Mechanics Of Solids
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Lecture - 50
Tutorial

Welcome back to the course Mechanics of Solids. So, as we discussed in the last lecture that we have concluded the chapter dealing with the bending stress. Now we will be taking couple of numerical problems. So, the first problem is that if you look at this problem.

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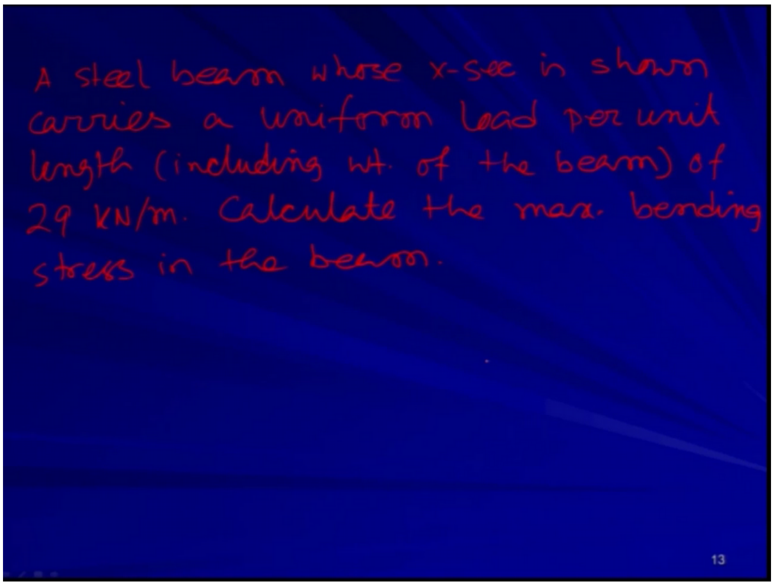

A steel beam whose cross section is shown, I mean, I will be showing the figure right now, carries a uniform load per unit length including weight of the beam of course, of 29 kilo Newton per meter, calculate the maximum bending stress in the beam. So, that is the problem ok.

Let me draw the figure. So, this is the cross section of the beam I beam.

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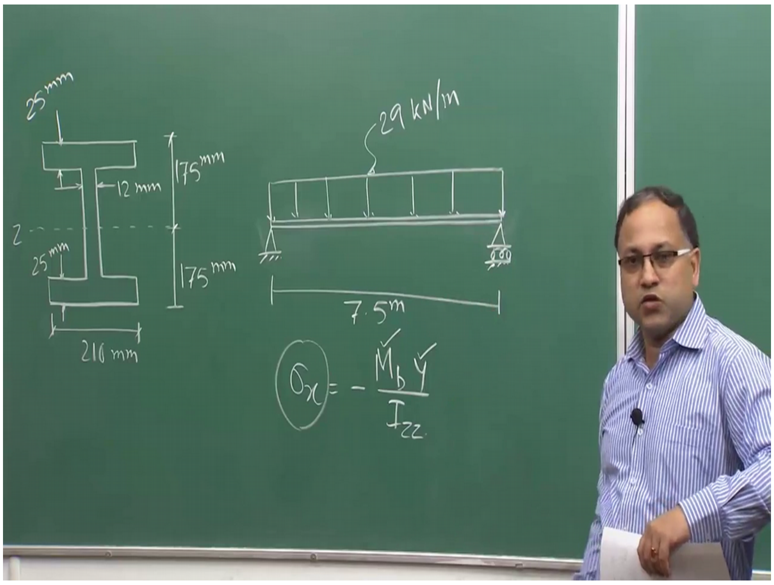

This is 210 millimeter, this thickness is 25 millimeter, this thickness is 12 millimeter, this is the centroid of the I beam. That is your z axis, and this is 175 millimeter, this is 175 millimeter symmetrical cross section, this is also 25 millimeter. And problem says this is the beam simply supported beam, simply supported beam. You have uniformly distributed load of 29 kilo Newton per meter as given in the problem. The length or the span of the beam is 7.5 meter. So, this is the problem. So, you need to find out the maximum bending stress in the beam.

Now, if you want to find out the maximum bending stress, if you recall the equation of bending stress is this right. Now if you try to find out the maximum if this is going to the maximum, then this has to be maximum; that means, the bending moment has to be maximum. As well as y has to be maximum. What is y? That is a distance from the neutral surface to the upper fiber or the lower fiber right. So, this distance should be maximum.

