Mechanics of Material
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Stresses and deflection in homogeneous beams loaded about one principal axis
Lecture – 61
Connection design

Now, there are multiple ways by which again constructions.

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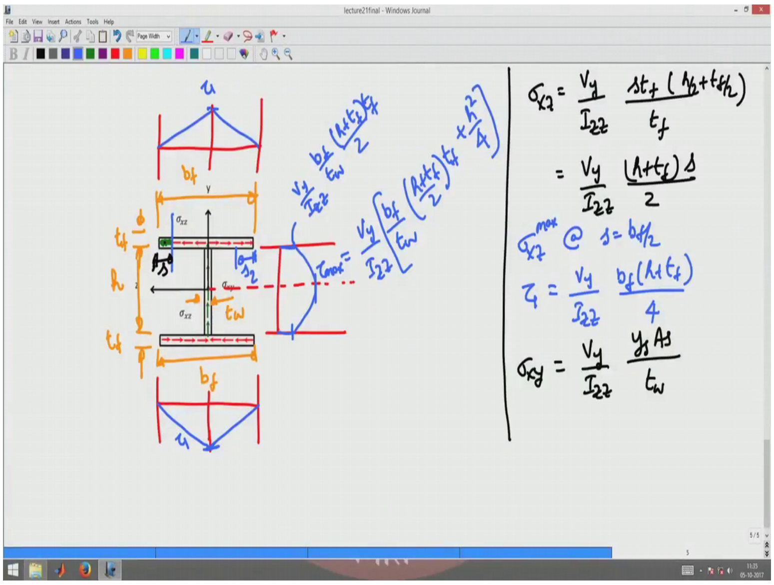

$$\sigma_{xz}=\frac{V_y}{I_{zz}}\frac{s t_f\,(h/2+t_f/2)}{t_f}$$

$$=\frac{V_y}{I_{zz}}\frac{(h+t_f)s}{2}$$

σ_{xz}^{max} @ $s=b_f/2$

$$\tau_1=\frac{V_y}{I_{zz}}\frac{b_f(h+t_f)}{4}$$

$$\sigma_{xy}=\frac{V_y}{I_{zz}}\frac{y_s A_s}{t_w}$$

This I section say I am making this I section from 3 plates or I can make the I section from 5 plates. So, there depending upon how you build up this I section, you have to use the appropriate shear stress; now let us say the I section is made like this.

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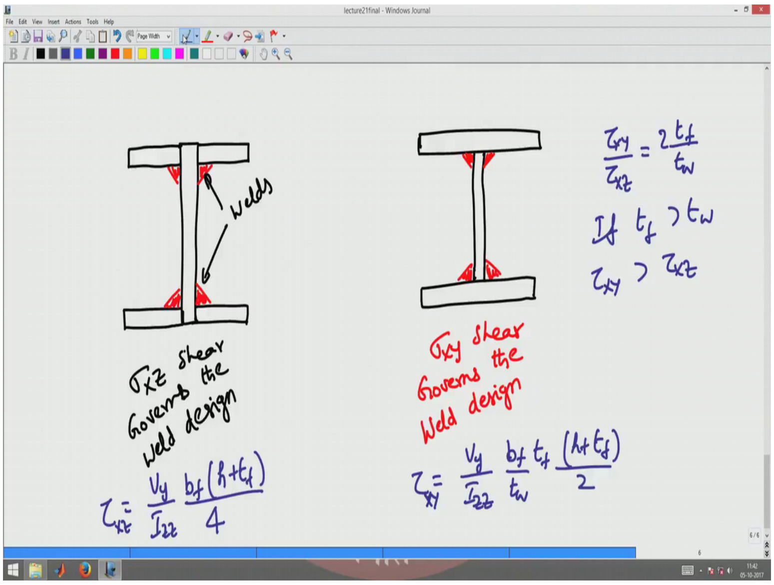

σ_{xz} shear Governs the weld design

$\tau_{xz} = \frac{V_y}{I_{zz}} \frac{b_f(h+t_f)}{4}$

σ_{xy} shear Governs the weld design

$\tau_{xy} = \frac{V_y}{I_{zz}} \frac{b_f t_f}{t_w} \frac{(h+t_f)}{2}$

$\frac{\tau_{xy}}{\tau_{xz}} = 2\frac{t_f}{t_w}$

If $t_f > t_w$

$\tau_{xy} > \tau_{xz}$

I have a plate which runs through the entire depth of the I section, and I have flanges coming out like this, and I have welding it and say I am welding it here and here.

