Design of Connections in Steel Structures
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Module - 3
Lecture - 18
Design of Simple Seated Angle Connections

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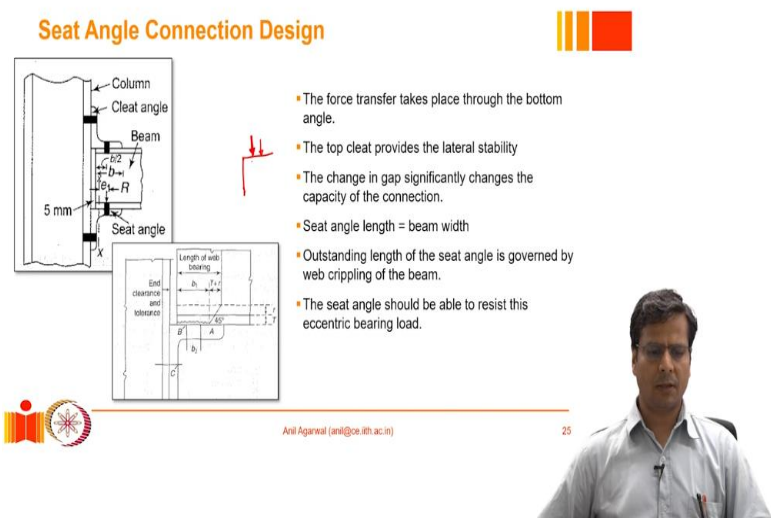

So, we have just seen how to design a double angle connection, including the effect of eccentricities. Now, let us also do one example wherein we will solve a simple connection which uses a seat angle. As we had discussed before, in a seat angle type of a connection, the angle that is provided at the top is often known as top angle or cleat angle. That only helps provide stability to the connection; it does not really help with the resistance of the load, because such an angle does not have very high stiffness when we pull it downward.

However, so, most of the load is basically transferred to the bottom angle that is called the seat angle. And the loads that are acting on the beam have to be transferred through bearing mostly between the bottom flange of the beam and the top edge of the seat angle. Subsequent to that, this force has to be transferred from this leg of the angle to the vertical leg of the angle. And then, that has to flow through the bolt here to the column flange.

This type of a connection usually is not possible to be provided on floor systems, that is between the girder to beam connections. Because of the presence of these two angles, it makes it relatively cumbersome for floor systems. However, it is relatively easy to provide it with a column. Here, one must realise that there is again a gap left between the beam and the column.

And the purpose is the same that it should allow some flexibility for the beam to rotate. So, therefore, there is a gap left. Now, if that gap is too little, it will not give the beam any flexibility to rotate. And when the beam wants to rotate, it will pull on this cleat angle and it will introduce unnecessary tension force demand, which we can avoid simply by increasing this gap.

However, the downside of it is that, if this gap is too high, then the angle here will be loaded with a very large eccentricity. You can appreciate that if this gap is increased, the gap between the beam and the column flange is increased, that increases the eccentricity which is acting on this angle. So, if I may draw this angle; if this is that angle, and depending on where this load is acting, whether if the load is acting close to this edge like shown here, then the moment demand will be less; therefore, we do not require a very strong angle here.

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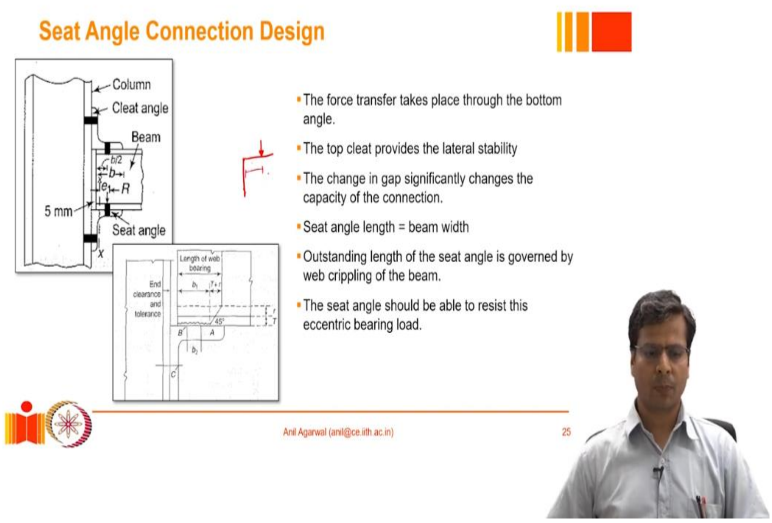

However, if we increase that distance for the same amount of shear force that we are applying, the distance meaning that the lever arm would increase and therefore the moment demand would increase;

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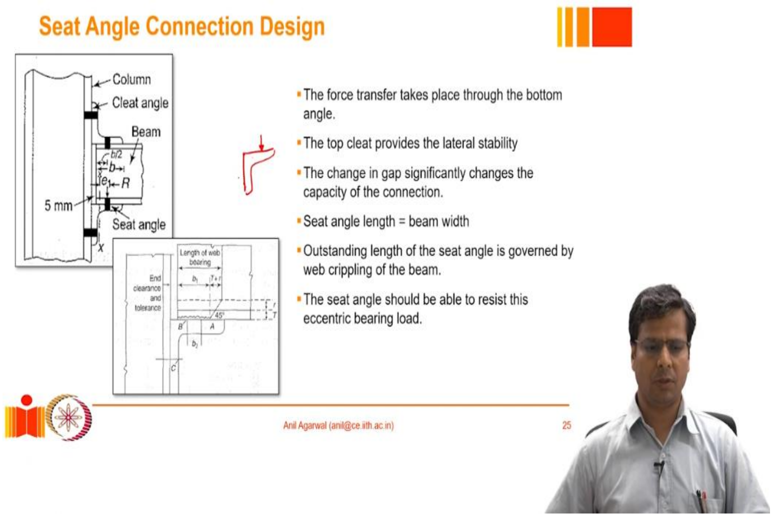

And that may require a very strong, very high strength angle to be utilised. Typically, the bearing surface is basically, the angle would cover the entire bearing surface of the bottom flange; so, the effective width of the angle will be same as the width of the beam flange. Here, what we may appreciate is that, not only that we need to design this angle, the top leg of this angle for the moment and shear demand which is acting at this location, right at the beginning of the root of this fillet, the demands here, but also we should be careful about the high stress that may develop in the beam because of this localised bearing area.

So, the portion of the beam web which has the smallest cross-section is right above the root. Here what you may see is that, this is the flange of the beam which is marked as T, that is the thickness of the flange of the beam. Then there is a root of the beam.

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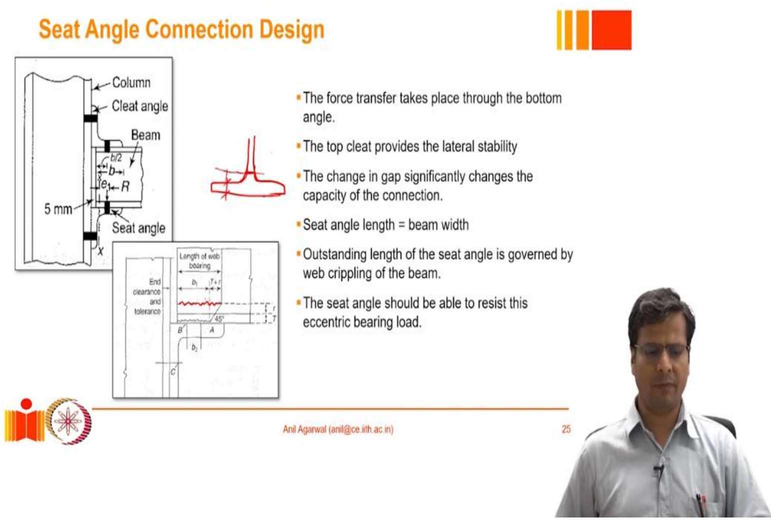

So, if I can look at the cross-section of the beam, typically, the beam cross-section near the bottom flange would look somewhat like this. So, we have got T which represents the thickness of the flange. Then there is a root which is represented with r here in this diagram. So, T + r is the initial portion, after which the cross-section in the web is the smallest. And that is where we will have the highest stresses developing.

