonewton meter. Let us review this again. Taking moments about this point, what do we generate?

We generate that this moment plus this moment is equal to this moment (Refer Slide Time: 36:43). M is M plus10 into 2.5 minus 8.28 into 5 is equal to 0, that is sigma M is equal to 0. If you take that, you will see that this is going to be plus16.4. If you take V, V plus 8.25 minus 10 is equal to 0, so V is going to be equal to this and sigma f_x is equal to 0 is going to give me P is equal to 0 here. In this particular case, what do you get? If you take sigma f_y is equal to 0, you will get P minus 1.72 is equal to 0, so you get P; you get V prime minus 10 is equal to 0, so you get V prime. Similarly, moment plus 33.60 minus 10 into 5 is going to be equal to 0, so moment is going to be equal to this. I have found out at the ends of the two members. Similarly, I can actually find out the forces at the joints also. Let us look at that; I am going to spend some time looking at equilibrium here, because after this I am not going to be looking at equilibrium.

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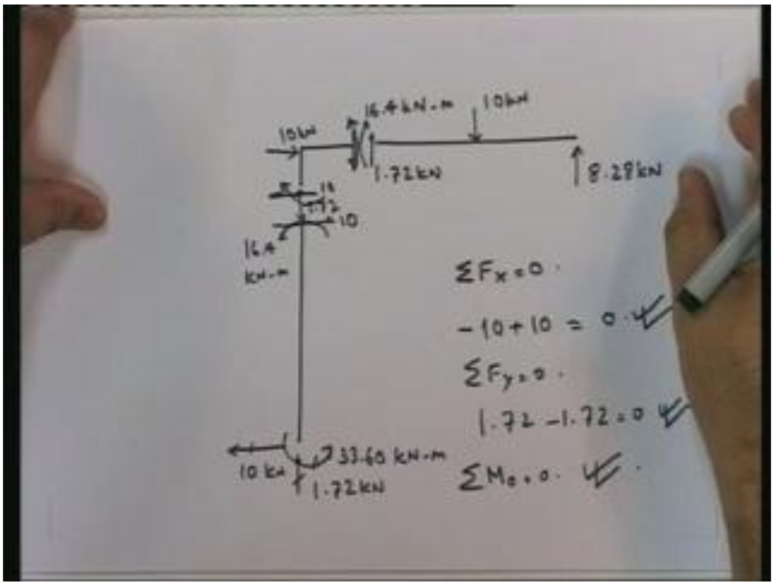

I have already done this, so I am just going to put them down: 8.28 Kilonewton here, 1.72 Kilonewton, load 10 Kilonewton, moment over here is 16.4 Kilonewton meter. What else? Over here, I have 1.72 Kilonewton meter, this is going to be 10 Kilonewton, the moment over here is 33.6 Kilonewton meter. At this point, I have 10, I have 1.72 and I have moment equal to 16.4 Kilonewton meter. Now, let us do it on this side. This side is going to give rise to this force, which is going to be equal to 1.72. It is going to give rise to moment here. Here, I have the 10 Kilonewton force, over here, I am going to have 1.72 which is going to be in this direction, 10 and the bending moment is going to be in this direction. Let us look at the equilibrium of the joint.

Let me take equilibrium of the joints sigma f_x equal to 0. I have minus 10 here, so I will put minus 10; I have plus 10 here, plus 10 that is it, there is no other force here, so this is equal to zero, automatically satisfied. Then, we look at sigma f_y equal to 0; sigma f_y equal to 0 is going to give me that this is upwards 1.72, there is no load over here and over here, it is downwards 1.72, so it is zero. Check. Then, let me take a moment equal to zero, let me take moments about this point. These distances are zero, these do not give rise to any moments. What is the moment? I have a clockwise moment here and an anticlockwise moment. The clockwise moment is 16.4, the anticlockwise moment is 16.4. Check. That means all that I have done is correct and so now once I have this particular loading done, the next thing that I am going to be doing is I am going to be actually putting together the bending moment diagram. Since I know all of those, how will the bending moment diagram look?

