Design of Steel Structures

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Module - 4
Tension Members
Lecture - 2
Design of Tension Member

Hello. Today, we will be going to discuss about the design aspects of the tension member. In last lectures, we have discussed details of the net sectional areas which are going to carry the tensile forces. In last lecture, we have focused that how to find out the net area for different orientation of the members. The members are connected in different way with a riveted connections, with welded connections, one leg connected, two legs back to back connected. So, for different cases we have seen how to find out the strength of that particular member from tensile point of view.

Today, we will do just reverse one; that means first we will assume some appropriate section, then that section with that section whether the given load is able to take that section or not that we will see. That means first we will find out an approximate section, then with that section we will see whether the applied load is being able to carried by that section or not. If not then we will increase the section; if yes then fine, like this we will go. And we have some basis of considering that approximate area; all these basis we are going to discuss. Other things that we will just discuss through some steps through which systematically we will be able to design a tension member.

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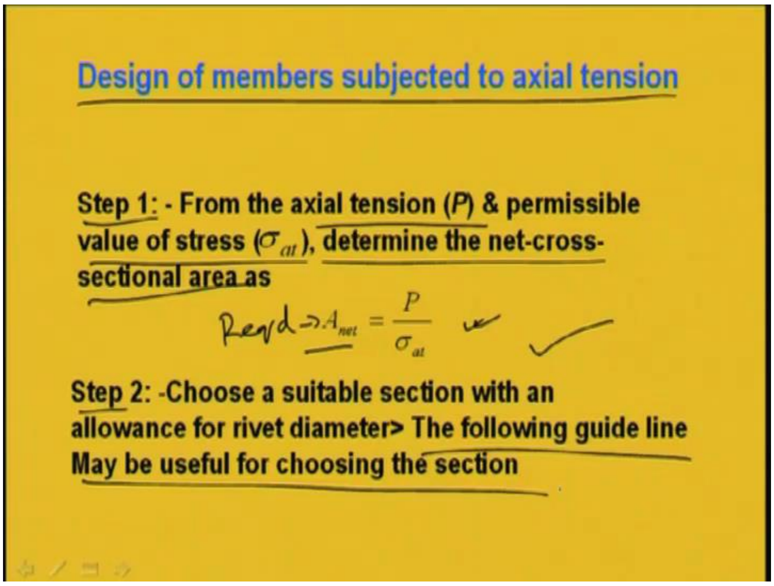

Now, say first design means we will discuss only about the axial tension not the bending. So, tension members means the tension member may have axial tension as well as also bending. But right now, we will be focusing our discussions only on axial tensions. So, first steps what we will do? Step one that first we know the axial tension and permissible value of the stress for that particular grade of steel which we are going to use. So, from that we can find out the required net cross sectional area.

So, means this is required; required net cross sectional area can be found out from this formula that P by sigma a t. So, this is the first steps we have to do. Then what we will do? In step two that we will choose a suitable section with an allowance of rivet diameter; that means we have the net area; now we will choose a suitable section. But we know some allowance has to be given because of net area and gross area is different. So, we have to increase little more. And the following guideline may be useful for choosing the section. So, for choosing the section we will have some guideline.

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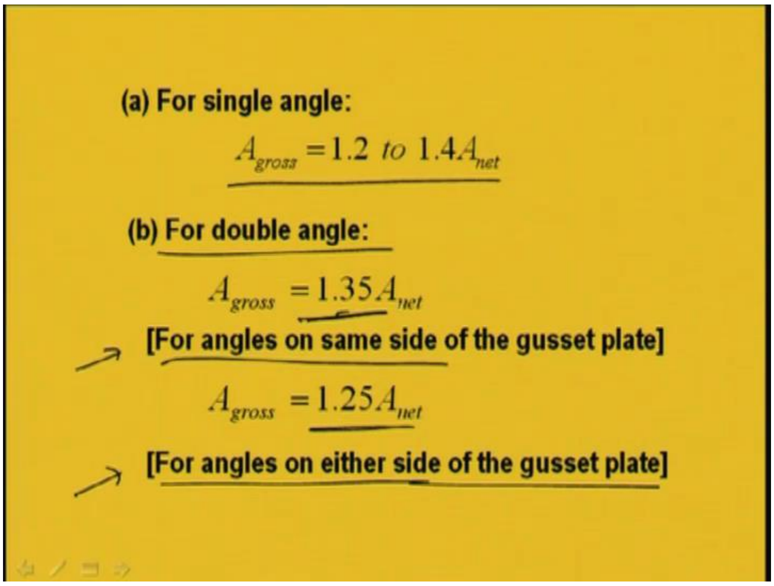