So, we should look at the possibility of crippling failure of the beam web in this cross-section. So, these are the 3 primary limit states that we need to design it for. So, we should be able to design the angle to resist this load and we should be able to make sure that the web does not cripple under this concentrated force at this location.

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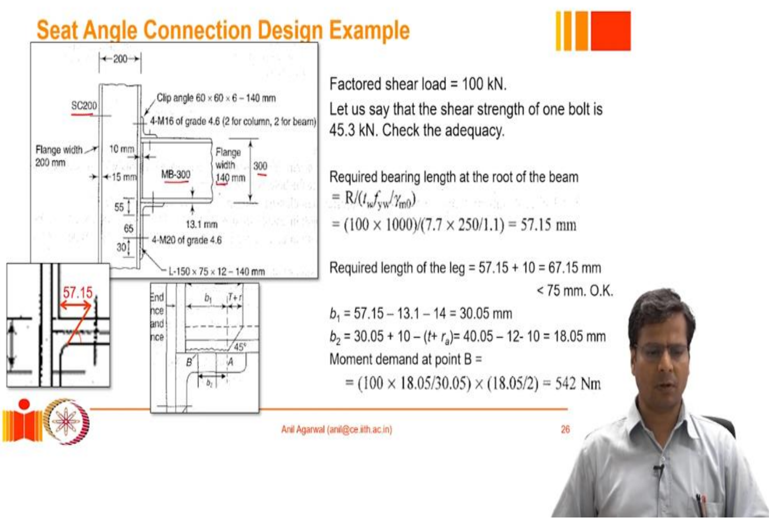

So, let us do an example. Let me describe with a problem. This is a column of section SC 200. This is supporting a beam of ISMB 300 size. Of course, this beam we all know that it should have a total depth of 300 millimetre. And ISMB 300 beam has a flange width of 140 millimetres. Now, how is this load transferred? This load is transferred with the help of these two angles.

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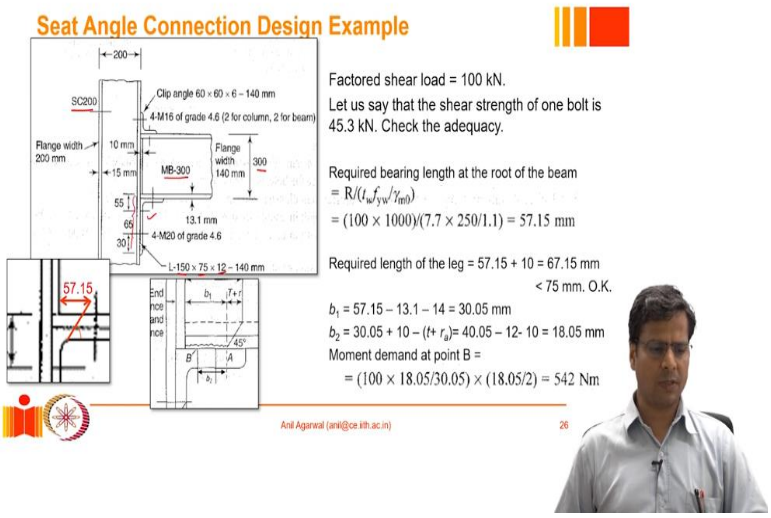

One angle is the seat angle. This is an angle of size 150x75x12. So, 150 is the vertical dimension of this angle, vertical leg. And the horizontal leg is 75 millimetre wide. And 12 millimetre is the thickness of both these legs.

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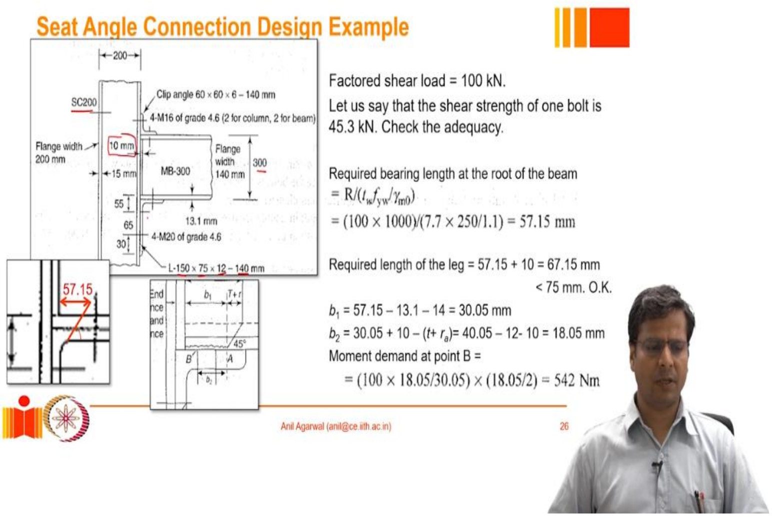

And 140 here represents the length of the weld which is basically equal to the width of the beam flange in the direction perpendicular to the screen. Also, additional information which is relevant here is that we are leaving a gap of about 10 millimetres between the beam and the column surface. The column dimensions are given, 15 millimetres thick flange is present.

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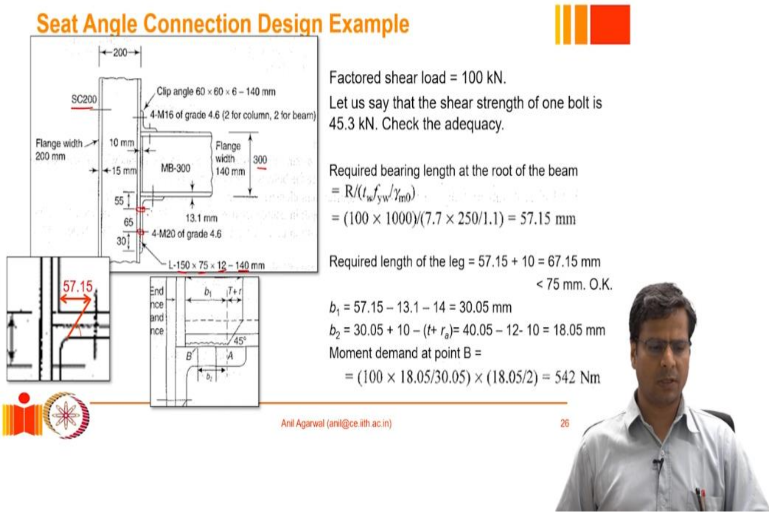

And also there are these bolts there, which we can design these bolts based on our understanding. So, for this example, we will not worry about designing of these bolts; we are just going to focus on designing of this angle;

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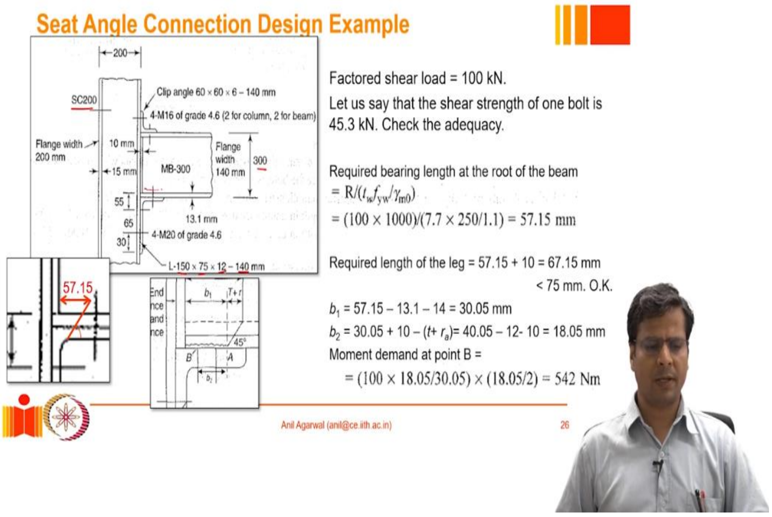

And making sure that we have sufficient bearing surface available, to prevent a crippling kind of failure at the beam web.