Now, Izz is constant, if you are not dealing with say different the variable cross section along the along the spam. So, Izz is constant for any particular cross section, isn't it? For this I beam basically you can calculate Izz and that is constant. So, you need to maximize both the things together to get the maximum bending stress. So, what I need to find out, I need to find out the maximum bending moment in the beam under this kind of loading condition. And the fiber at which the maximum or the maximum or the extreme fiber rather from the neutral surface ok.

So obviously, the neutral surface is this which will be passing through the centroid of the cross section. So, the extreme fiber will be always either this side or this side right. Top or bottom depending on that you will be getting tension or compression that is different thing.

We are talking about the absolute maximum bending stress, whether it is compression or whether it is tension that is not the matter of constant. We are going to find out the absolute maximum bending stress. So, y has to be maximum So, as I told you that it should be the over the extreme top surface or the extreme bottom surface then y will be maximum that is, now let us find out the maximum bending moment first.

So, the maximum bending moment as you know From our earlier discussion.

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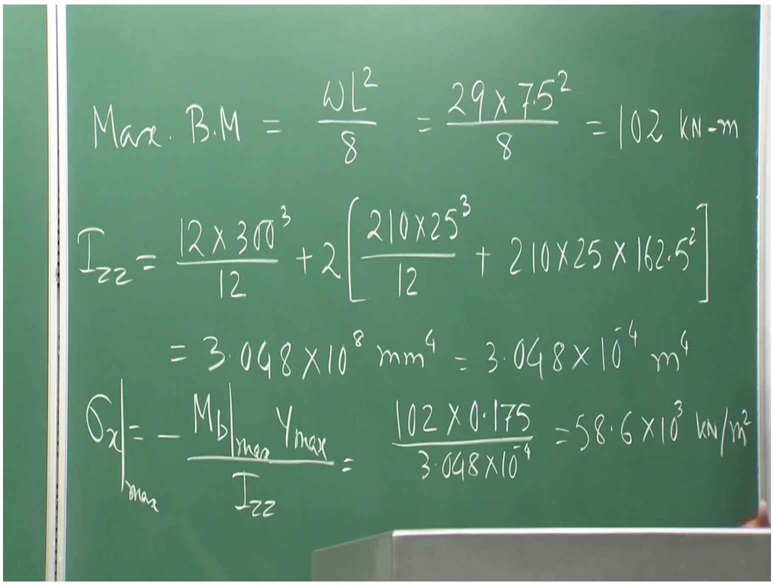

For this kind of simply supported beam with uniformly distributed load the maximum bending moment will be happening at the center right and that maximum bending moment that you can check it I mean I am not going to do that thing again, because you are quiet familiar to the solution procedure and by which you can find out the maximum bending moment.

So, maximum bending moment for this kind of loading system or the beam will be WL square by 8 that you can check it where W is nothing but the uniformly distributed load 29 kilo Newton per meter. So, I can simply write 29 and L is the span of the beam that is 7.5 square by 8. That comes as 102 kilo Newton meter. So, that is the maximum bending moment ok.

So, you have got the maximum value of this bending moment of course, maximum value of y is also known to you that is either 175 top or bottom no matter. Now you need to find out Izz for this I beam, and I hope that you know how to find out Izz for this kind of cross section. So, let us find out that.

So, Izz will be equal to 12 into 300 by 12. 12 into 300, 300 is 175 plus 175. So, that is the total length that is the total height into 12 divided by 12. So, this is the way you can find out I mean there are several options by which you can find out the Izz.

You can find out the Izz for the whole say cross section like considering this is a rectangular beam rectangular cross section, and then you just subtract this part, there are several ways as you know. So, that I am not going to repeat. So, I am just calculating that thing plus 2 times 200 10 into 25 cube by 12, plus this is the parallel axis theorem we are in cooperating the parallel axis theorem 162.5 square, agreed?

So, this is the Izz considering this flange with respect to it is own CG. Now this CG has to be shifted because this is the global CG for this cross section. So, we can use the parallel axis theorem like this, fine.

So, this will be coming as 3.048 into 10 to the power 8 millimeter to the power 4, which will be nothing but 3.048 into 10 to the power minus 4 meter 4 ok.

Therefore you can find out sigma x which is equal to minus, if this has to be maximum this is also maximum y max divided by Izz. So, that comes as So, M b is given So, just we are putting the values M b is equal to 102 into 0.175 in meter by 3.048 into 10 to the power minus 4. So, we are not considering the sign because this I mean if you consider the tension that bottom fiber that will be under tension. So, we are putting y max equal to negative will be positive. So, that gives me 58.6 into 10 to the power 3 kilo Newton per meter square, understood? So, this is the way you have to calculate the bending stress.