What is that? That for single angle we can use gross area as 1.2 to 1.4 of net area. That means if we are going to use the single angle, then the gross area can be increased 20 percent to 40 percent of the net area. If we are going to use double angle, then we can use 35 percent extra of the net area. So, this is the guidelines which we can follow, but this is not strict; we can change, and we can see whether it is or not. So, basis on that we can make. But at the preliminary stages we can start with this.

Now for angles on same side means this is net area means for double angle for angles on same side of the gusset plate. And if angle is on either side of the gusset plate, then 25 percent of net area can be taken as additional to that. That means for double angle, one is this, another is this. If angles are on same side of the gusset plate, then we can take 1.35 into A net. And if angles are on either side of the gusset plate, then we can take 1.25 into net area that this is how we can start.

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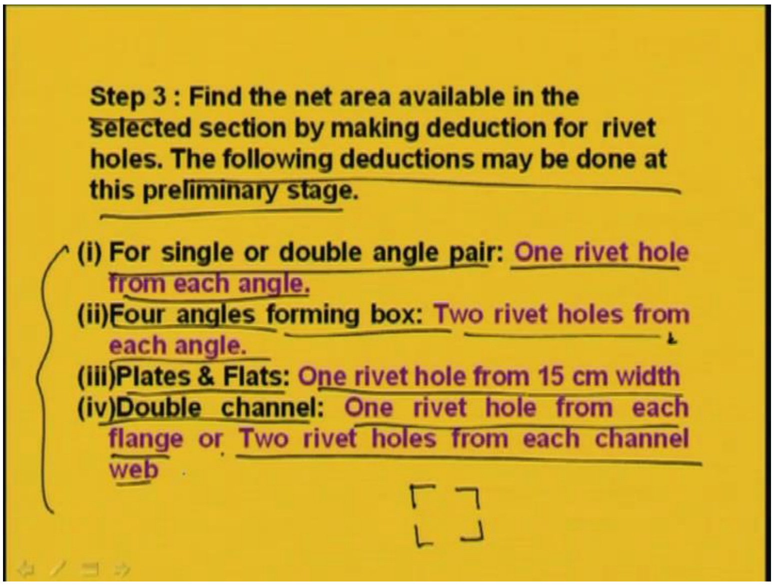

Next, the step three is that find the net area available in the selected section by making deduction for rivet holes; that means we know the rivets are there. So, deduction due to rivet hole has to be made. So, the following deductions may be done at this preliminary stage. So, some guidelines we have. So, these are the guidelines through which we can deduct at the preliminary stage.

However, we have to remember that after doing all the things, we have to recheck all the details because how many numbers we are going to provide the rivet, what are the exact situations we are facing; on that basis, we again have to recheck all the things to ensure that the designed member is capable of taking that much load. So, for single or double angle pair, we can make one rivet hole from each angle; if the single or double angle pair is there, then one rivet hole from each angle we can reduce.

In case of four angles forming box; that means four angles means like this one angle and forming box. So, in this way if it is, then two rivet holes from each angle; two rivet holes from each angle we can reduce. Plates and flats we can make one rivet hole from 15 centimeter width. So, if it is 30 centimeter width, two angle means 15 to 30 centimeter width if it is, then we can make two angle. 30 to say 40 or 45 three rivets; so like this we can make. These are the some guideline.

But we do not know how much it will be finally. Again double channel, in case of double channel, one rivet hole from each flange or two rivet holes from each web. So, this has the deduction of hole at this preliminary stage can be made; two rivet holes from each channel web or one rivet hole from each flange for the double channel we can make.