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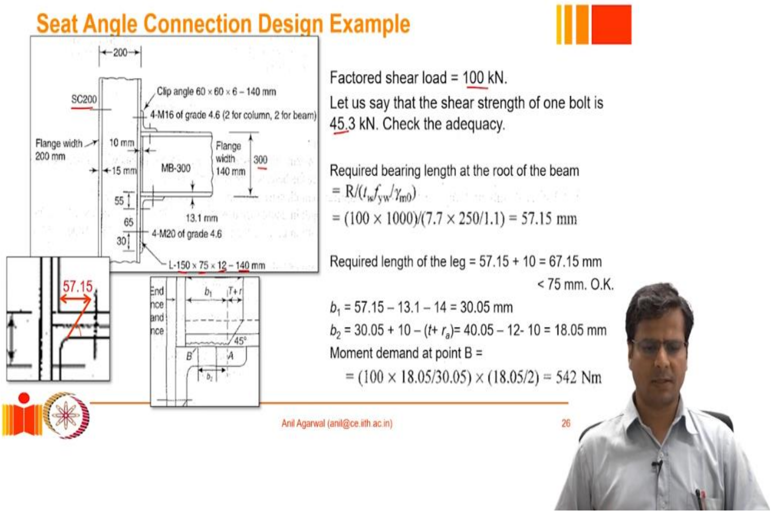

The factored shear load is given us 100 kilonewton. Of course, there is no explicit moment acting here. At the end, only 100 kilonewton shear force is acting. And let us say we already know that the shear strength of each bolt is 75 kilonewton. So, 1 bolt can resist a shear force of 45 kilonewton; and the external load is 100 kilonewton. Now, we will start with looking at the design of the crippling failure in the beam web.

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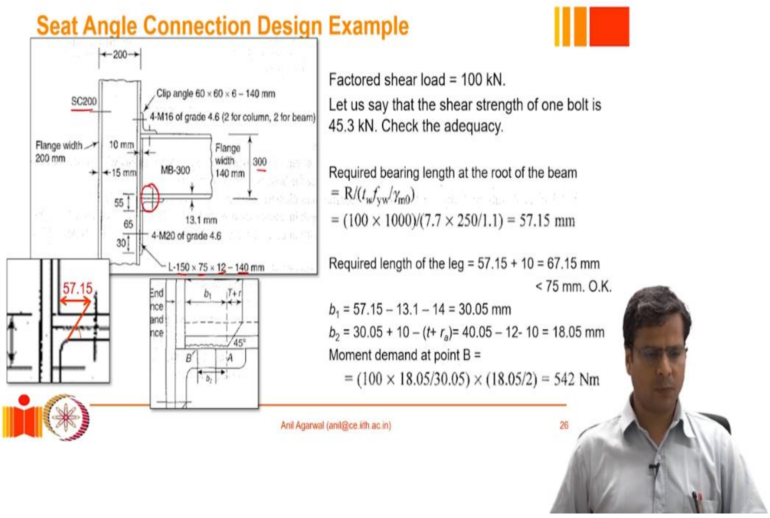

So, let me zoom-in into this area here. So, where should we worry about a crippling failure?

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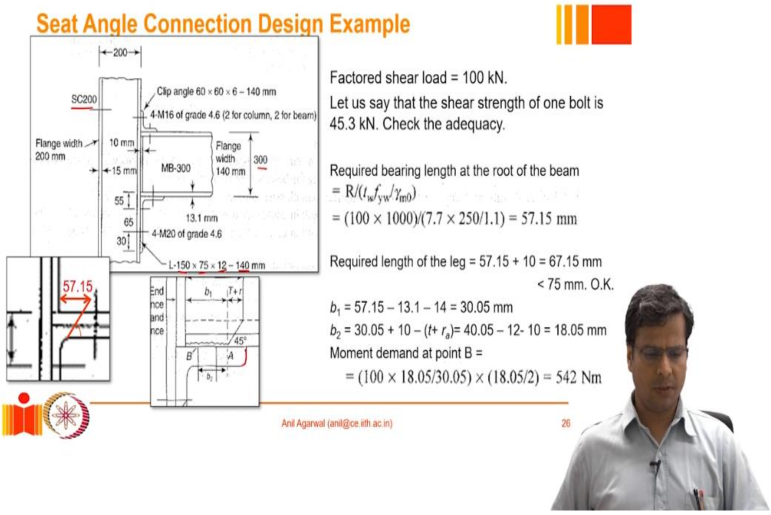

This is the angle, what you see here; this is the horizontal leg of this angle. This is where the beam starts.

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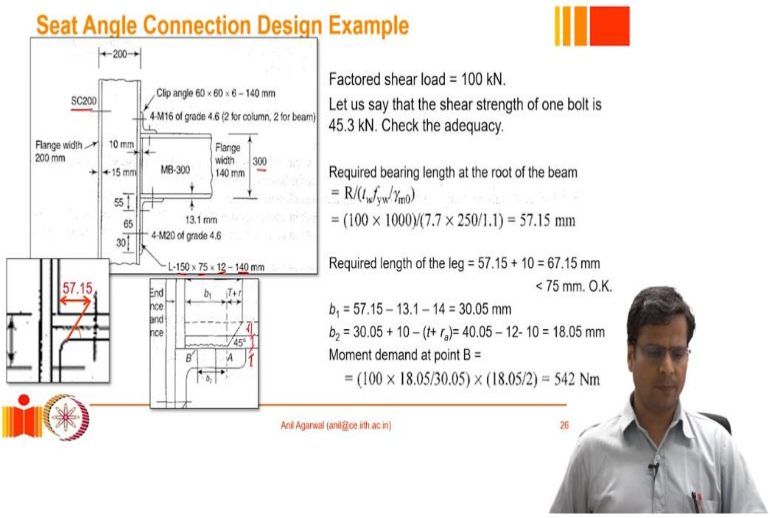

So, this first, this length is or this depth is the thickness of the flange. Then this is the radius of the fillet.

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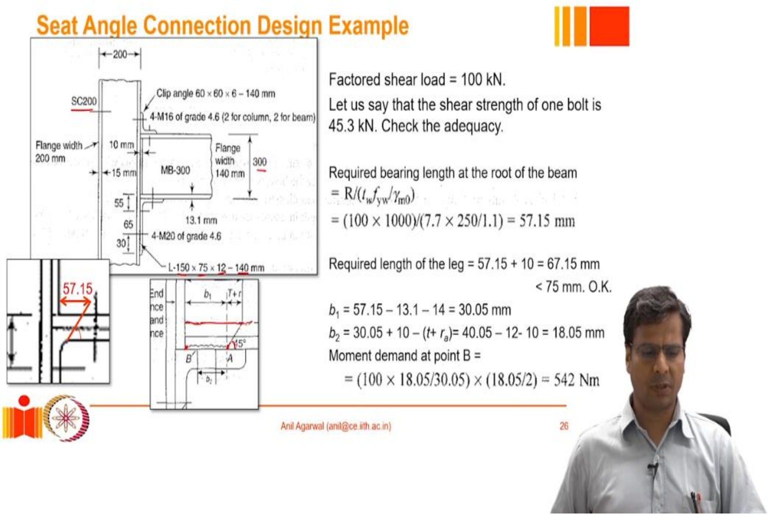

So, this is the cross-section; this should be critical cross-section above the radius of the fillet; that is where the crippling failure could occur. So, we should look at this cross-section and we should; generally, we assume that if the stress is acting over this length between, at the bearing surface;

