Design of Connections in Steel Structures
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Module - 2
Lecture - 11
Design of Groove Welds

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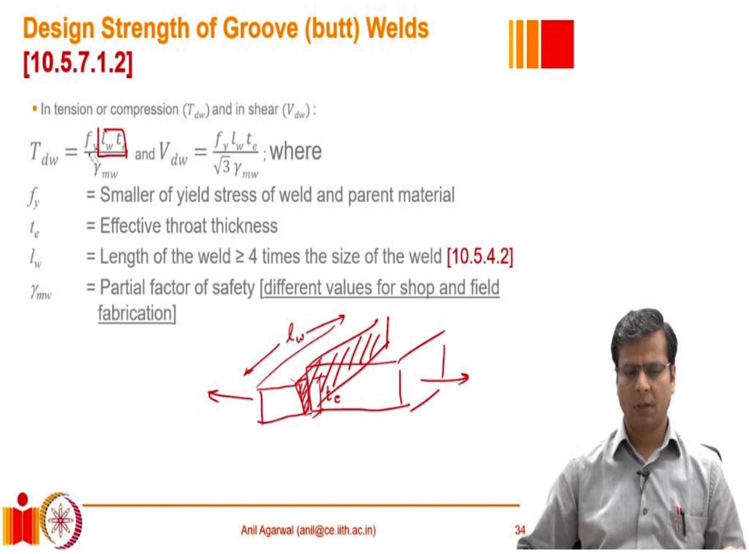

First we will start with the design provisions for groove welds because they behave in a very simple fashion. They do not completely alter the geometry, or the stress flow remains very similar to what it was in the parent material. And therefore, the designing of groove welds is very simple. If it is a full penetration groove weld, we basically take the thickness of the thinner plate that is joined at that location.

If it is a partial joint penetration type of a groove weld, then we take the effective throat thickness as we have discussed in the earlier sections, which is again basically can be taken as the summation of the 2 throat, 2 portions of the weld which are provided. So, if the groove weld is subjected to tensile or compressive stresses, then the strength of such a weld is governed by the yield stress of the material.

So, which yield stress would we take? We take the yield stress of whichever one is the smaller, smaller of the weld and the parent material. So, if we are using an Fe 410 steel, it has a yield stress of 250 MPa. And let us say we are using a EX40 type of a welding material, that is electrode, which has a yield stress of 330 MPa approximately, then we would use an f_y of 250 MPa. l_w basically represents the length of the weld.

So, let me draw it for an easy understanding. If we wish to join these 2 plates using a groove weld, let us say these 2 plates, and we provide a welded joint between these 2 plates. The thickness, that is the throat thickness of the weld is this one, that we will use in t e. In the third dimension, in the direction perpendicular to this plane, we will take the l value, that is l_w, that is length of the weld.

So, if it is a single continuous weld, we will take the entire length; if it is an intermittent weld, we will take the length appropriately. f multiplied by f_y; so, basically, t multiplied by l_w gives us the total cross-section which is subjected tension. And this plate is subjected to tension in this direction. So, the entire cross-section which is subjected to tension, that cross-section is given by l_w multiplied by t_e. This will be multiplied with f_y.

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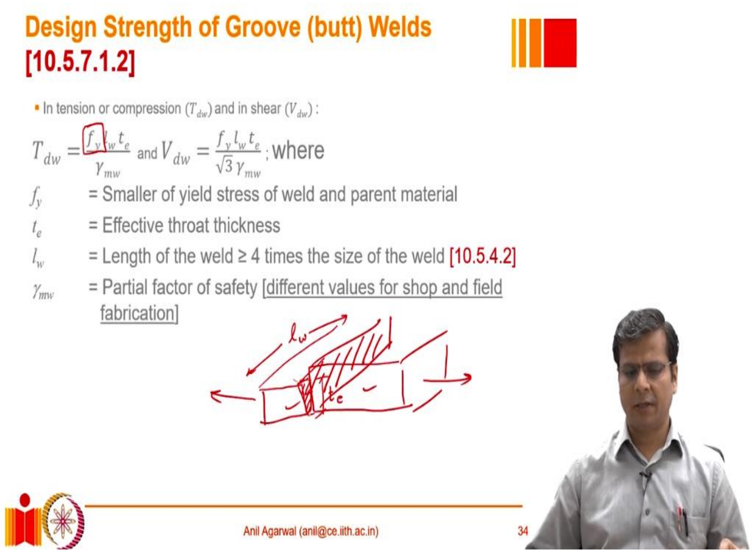

f_y is the yield strength, minimum of the two, because the parent material and the weld material, they are acting in series, and therefore the overall strength will be minimum of the two. That is why f_y is taken as the minimum of the parent material and the welding material.