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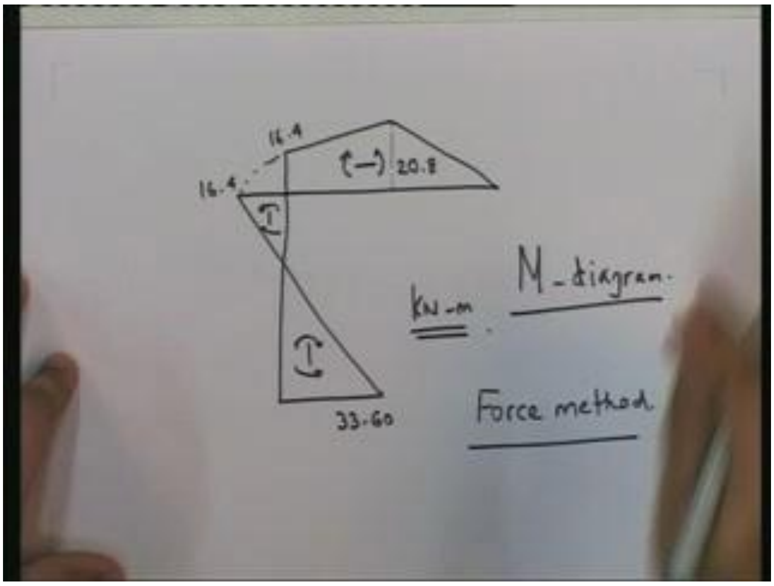

This side remains the same. It is going to be 16.4, 33.6, so ab, there is no mistake, it is 33.6; and this is 16.4, this is also 16.4, this is this way, and let us see what the moment at this point is going to be.

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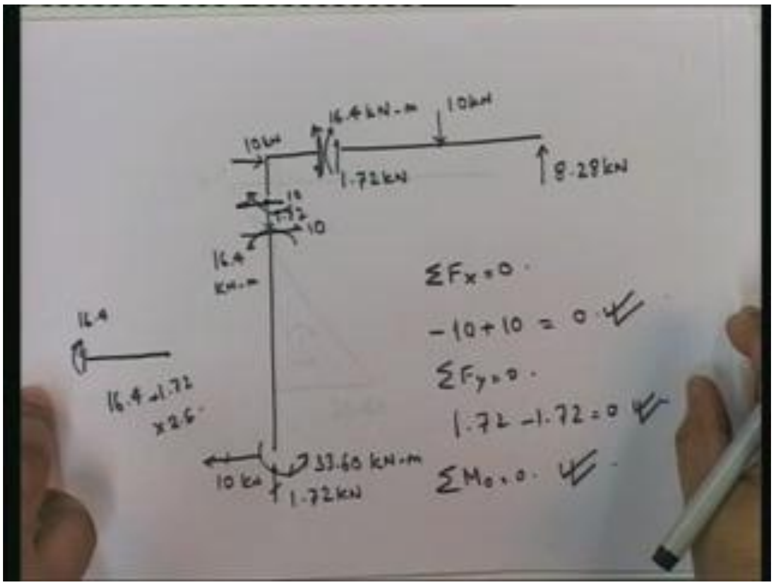

If I take a cut here…. I am taking a cut exactly to the left of this load so what is going to be the moment? It is going to be 16.4 and if you take moment about this point, it is going to be 16.4 plus 1.72 into 2.5 so that is going to be equal to…. This is going to go this way, this is going to be equal to 41.6, so it is going to be 20.8 (Refer Slide Time: 42:27). This value is going to be 20.8, this is going to be 16.4 and all of them are in Kilonewton meter. This is the bending moment diagram for the actual structure where I have included both the effect of the actual loads as well as the redundant force. This in essence is my force method solution.

I hope that with this kind of procedure I have gone through a detailed frame analysis problem so that you know exactly how the force method is used to solve a frame problem. Till now, I have always been talking about the basics, so this time I have gone through all the details so that you can actually feel comfortable using the force method for solving a frame problem. Just to refresh your memory, up till now, all that I have done was going to be a review. You already hopefully used the force method etc., for solving both truss as well as beam and frame problems. Let me just go back and say, in essence, what the force method entails.