Now, how will this I section fail? This I section will fail because the web flange interface is going to show a differential motion like this. So, this is nothing but sigma x z shear here is what this weld should resist. This is the weld these are welds and this weld should resist sigma xz shear, this is gone by sigma xz shear governs the weld design ok.

In contrast to this I can make a I section like this or I have a through plate for the flange, a through plate for the web and a through plate for the bottom flange too.

Here again now I am going to weld at this interface, now what shear stress governs the design? The shear stress that governs the design here is sigma xy shear governs the weld design or the connection design; it can be nailed also because, in this case I have the web and flange sitting like this, when there is a differential bending this flange is going to slide off like this. So, this is basically going to produce a shear the sigma xy shear.

This sliding is going to provide a sigma xy shear because, x is along this direction of the force y is perpendicular to the web surface on which this flange is moving, this produces a sigma xy shear stress. So, the web has to be designed the weld has to be designed for sigma xy shear stress.

Now, which one of this would you prefer in a design if I want to economize on my welding depth then which 1 would you prefer. Now what is the maximum sigma xy shear stress that comes at this interface. So, I have to design for a shear stress of let us go back a slide tou 1 is V y by I zz into bf into h plus tf by 4, basically you are looking at this tou 1 value; the tou 1 value is given by V y by Izz into bf into h plus tf by 4. So, the value here is V y by Izz into bf h plus tf by 4, that is the shear stress that the weld should resist whereas, here the shear stress that this weld should resist is given by this expression in here maximum shear stress, at the web flange interface is bf by tf into sigma xy of the top flange or V y by I zz into bf by tw into tf into h plus tf by 2 ok.

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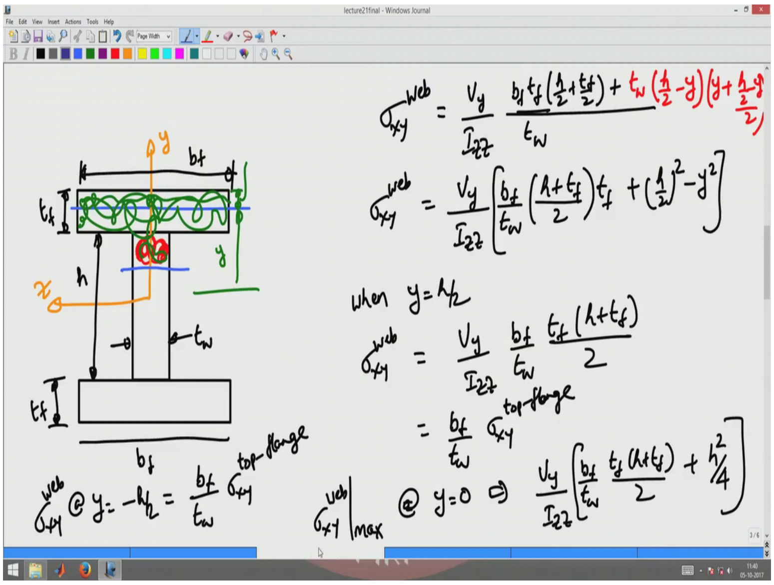

$$\sigma_{xy}^{web} = \frac{V_y}{I_{zz}} \frac{b_f t_f\left(\frac{h}{2}+\frac{t_f}{2}\right) + t_w\left(\frac{h}{2}-y\right)\left(y+\frac{\frac{h}{2}-y}{2}\right)}{t_w}$$