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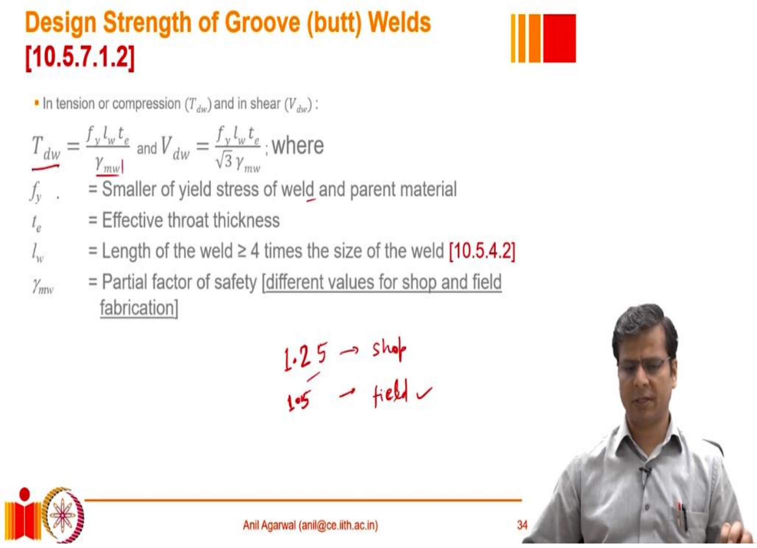

And then we divide it with gamma mw, where gamma mw is basically partial safety factor for welded joints. There are 2 different values given for partial safety factor for welded joints in the Indian code. It is 1.25 if it is a shop weld, and it is 1.5 if it is a field weld. The reason for providing a larger value for a field weld is that, in field typically, there is a high likelihood of making some kind of a mistake and allowing some kind of impurities or some kinds of a sharp surfaces or not fully fused surfaces into the weld.

So, because field welds are relatively less reliable, therefore, the factor of safety is increased. So, the design strength is decreased. When we design the same weld for shear, again through an example, let me show you.

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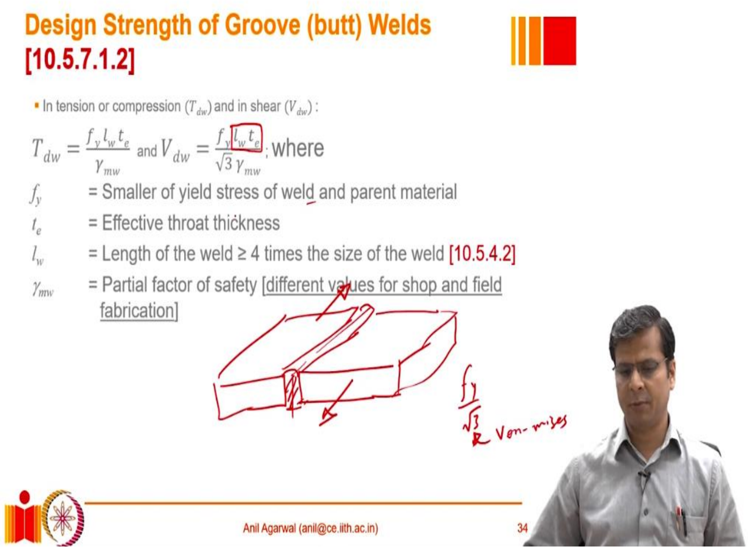

So, these are the 2 plates that are joined together using a groove weld. Then it is subjected to shear force like this. If this is the shear force demand, again the cross-section area that is going to resist the shear force is the same, which is l_w multiplied by t_e like before; that will be used. And instead of f_y, this time we will use f_y divided by $\sqrt{3}$. And we might have discussed, where does this $\sqrt{3}$ come from?