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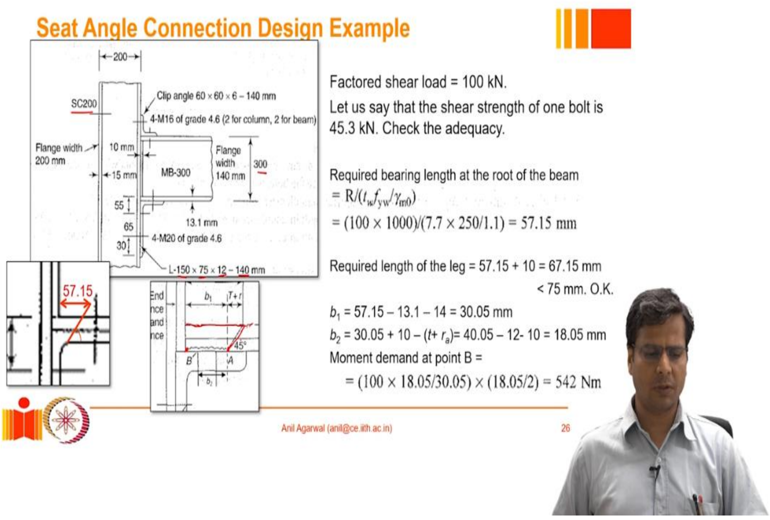

As we go up, the stress distribution or the area over which the stresses are distributed would be spreading out at an angle of 45 degrees. This is the general assumption we can make that is used for steel structures. So, if we go with that assumption;

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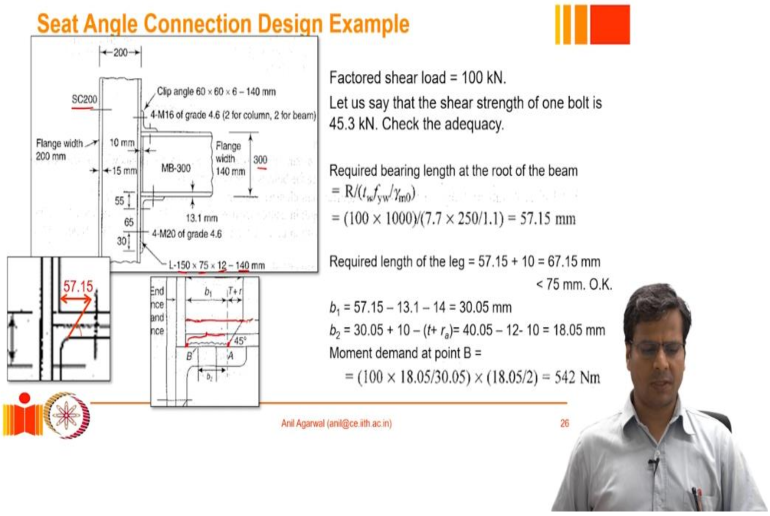

And let us say there was certain length over which this force was applied, that length would increase as we go up further into the flange and then the fillet.

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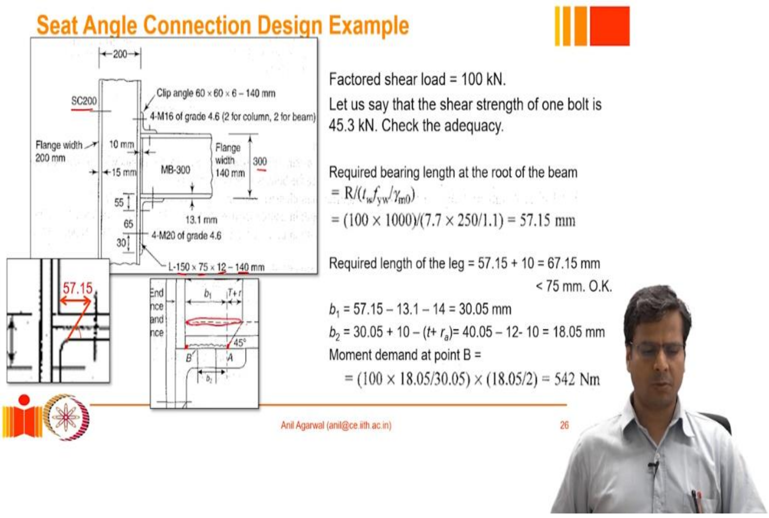

So, let us try to first find out how much is that length over which this stress should be distributed, so that we do not have a crippling failure of the web. So, that length will be b_1 + T + r. So, let us try to find out that. So, the crippling failure of the web; so, this web is subjected to compression. So, it will be governed by the yielding of the web surface.

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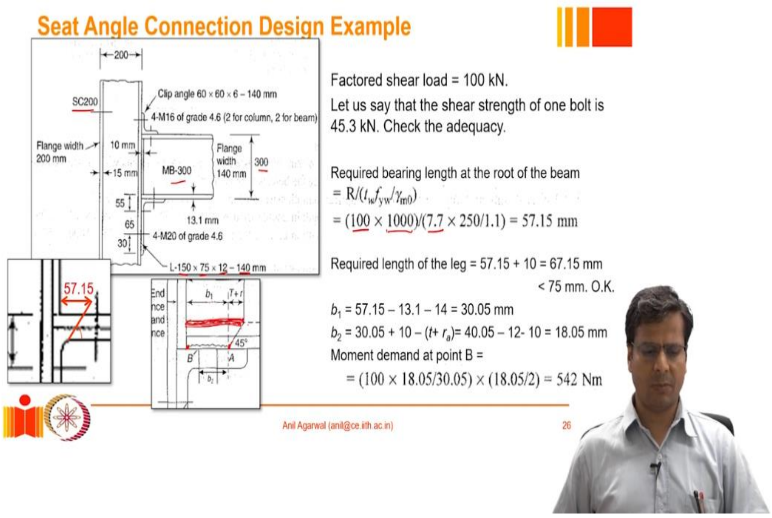

So, the total force is given as 100 kilonewton. Converting that to newtons, meaning that I will multiply with 1000, then the web thickness for as ISMB 300 section is 7.7 millimetres. So, what we are doing is that, we are calculating the total force that is acting on this beam and we are calculating the area, cross-section area of the web which will be resisting that force. So, that web cross-section area is this length multiplied by 7.7 millimetre. That is the thickness of the web.

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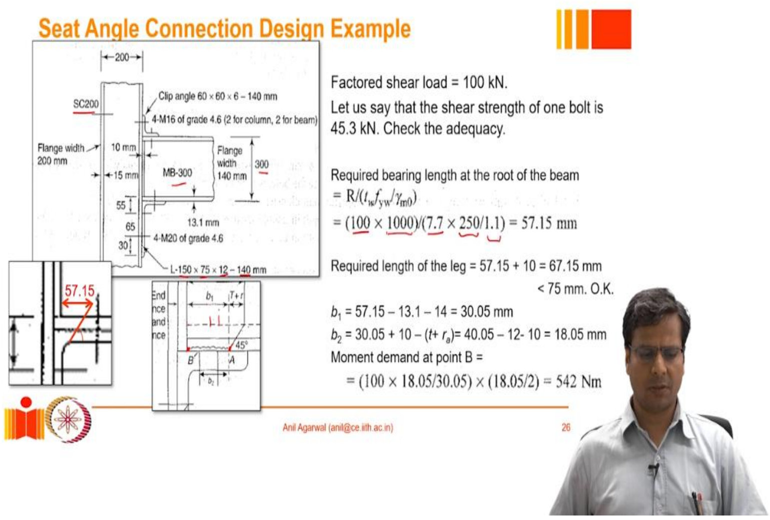

Then, divided by the yield stress and a factor of safety of 1.1; these are taken. So, this is because this primarily compression. So, it is governed by yield stress. And what we get is a 57.15 millimetre.