$$\sigma_{xy}^{web} = \frac{V_y}{I_{zz}}\left[\frac{b_f}{t_w}\left(\frac{h+t_f}{2}\right)t_f + \left(\frac{h}{2}\right)^2 - y^2\right]$$

when $y = h/2$

$$\sigma_{xy}^{web} = \frac{V_y}{I_{zz}}\frac{b_f}{t_w}\frac{t_f(h+t_f)}{2}$$

$$= \frac{b_f}{t_w}\sigma_{xy}^{top-flange}$$

σ_{xy}^{web} @ $y = -h/2 = \frac{b_f}{t_w}\sigma_{xy}^{top-flange}$

$\sigma_{xy}^{web}\Big|_{max}$ @ $y=0 \Rightarrow \frac{V_y}{I_{zz}}\left[\frac{b_f}{t_w}\frac{t_f(h+t_f)}{2} + \frac{h^2}{4}\right]$

So, let us write that I zz to bf by tw to tf to h plus tf by 2 rights let us say this is xz y xy now what is the ratio of sigma xy by sigma xz, that will be tf by tw 2 times that right. So, typically tf by tw will be greater than 1. So, you can see that if tf is greater than tw sigma xy or tou xy is greater than tou xz. So, you want to design if you have weld (Refer Slide Time: 06:02) is critical you have to design as this because, it will require less amount of weld depth compared to this design.

Now, let us say I am not interested in welding it, but I am interested in nailing this I section like this, I am going to build up a I section from wood instead of steel.

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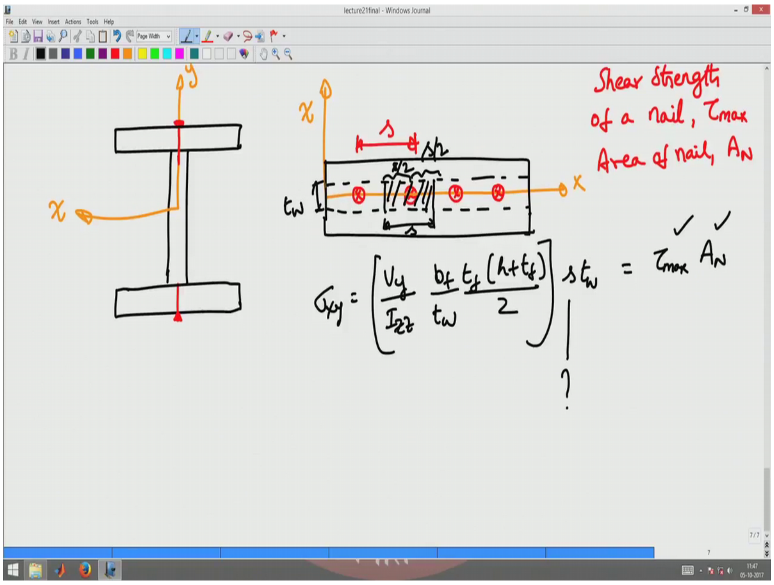

And I have nail which goes through like this and I have nail which goes through like that, in the top view this is y and z and if I plot a top view, which is x and z. Now this nail would be pushing at some regular intervals, say this place in between the nails was s and I am interested in finding out what should the spacing be given that the shear strength of a nail is tou max.

So, and area of the nail is AN, now I am interested in finding what should be the spacing of this nail. So, that it can withstand the shear stresses that are coming on that section. So, here as you see it as to withstand sigma x y stress, the nail has to withstand because the flange is going to slide like this, the nail has to withstand the sigma xy stress and the sigma xy stress at that interface is given by V y by I zz into bf, from here bf by tw to tf to h plus tf by 2 ok.

Now this shear stress into s into tw that is what you are saying is here the web is like this is tw. So, this nail should withstand whatever stress comes in this region this distance is s, I am assuming the nails are uniformly spaced and hence I am assuming that s by 2 is the distance, the distance is s by 2 and this distance is also s by 2 ok.