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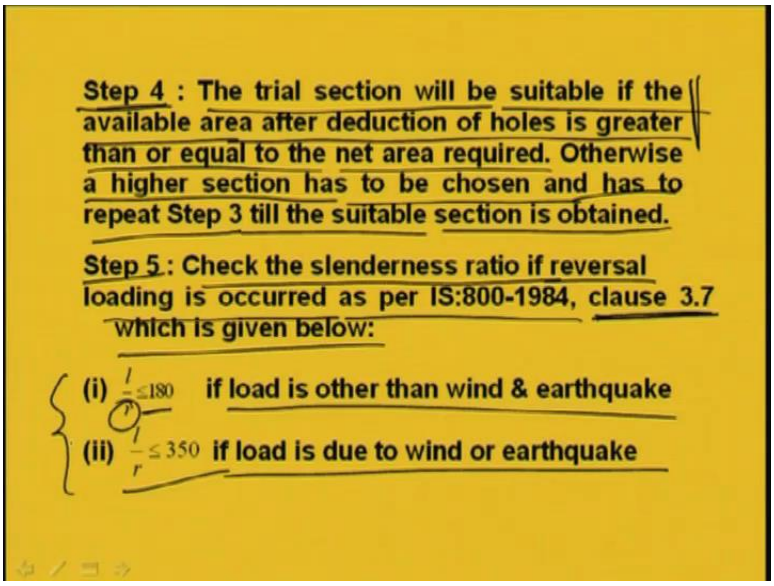

Now step four; now the trail section will be suitable in case, what we will do? The trail section will be suitable if the available area after deduction of holes is greater than or equal to the net area required. That means we know what is the available area after these deductions and we have the net area. Now if the available area is more than the net area, then we can go further. Otherwise, we have to increase the section; otherwise, a higher section has to be chosen and has to repeat step three till the suitable section is obtained.

So, still now what we have done that net area required we have. Now with an increased area, we consider some sectional property means section; with that section, again we have deducted the hole, etcetera, then we have seen what is the available area we are getting. Now this available area if it is less than the required net area, then we have to increase the section; otherwise, we can continue with that.

Now in step five, what we will do? Check the slenderness ratio. If reversal loading is occurred as per IS 800-1984 in clause 3.7, in clause 3.7 of IS 800 has given that slenderness ratio has to be less than 180 if the load is other than wind and earthquake; if other than wind and earthquake, then l by r should be less than or equal to 180. And if load is due to wind or earthquake, then the slenderness ratio should be checked from this that is l by r should be less than or equal to 350.

So, as per the clause 3.7, this codal provision has to be checked. So, where do we get the r? R value we will get either from calculation or from the code that handbook. Because if single angle is there means single angle or I section or Tee section or channel section is there, then its all the properties has been given in the SP 6 handbook. But if we provide the built-up section, then we have to calculate the r radius of gyration. Then we have to find out the l by r ratio, and we have to check whether this is following this codal provision or not. If it is not following, then we have to increase the section again.

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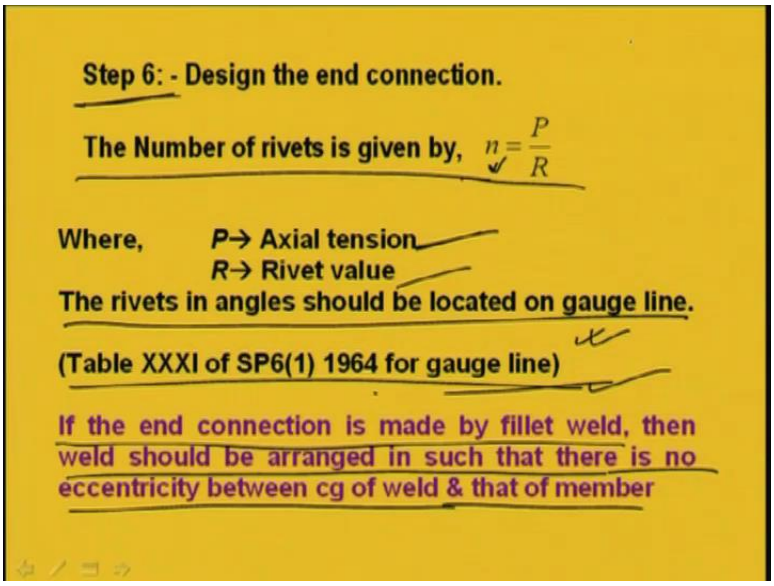

So, the section whatever is required we have found. Now what we will do? Now we will go for the end connection; that means connections we have to do through which the load will be passed from one member to another member. So, number of rivets can be calculated from this formula easily that n is equal to P by R as this is a direct mention. So, simply number of rivets will be equal to P by R, where P is the axial tension which has been provided, and R is the rivet value that can be calculated from the particular diameter of the rivet and type of rivet.