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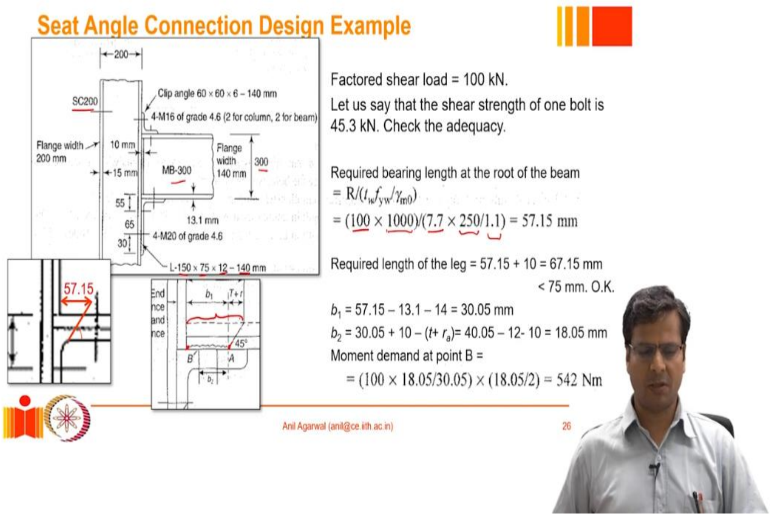

So, basically, this length, that is $b_1 + T + r$ is; we need at least 57.15 millimetre length here, so that the web crippling can be prevented for the given load. Now, since we know that the area over which this stress is acting spreads starting from here to here at an angle of 45 degrees;

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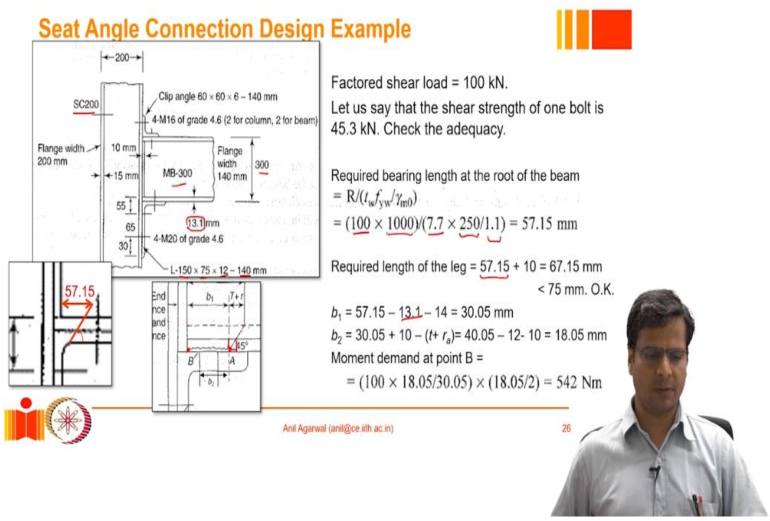

So, what we will do is, we will take this 57.15, and then we will remove the 13.1 millimetre. What is 13.1 millimetre? 13.1 millimetre is the thickness of the bottom flange of this beam. So, first we remove the 13.1 millimetre which is thickness also this width. So, first we remove this portion which is basically T. So, we take away T. And then we take away 14 millimetres, which is the fillet radius approximately. So, we take T and r out.

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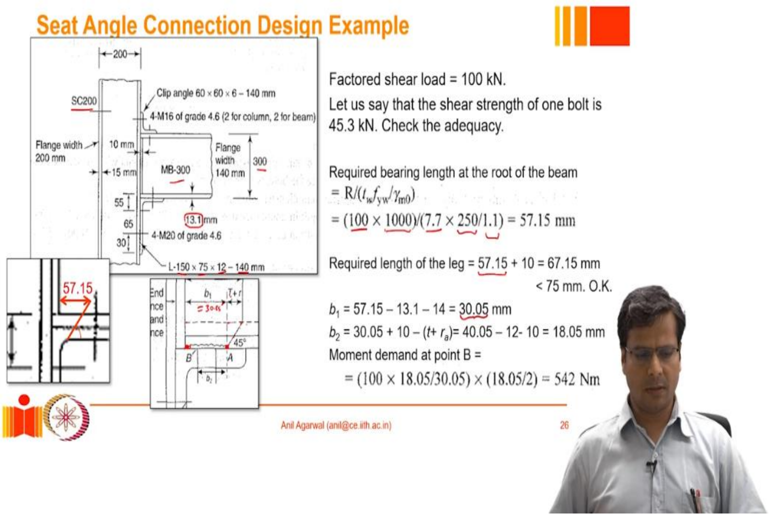

So, what we are left with is 30.05. That is my b_1 value. That is the minimum bearing surface we need between the angle and the beam. Now, the leg, of course, needs to be longer than that.

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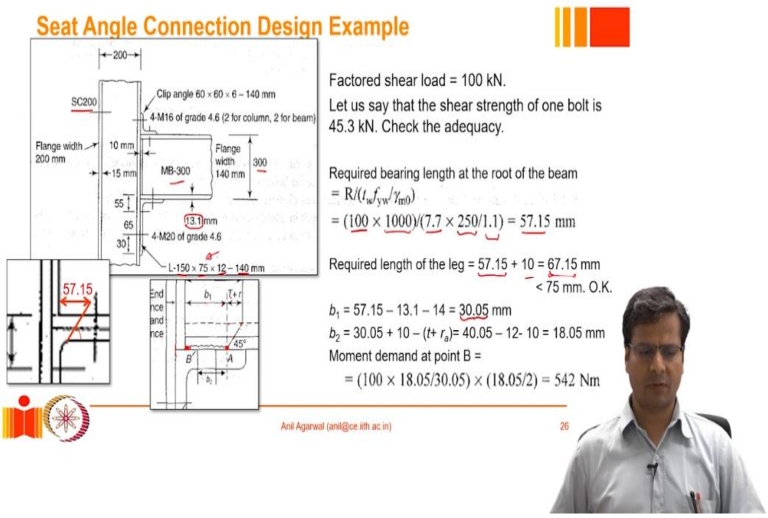

So, the leg can be taken as whatever the total length of this force was, in addition to that, we will add some additional 10 millimetres to account for the gap between the beam and the supporting column. And for that we add 10 millimetres, which we get as 67.15 millimetres. And that is what we will use here. So, we need the leg to have at least a dimension of 67.15 and the angle that we are using has a leg width of 75 millimetres, which is more than what is minimum required. And therefore, this is safe.

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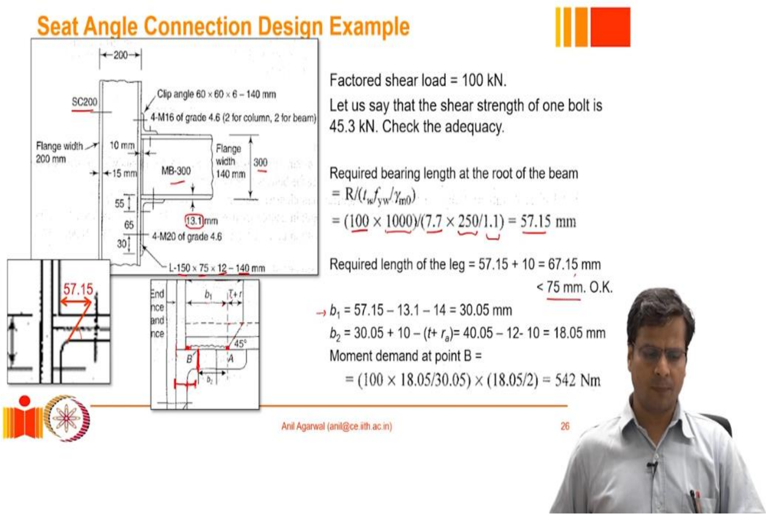

So, we have enough width available in our leg to handle this kind of a load. And now we know that we need a b_1 of at least 30.05 millimetre. Now, if we make sure that b_1 is this much, we will ensure that there is no web crippling happening in the web. Now we need to worry about the failure at this interface, which is the critical interface. Which interface it is? This is the column angle interface; this is the thickness of the vertical leg of this angle; then there is this fillet radius of this angle. So, basically we are talking about the interface that is right after that fillet.