Now, coming to the next problem, the next problem says.

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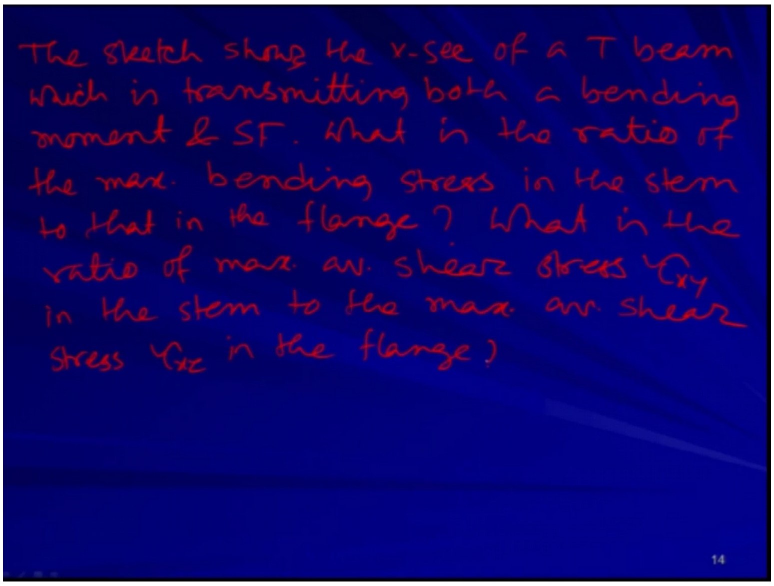

The sketch I will be showing the sketch right now, the sketch shows the cross section of a t beam, which is transmitting both a bending moment and shear force, what is the ratio of the maximum bending stress in the stem? Stem means wave, whatever we discussed earlier. Stem and wave both are same in the stem to that in the flange. And what is the ratio of maximum average shear stress tau x y in the stem to the maximum average shear stress tau x z please remember because tau x z is more critical for the flange in the flange.

So, there are 2 things one thing is that you have to find out the ratio of the bending stress in the stem as well as the flange, and you need to find out the ratio of the shear stress shear stress of course, tau x y is critical for the stem and tau x z is critical for the flange already we have seen that. So, that that ratio also has to be found out ok.

Now, let us let us draw the cross section first.

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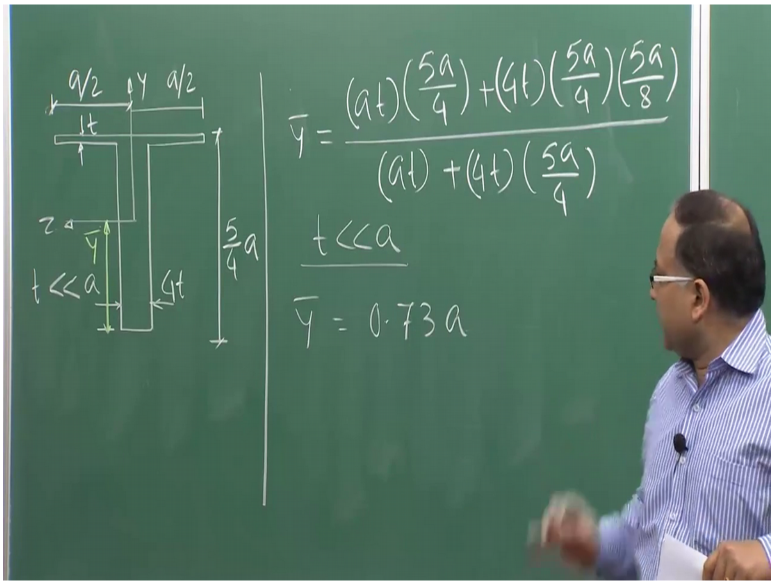

So, this is the t beam very thin flange, and very thick stem. This is z, z axis normal to the board is your x axis. So, this is given by a by 2, this is given by a by 2, this is given by 5 by 4 a this is 4 t. And it is given in the problem t is very, very less than a and this thickness of the flange is t. So, this is the problem. So, we need to find out the ratio of the stresses.