So, the number of rivets can be found out. So, the rivets in angle should be located on gauge line. So, that also is given in the code in SP 6 1964, it has been given the gauge line. That means what are the gauge line, what are the edge distance; all the details has been given in the code and as per that we have to follow. So, what we have done here?

The number of rivets once we found as per the codal provision, we can find out the gauge line and we can make accordingly.

And then what we have to do? We have to recheck once again that because how many number we are providing; depending on that, we have to see whether the net area is available or not. Means what are the new area we are going to get actual area which should be more than the net area required which has been calculated at the step one. So, from this we have to find out.

Now if the end connection is made by fillet weld, then weld should be arranged in such that there is no eccentricity between CG of weld and that of member; it is very important. In case of welding member, we have to ensure that the CG of weld and CG of the force means force of acting should match. Otherwise, eccentricity will occur and because of that eccentricity, the joint will again come into picture due to the moment which has to again redesign. So, in case of weld design, we have to ensure that the CG of weld and line action of force should coincide.

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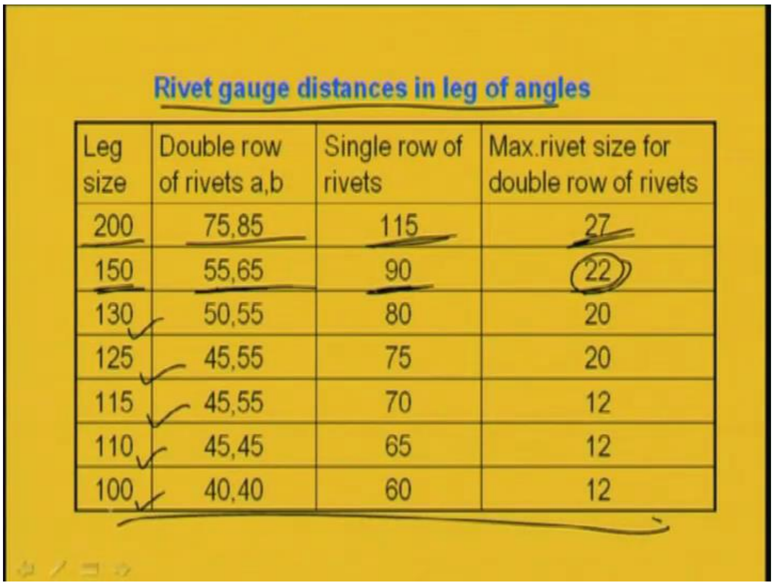
Rivet gauge distances in leg of angles

Leg size	Double row of rivets a,b	Single row of rivets	Max.rivet size for double row of rivets
200	75,85	115	27
150	55,65	90	22
130	50,55	80	20
125	45,55	75	20
115	45,55	70	12
110	45,45	65	12
100	40,40	60	12

So, as per the codal provision which has been given in the table 31of SP 61 that the rivet gauge distance in leg of angles; so for different size of leg, say 200, the double row of rivets a and b has been given. One is 75, another is 85. And in case of single row rivets, this is 115. And maximum rivet size of double row rivets will be 27. So, these are the provision which has been given in the code which has to be maintained while designing the member.

Similarly, for leg size of 150, the double row of rivets a and b, this gauge line will be 55 and 65, and if it is single row of rivets, then it should be at 90 mm. And the maximum size of double row of rivets will be 22. Similarly, for 130, for 125, 115, 110, 100; so all these details has been given in the code, right.

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95	-	55	-
90	-	50	-
80	-	45	-
75	-	40	-
70	-	40	-
65	-	35	-
60	-	35	-

So, similarly again we see for different angles; means below 100 mm leg size, we are not going to provide double row. In that case, we are going to provide only single row. So, the gauge line will be here, and there will be no double rivet; that is why nothing has been provided.