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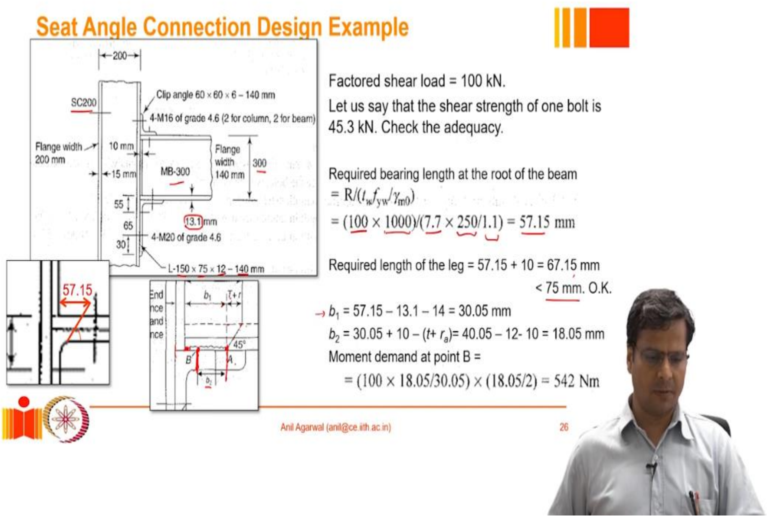

So, for that location, in order to find this location, we will call this distance b_2, the distance between the point where the bearing started or the bearing stresses start developing to the point where the critical section is; that distance, let it be b_2.

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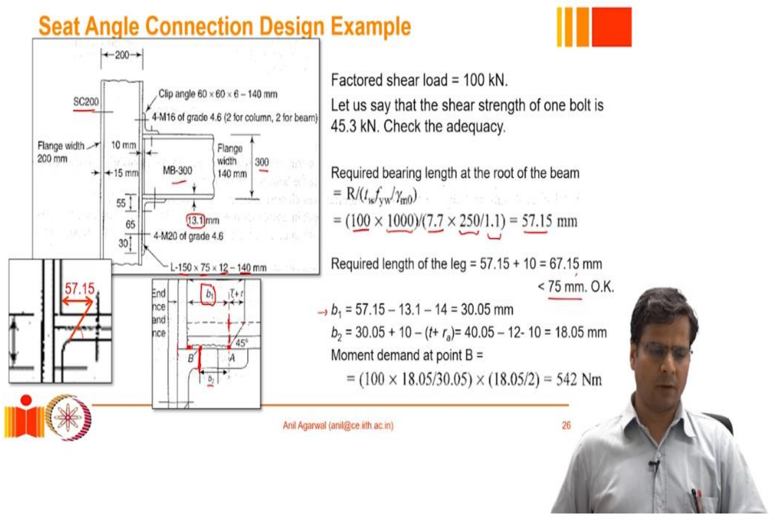

We already know the b_1 value. b_1 value is also the distance between the point over which the force is distributed, stress is distributed to the end of the beam, that is b_1 . So, now, in order for us to calculate b_2, what we can do is;

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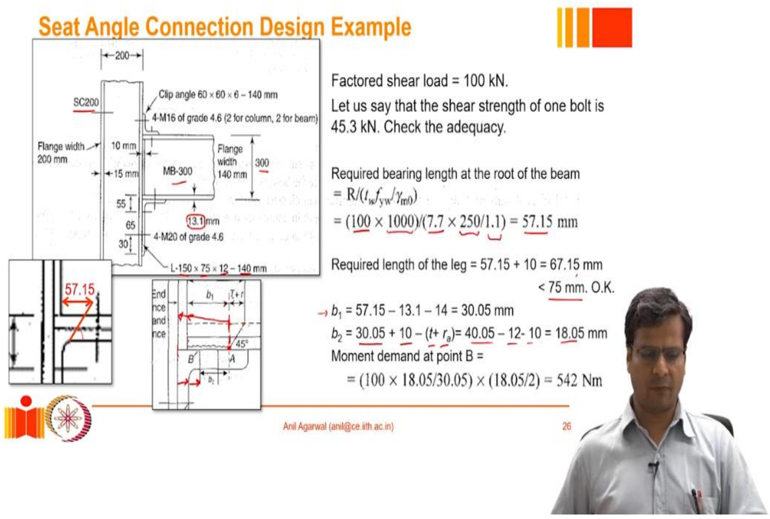

First we can use b_1, then we can add this gap to that. So, we will know the full distance. Then, from there we deduct the thickness of the angle and then deduct the radius of the fillet. So, that is what we do. We take b_1; we add 10 millimetres for the gap; then we deduct the thickness of the leg; and then we deduct the radius of the fillet. And these numbers basically lead us to reach a value of 18.05 millimetres.

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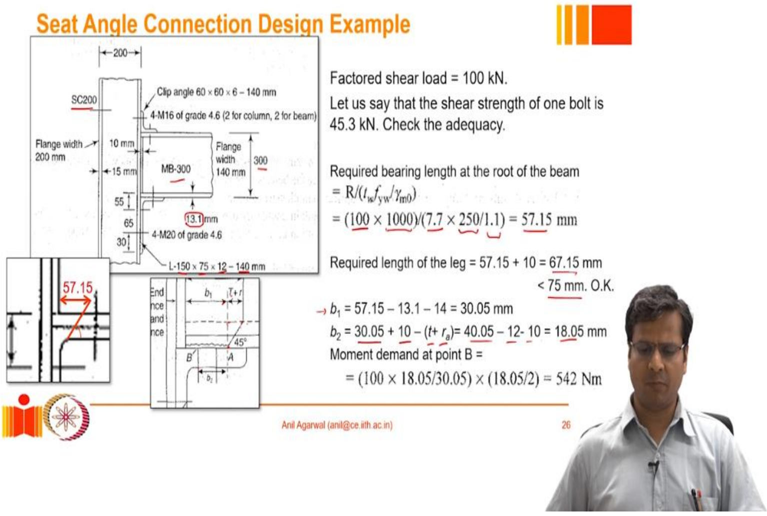

So, now what is happening is, by ensuring a leg of size 67.15 millimetre or greater;

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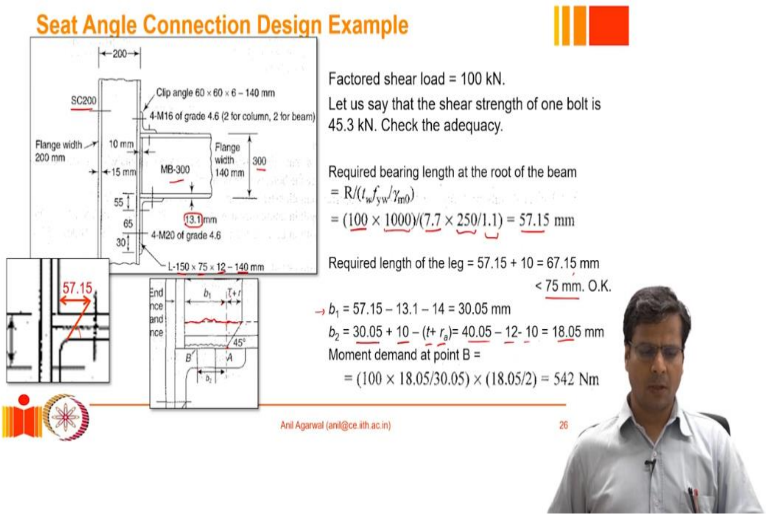

They have ensured that there is no crippling failure here. Also, now we need to make sure that for whatever dimensions we got, we calculated b_2.