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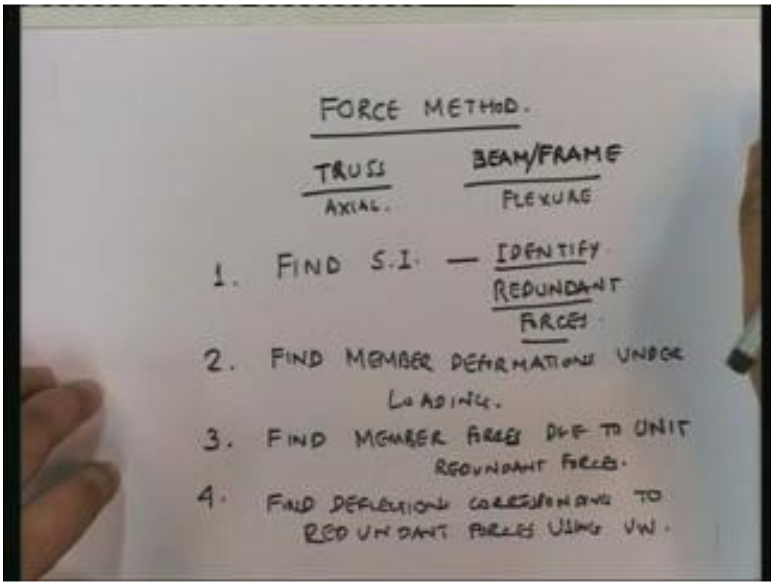

This is irrespective of whether you have a truss or beam frame.

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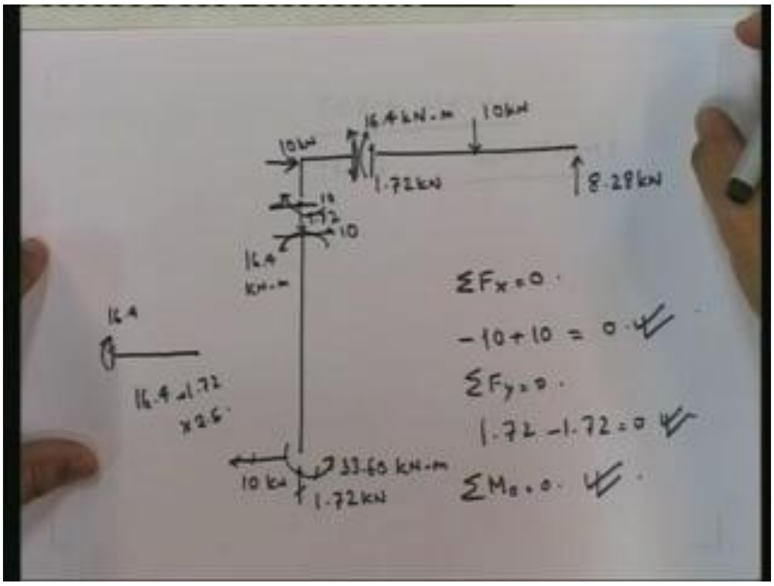

If you notice, the only difference between a beam and a frame that I pointed out that day was that in a frame, all that happens is this: what is shear over here becomes actual force over here, and whatever is shear over here may become actual force here; it would have if this had not been there. So, the only difference between a beam and a frame is that in a beam, if you have multi-span beams, a shear in one beam will always be a shear in another beam and axial force in one beam would be an axial force in another beam. But in a frame, a beam and a column, the shear forces in the beam may land up giving axial forces in the column and the shear forces in the column may land up being axial force in the beam; that is all that is there. Otherwise, equilibrium and all the forces that you develop are identical whether you have a beam or a frame.

The equilibrium considerations may be different in a beam and a frame, but as far as the solution is concerned, there is no difference between a beam and a frame, you only consider flexure, and in a truss you only consider axial. So, what does the force method entail? The force method entails the following: one, first find static indeterminacy – this is fundamental to using the force method. If, by now, you do not have confidence in obtaining the static indeterminacy or structure, there is no way you are going to be able to use the force method. Given any structure, you should be able to find out the static indeterminacy of the structure. I have spent the first two lectures looking at how to determine the static indeterminacy for a truss, as well as the beam frame structure. So, by now, you should be able to get the static indeterminacy. If you cannot, please go back and look at enough problems, look at any book on structural analysis, take up some problems, essentially structural analysis of statically indeterminate structures, take up any structure and find out the static indeterminacy. If you are confident that you have found out the static indeterminacy properly, you can use the force method easily. So, find the static indeterminacy

Once you find the static indeterminacy, you identify the redundant forces. What are the redundant forces? Those are the forces on the structure; they could be a support reaction, they could be internal forces. In the frame problem that we looked at, we took the support to be a redundant force.