So, the net distance is s and the net area is this entire area that is s into tw. this should be resisted by tou max into area of nail. So, the entire shear stress that comes shear force that comes in that area has to be resisted, but by that single nail there. So, a into AN now I know AN I know tou max I know the cross sectional dimensions I know V y, Izz and all those things. So, from here I can find what s is, this facing of the nails I can find from here ok.

So, as we saw in the previous lecture if I did not have this nail and if I add just the plates on top of the other, there would not be integral action and hence there would not be there will be suppression of the surfaces between the web and the flange, and hence do not resist the load as we would not resist unless you design the connection properly. So, that is the reason you have to find the shear stresses and there is a reason why you have to design the connection to resist the shear stress that comes on that section appropriately ok.

Now, now let us look at the equilibrium of forces on moments due to the shear stresses shows on defection. So, I have an I section.

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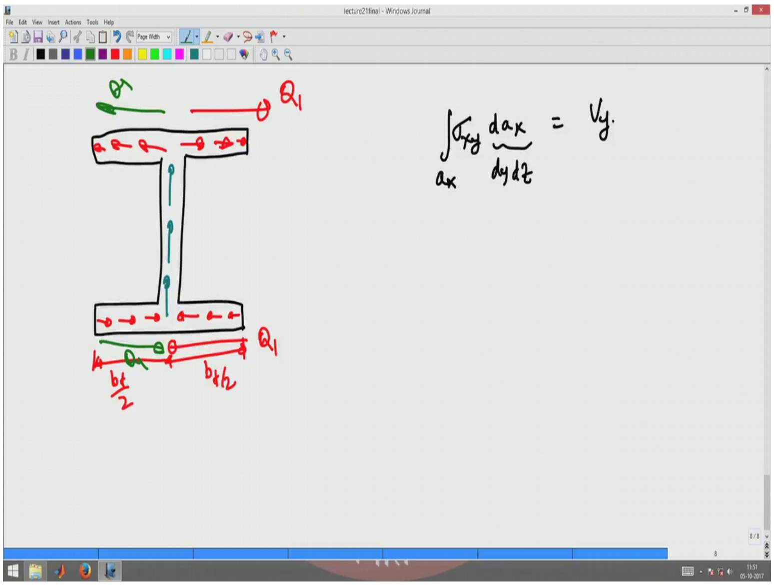

$$\int_{a_x} \sigma_{xy} \underbrace{da_x}_{dy\,dz} = V_y.$$

So, the flanges with along the 2 directions were the same. So, basically what will happen is I add a shear flow like this. So, this was bf by 2 and these two horizontal forces cancels out each other they will be of the shear magnitude, as thus the horizontal force on the top flange here on this side ok.

And the sum of this vertical shear stresses would integrate to give you Vy, that is integral sigma xy dax ax would give me Vy, you can show that I am not going to show in this course, but you can integrate the expression that we got for sigma xy; integrate this dax is dy dz you can integrate and you can see that it will lead to Vy; now let us look at so the force equilibrium is satisfied now let us look at the moment equilibrium ok.

The moment equilibrium what happens, there is a net horizontal force here since this Q1 there is a net horizontal force for same magnitude Q1 on this side. So, what is this going to do this is going to produce a clockwise movement. Similarly there is a net force this will also be a flanged Q1 acting like this, Q1 will be a net force Q1 acting like this and the net force Q1 acting like this.

Now, these are again balanced forces separated by a lever arm this produces a anticlockwise movement or say magnitude as the clockwise movement that was produced by the shear stresses or by the other shear stresses right. So, what will happen is now this section there is no torsion in it; torsion in the section. This movements that is generated due to this Q1 being separated by some distances a movement along the axis of the beam. The movement that this Q1 is generate is along the axis of the beam and even the those are torsional moments.

In this cross section since all the forces were equal and separated by the same lever arm, the torsional moment and net torsional moment is 0 for this section. But there are sections where this will would not happen, and in the next class let us see what happens for those sections.

So, in the next class you will see what happens to those sections where there is a net torsional moment coming in because stress distribution ok.

Thank you.