Now, before going to the analysis what we need to find out? We need to find out the neutral surface right. Here actually if you look at the cross section with respect to z axis it is not symmetrical right. One side you have the flange other side you do not have the flange. So, therefore, you can not say that the z axis or rather neutral surface will be passing through the through the midpoint of the stem, you can not say that because you need to calculate or need to find out the CG of the cross section. By following the same procedure whatever you have learnt in physics or may be some other advanced level of physics course.

So, in the if I following the idea or by following the principle you can find out the CG of this cross section. And that CG and through the CG basically your neutral surface will be passing ok.

So, let us find out the CG say that is nothing but say y bar we are saying. So, this is say that is my say y bar. So, that will define the CG distance. So, this y bar can be obtained as you know I mean I am I am I am I expecting and I am anticipating that you know how to calculate the CG of a particular cross section ok.

So, 5 a by 4, a t, a t into 5 a by 4 plus 40 into 5 a by 4 into 5 a by 8 divided by the area. And since and this is true because t is very, very less than a. So, based on that we can write this equation for y bar and that y bar will be coming as 0.73 a So that means, first job is done. So, the you have you have identified the location of your neutral surface ok.

So, once you have identified the location of the neutral surface then your stem Sigma x max is equal to M Izz y max stem.

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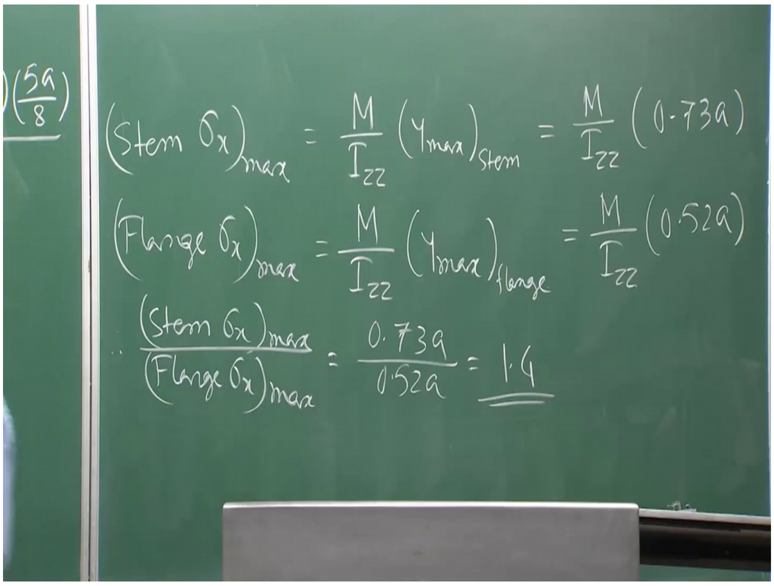

So, that is nothing but M I am not, I am not considering the sign. So, that is quiet understood. So, M divided by Izz because M is constant for this cross section 0.73 a that is a y max for the stem. This is the neutral surface. So, their extreme bottom surface is points y bar distance apart from a neutral surface that is nothing but 0.73 a So at that you have got.

Now, in case of flange sigma x max, that is M Izz y max, we are taking the absolute value we are not talking about we are we are just interested in the value because we are going to find out the ratio, we are talking about the sign whether it is compression or tension that is immaterial for this at least for this problem ok.

Only the value will be the major constant M Izz. So, that will be 5 by 4 a minus y bar. So, that will be coming as 0.52 a. So, therefore, your stem sigma x max the ratio of that to flange sigma x max is equal to 0.73 a by 0.52 a which is nothing but 1.4. So, this is the first job we have done.

Now, the second job is to find out the ratio of the shear stress.

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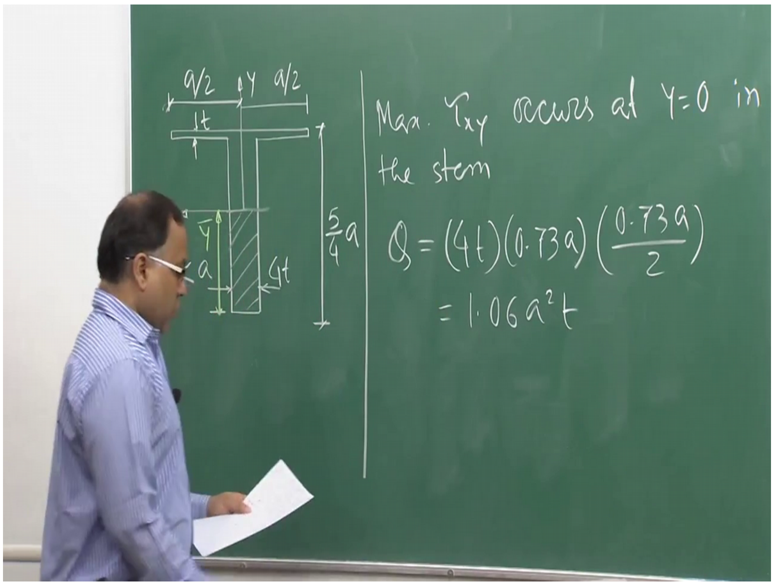