If you look at the truss problem that we solved, we took internal members forces to be redundant forces. The only thing is that the redundant forces have to be such that if they were 0, the structure would still remain stable; that is most important. You cannot take out redundant forces, put something equal to 0 which will make the structure unstable; that cannot be done. It does not matter if you have static indeterminacy in support reactions; you can remove some support reactions and take them as redundant.

If you do not have redundants, for example, if you looked at the truss structure that I had, I had a hinge at one end and a roller at one end. I cannot remove a support reaction without making the structure unstable. Therefore, in that particular case, I had to take redundant forces which were internal. In the frame case that I considered, I could remove the roller support and still have a stable structure; therefore, I removed the stable support. Is that clear? Overall, the concept is that you identify redundant forces such that you get a stable, statically determinant base structure by taking redundant forces equal to 0.

Second, what you do is, you find the member deformations under loading. How do you find out member deformations? The way you find out the member deformations if you have a loading is that you find out the loads if member forces due to by solving the statically determinant problem and you find out the member forces. Based on that, once you know the member forces, for example, if it is axial force, if it is a truss member's axial force, the axial deformation is given by PL upon EA, that is the axial deformation. If you look at flexure, then the flexural deformation is given by M by EI. So, these are the member deformations that you find out under the loading. If it is temperature loading or a lack of fit, then you know the member deformation directly. That is the overall.

Third, find member forces due to unit redundant forces. If you have two redundants, you will apply one redundant first and put the other redundant equal to zero. You put X_1 is equal to1 and X_2 is equal to 0; then, you find out another member force putting X_1 is equal to 0 and X_2 is equal to 1. Find the member forces; this helps you to essentially find deflections corresponding to redundant forces using virtual work.

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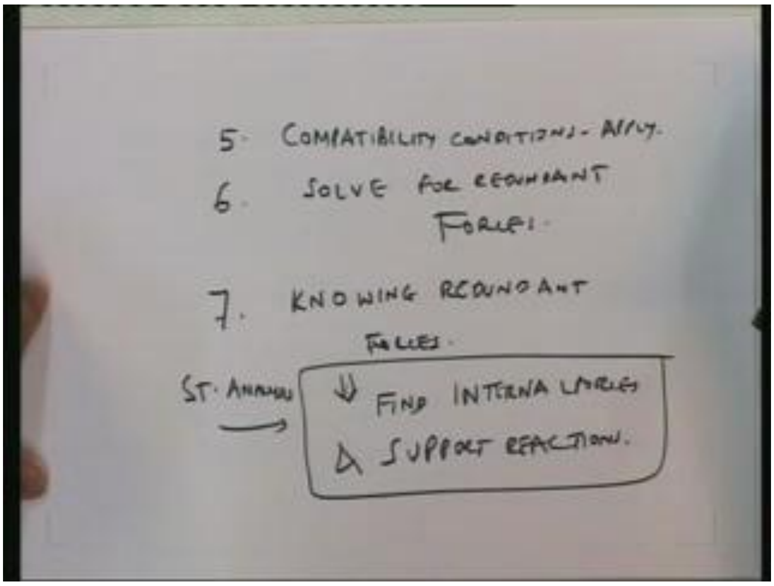

Once you find the deflection, the next step, step five is apply the compatibility conditions and from that, solve for redundant forces. Seven, knowing the redundant forces, find the internal forces and support reactions. This is your structural analysis. I have essentially read out the procedure for using the force method. I hope at the end of this lecture, you are confident in using the force method to solve any truss or beam frame problem. Next time onwards, I am going to start with looking at the matrix approach to the force method. In this way, I am going to be introducing you to the matrix methods that are actually used in structural analysis of real structures. Thank you.