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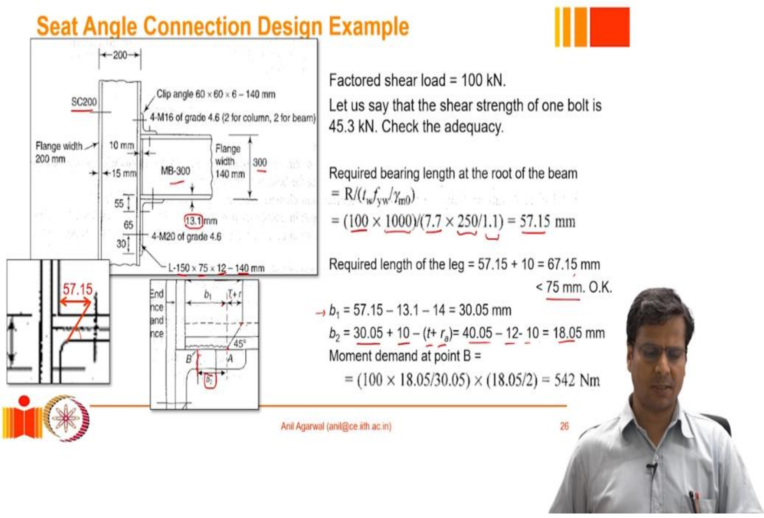

And now we need to make sure that the stresses here, the flexural stresses as well as the shear stresses do not exceed the desirable limits.

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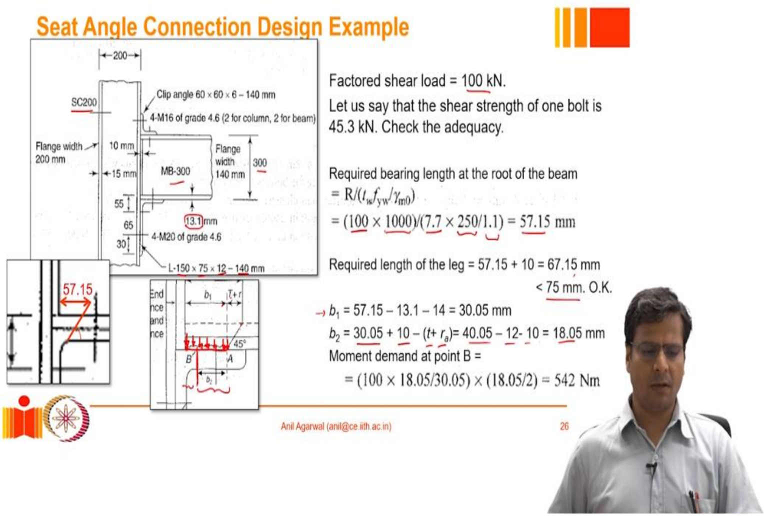

So, as I had discussed, for the angle, if I just look at this angle surface, the forces are distributed over this length. That total force is 100 kilonewton that is distributed over this length from here to here. And this is my critical section; that is where I need to worry about how much force is getting transferred. Now, for us to calculate the moment demand here, we obviously know that the entire force is not getting transferred on this side of this interface or this critical section; some of the force is getting transferred directly to the vertical leg through this side.

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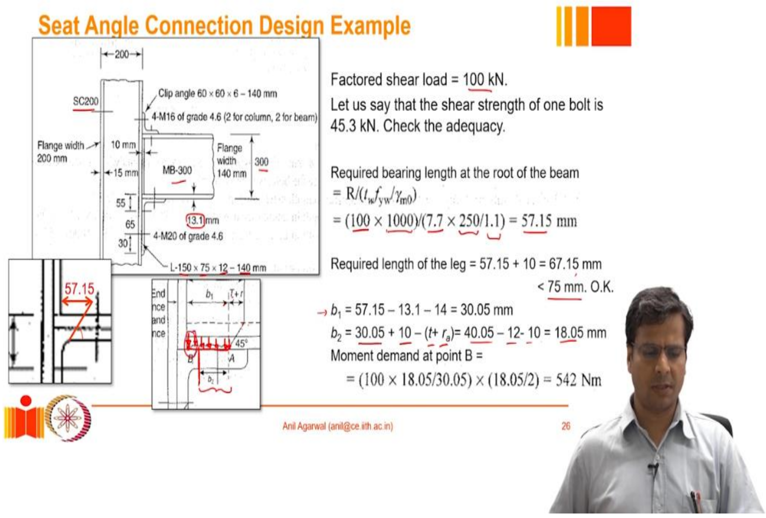

So, we need not consider that; we need not consider this part. So, how do we ignore this part?

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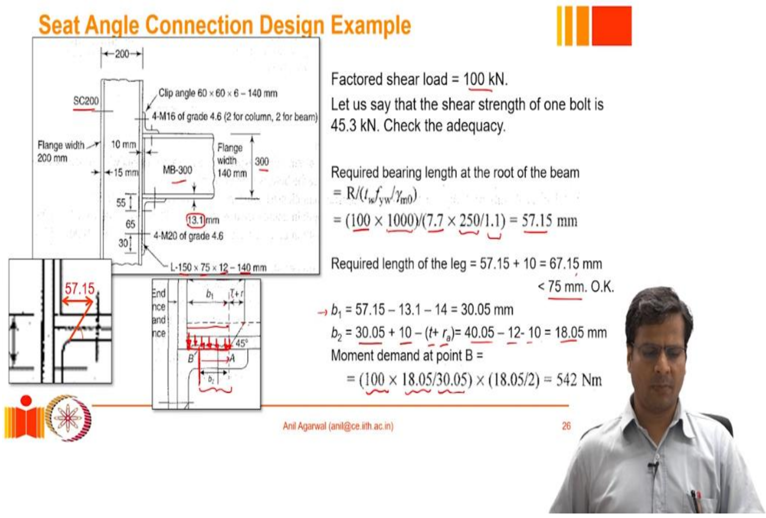

The total force was 100 kilonewton. Assuming that this force is uniformly distributed over this length, we can multiply it with b_2 and divide by b_2. So, total b_2, that was a total length, that was 30 millimetres. And only proportionally large, the length that is proportional to b_2, only that much length will be resisting this force; so, we multiply with that length. And that gives us the total force that is actually acting on that interface. Now, that much of force; let me erase these 2 arrows.

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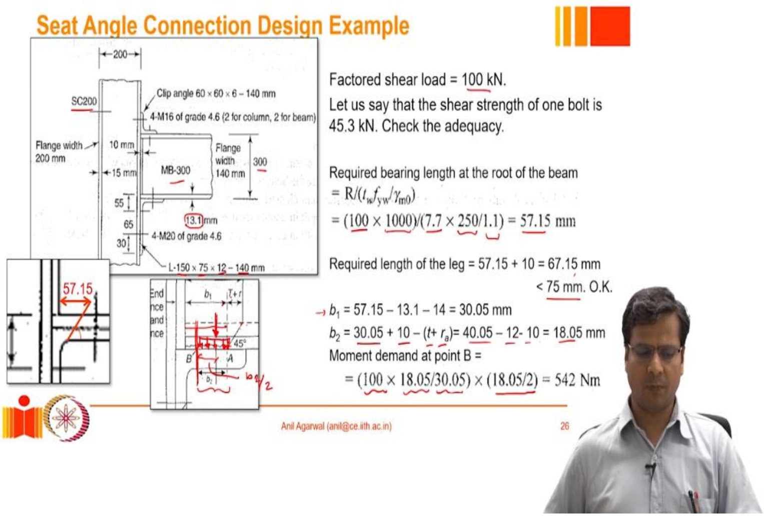

So, this is the force for which we need to design this interface. Now, this force has its centroid at a distance b_2 divided by 2 from the interface. So, this is the interface, and the resulted force is acting here, and it is at a distance of b 2 divided by 2. So, that b_2 divided by 2 will be equal to 18.05 divided by 2. If we multiply this lever arm with the resultant force, we will get the moment demand at the interface.