This $\sqrt{3}$ comes from the von Mises failure criteria for ductile materials. So, for ductile materials, when they are subjected to pure shear, they yield at a shear stress of f_y divided by $\sqrt{3}$, if f_y is the yield stress in pure tension; divided by γ_{mw}; γ_{mw} again is a factor of safety as discussed before. So, this is how we calculate the shear strength of a groove weld.

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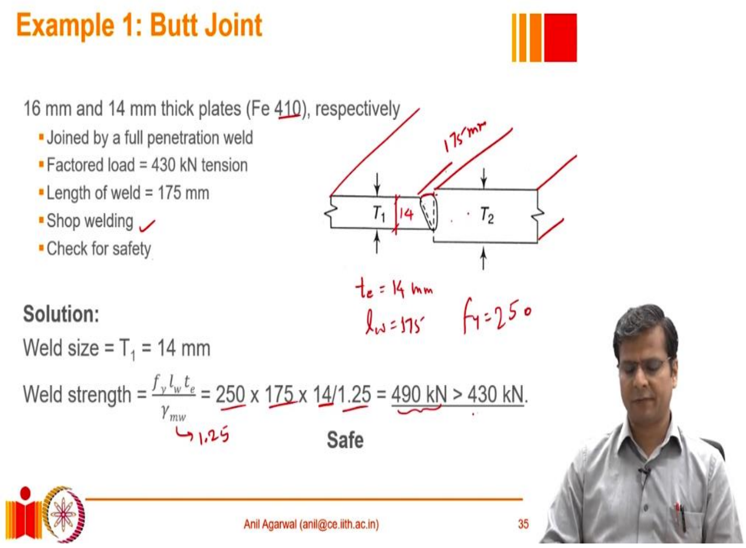

Here is an example. If we join these 2 plates; one is 16 millimetre thickness and the other one is a 14 millimetre thick plate. So, this one is 14 millimetres; this is 16 millimetres; these are joined. And we are using a full penetration weld, which is basically, the entire thickness of T_1 is welded with T_2. And a factor load of 430 kilonewton is to be applied in tension. So, these are pulled in tension.

Length of the weld is given as 175 millimetre. When we say length, we mean the value, the dimension in the direction perpendicular to the screen. So, in this direction, the length is 175 millimetre. It is mentioned that this is shop welding weld, therefore, γ_{mw} value will be 1.25. And we need to check whether this weld is able to resist this much of load or not. So, we know that T_1 and T_2, between T_1 and T_2, T_1 is smaller, which is basically equal to 14 millimetres.

So, if this is 14 millimetres, so, t_e will be 14 millimetres; l_w is 175; f_y which is minimum of the two and I have not mentioned the weld material, but weld material has 330, as we discussed before. And when we compare that to 410, Fe 410 yield stress, it turns out to be 250, which is smaller of the two. So, we will use 250 as the yield stress, 175 as l_w value; t_e is the size of the throat thickness divided by γ_{mw}

And what we get is the design capacity of this weld, which is 490 kilonewton. And the capacity is greater than the demand. The demand was 430 kilonewton, therefore, this welded connection is found to be safe.

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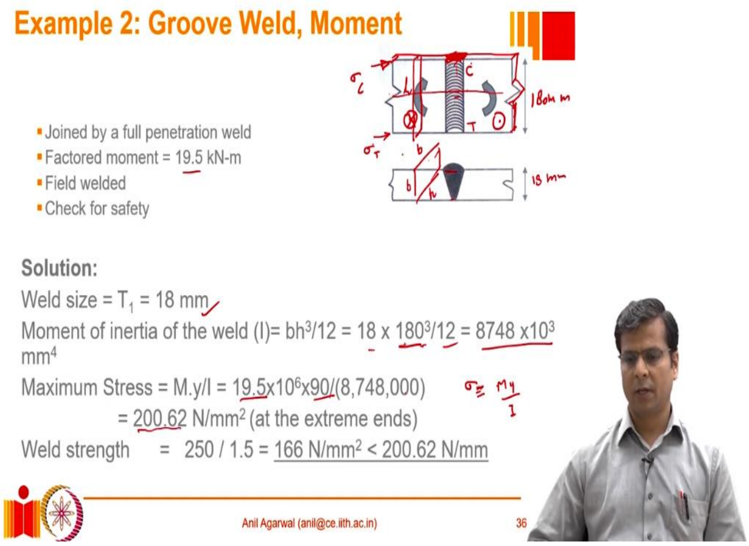

Now, let us take an example of a groove weld which is not subjected to tension, but it is subjected to bending. Now, as we know, bending basically consists of compression and tension combined. So, here you can see a plate which is joined to this plate. Both plates have the same thickness. The thickness is given as 18 millimetres. This is again a full penetration weld; that means, the entire thickness of the plate is welded together.