So, maximum Tau x y occurs at y is equal to 0 in the stem; that means, at the neutral surface, here for the stem at least tau x y will be maximum here, consider the parabola distribution, do you remember that? So, that will be maximum at the neutral surface. So, at y equal to 0 your neutral surface is passing through that point ok.

So, your q that is the first moment of area, understood? The first moment of area with respect to the neutral axis. So, that will be given by 4 t into 0.73 a that is the area, this area because when you are talking about the stem. So, this whole area will be coming into the picture. And the first moment of momentum is 0.73 a by 2. So, that is coming as 1.06 a square t ok. Now for flange.

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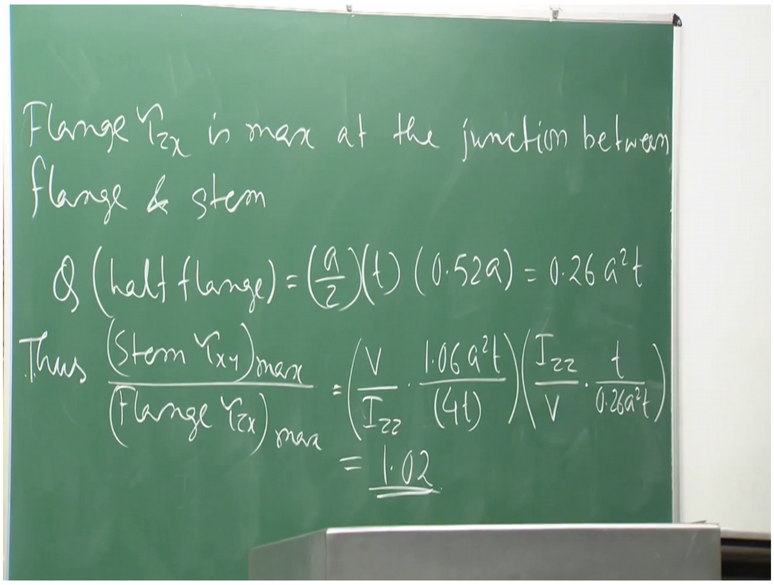

Flange tau z x is max at the, as we have seen when we are discussing about the development of tau z x at the junction between flange and stem right; that means, it will be here ok.

It will be here somewhere here this will be maximum. So, q for half flange is equal to that is the first moment of area, which is nothing but we are considering, because this we are considering the whole part. So, we are considering here it is maximum ok.

So, a by 2 into t that is the area. And that area that moment of this area with respect to z axis, that distance is 0.52 a from the z axis. So, this is the area when we are talking about the flange this is the area we are considering and the momentum is this that is nothing but 0.52 a.

So, that gives me 0.26 a square t, thus stem tau x y max by flange tau z x max is equal to V by Izz V is constant, Izz is constant 1.06 a square t by 4 t. V q by I b, I b means thickness is 40. If you look at this figure thickness is 40 in the stem. Divided by Izz for the flange Izz by V for the flange the thickness is t. If you look at the thickness of the flange that is t, so for the wave it is 40 for the flange it is t.

So, t by 0.26 a square t; so from this I can get this is 1.02, understood? Now you have got the idea that how we can calculate tau x y tau x z in the flange as well as in the stem and then we can how we can find out the bending stress and all those things you are familiar to that. Depending on the cases depending on the situation you can calculate few things you need to know how to find out the centroid, of a particular cross section because neutral surface will pass through that.

How to find out the Izz that is moment of inertia for that particular cross section with respect to the neutral surface. And how to find out tau x z tau z x if it is t beam or I beam, if it is a rectangular beam or the square beam then basically there is no problem only tau x y will be participating or tau x y will be contributing there ok.

So, with this I will stop and I will conclude this chapter. So, in the next class we will see the deflection of beam due to bending and there will be we will be discussing that whatever we have learnt here, based on that this curvature relation and all those things will be come into the picture and based on that we will be defining the or we will be deriving the expression for the differential.

Thank you very much.