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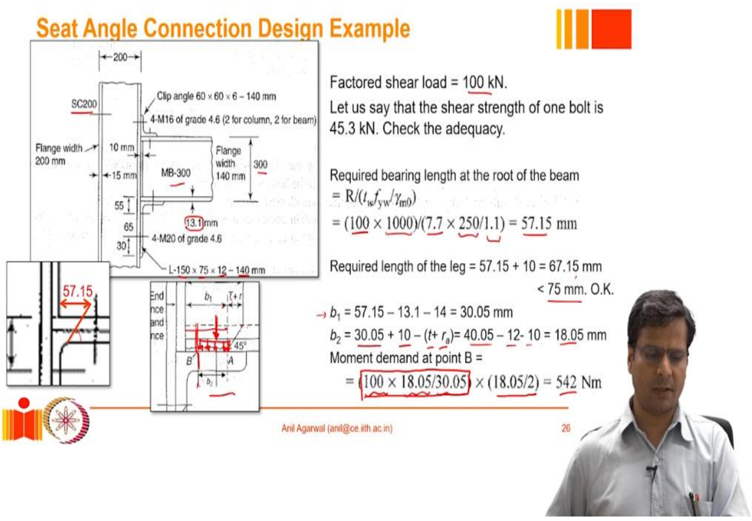

So, we get a moment demand of 542 newton metre at this interface. Similarly, the shear force demand at that interface will be only this much. So, now, we have calculated the moment demand at the critical interface and the shear force demand at the critical interface; we can calculate the capacity of the critical interface.

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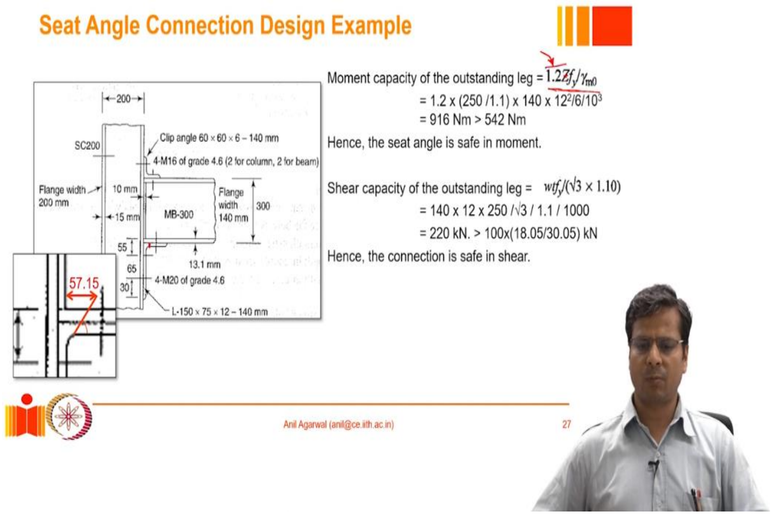

So, that critical section here in this angle can be considered to have a moment capacity of 1.2 times Z times f_y divided by γ_{m0}. What is the reason for 1.2? Basically, we are saying that even though Z we are taking the elastic section modulus, when we multiply with 1.2, that means we are willing to accept the plasticisation and we are actually accounting for the plasticisation of the section.

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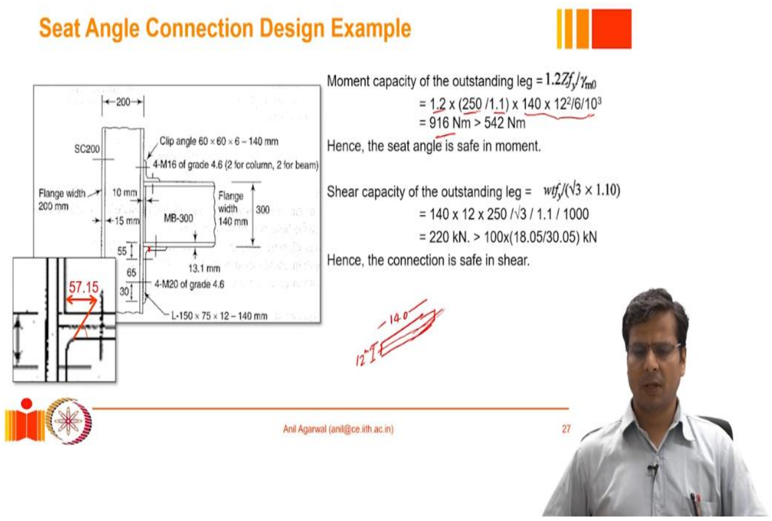

So, we will take 1.2 times the Z value. The Z value has been calculated for this cross-section multiplied by f_y divided by γ_{m0}. And this is basically the Z value, that is the Z value for this angle. So, the leg of this angle, the width of this thing is 140 millimetres and the depth is 12 millimetres. So, based on that, the Z of this angle about the neutral axis which is at the mid height can be calculated, which is calculated here. And then, the moment capacity is calculated to be 916 newton metre which is significantly greater than the demand which was 542.

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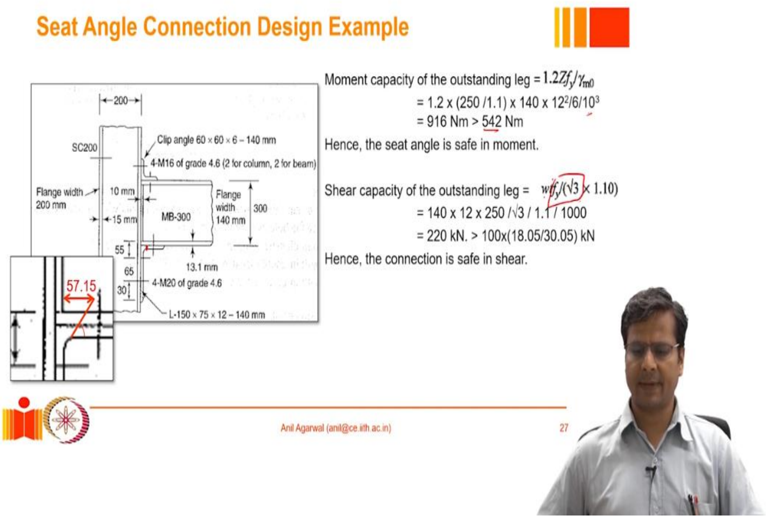

Therefore, this angle can resist the moment demand. Now, it comes to the shear capacity. For the shear capacity, again we will take the entire cross-section; width was 140, the thickness that is 12 millimetres; and we will take f_y divided by √3 as the capacity, because that is the shear capacity of a ductile material.

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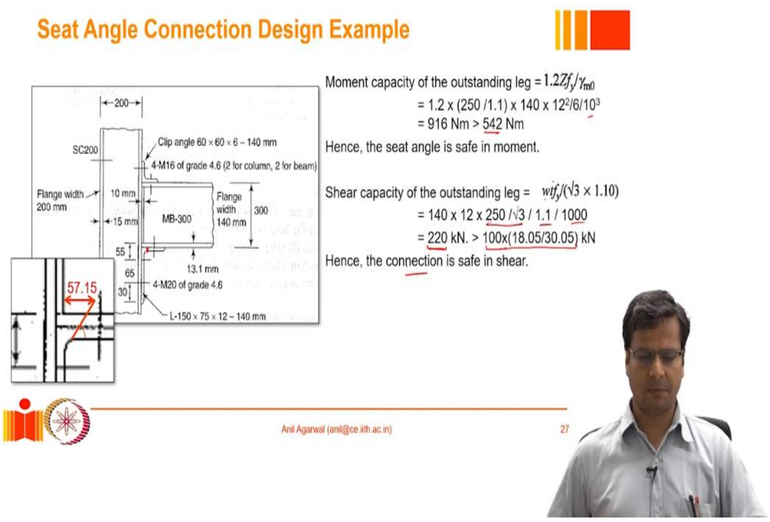

So, which is taken as 250 divided by √3 divided by the factor of safety. And this is just to correct the units into kilonewtons. And as a result, we get the shear capacity of the leg of this angle as 220 kilonewton, which is much greater than the overall shear force demand; but actual shear force acting at that interface is only much smaller than 100 kilonewton. Therefore, this connection is safe to resist the shear as well.