The moment demand is given is 19.5 kilonewton metre. So, if I may show it this way, the moment is actually acting in this direction and in this direction here. So, these are the moment directions. The plate has in the other direction, this is the plate thickness. And this is the thickness of the weld, what you can see here. So, now you can, I hope you can visualise this, how the moment is applied.

In this direction the moment is applied. So, as a consequence of this moment, we can expect this portion of the weld to be in compression and the bottom portion of this weld or the bottom portion of this plate to be in tension. And the neutral axis can be assumed to be at the centre because it is a symmetric cross-section. So, first we will start with calculation of stresses and we will see whether the stress here is within the permissible limit.

That is the basic design philosophy. So, in order for us to calculate the stress, we need to calculate the moment of inertia of the plate which is basically the same as the moment of inertia of the weld. So, we are basically going to calculate the moment of inertia of this cross-section, which is also the same cross-section, that is the weld. So, we will calculate the moment of inertia of this cross-section.

This cross-section moment of inertia will be $b\ h^3/12$, wherein the h will be this and b will be the thickness. So, this is b and this is the h value. So, half of the h is above the neutral axis, half of the h is below the neutral axis. So, h will be 180 millimetres. The thickness is given as 18 millimetres. So, we will use 18, 180 cube divided by 12. This gives me a moment of inertia of $8748 \times 10^3\ mm^4$

Now, we can very easily calculate the maximum stress in such a plate. If you know the moment of inertia, the maximum stress sigma will be Mxy/I. The same sigma will be present in compression at this edge, and it will be present in tension at this edge. This is sigma tension; this is sigma compression; but the same value. We do that; we put the value of the moment which is applied kilonewton metre.

And then, y value will be the distance from the centroid. So, in this case, 180 divided by 2, that is 90, divided by the moment of inertia which we had calculated before. And what we get is the stress value, which is 200.62 newton per millimetre square. How much stress is this weld allowed to take as per the limit state of the weld?

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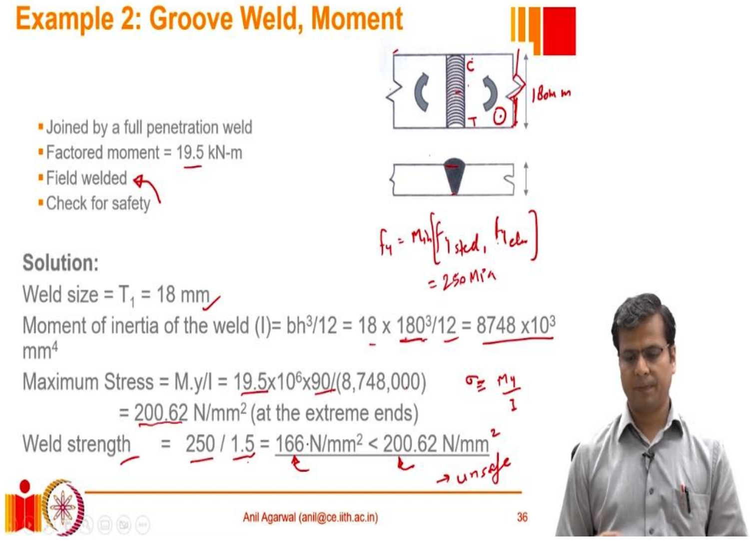

The weld strength can be calculated as which is basically f_y which is minimum of the two yield stresses, f_y of steel and f_y of the electrode. So, we use that; we get 250 MPa as f_y; we substitute that; divided by 1.5; because this is a field weld. If it is a field weld, the factor of safety will be 1.5. We use that and basically, we can get the weld strength which turns out to be 166 kilonewton per millimetre square. And the demand or the stress was 200 newton per millimetre square. And as a result, we can say that this weld is unsafe, because the demand is greater than the capacity.