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55	-	30	-
50	-	28	-
45	-	25	-
40	-	21	-
35	-	19	-
30	-	17	-
25	-	15	-
20	-	12	-

So, in this way up to 20 it has been given. So, with all these basis, we have to design a member. Now before going to an example of design of tension member, I will go through one another example through which the strength of the member will be calculated.

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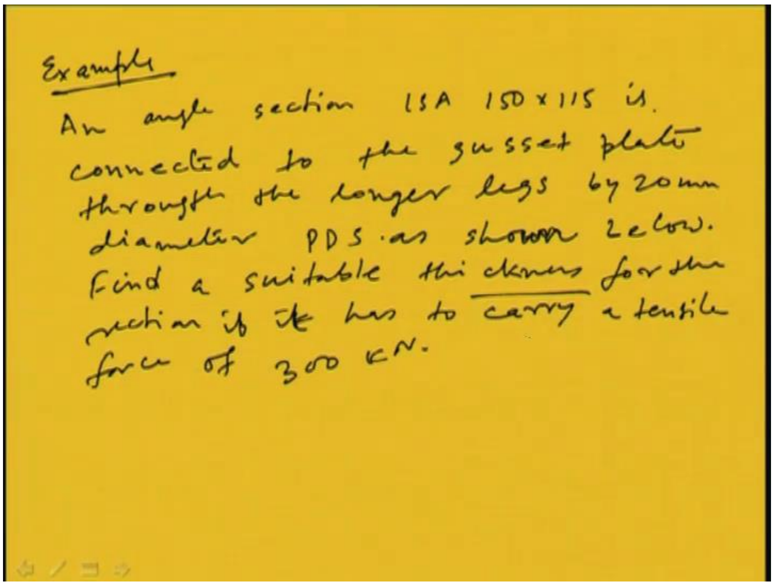

So, this is the question. Basically, this is one sort of design also you can say that an angle section of ISA 150 by 115 is connected to the gusset plate through the longer legs by 20 mm diameter of power driven soft rivets as shown below. Find a suitable thickness for the section if it has to carry a tensile force of 300 kiloNewton.

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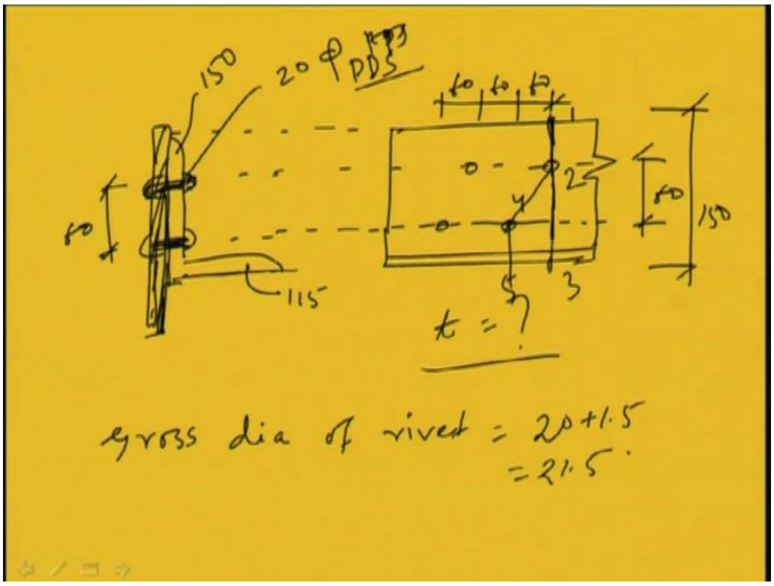

Now how it has been made let us see. If we see in the plan, it is like this. These are the rivet line; one rivet is here, another here, here, like this. So, this is 60, and this is the longer leg. So, 150 mm and these are given; these are all pitch distance is 60, all 60, right. Now if I see from elevation, this will be like this. This is the gusset plate. So, this is the angle, and these angles are connected two rivets like this, and these rivets are 20 mm diameter of power driven. So, PDS power driven soft rivet and this distance as 60, right.

Now we have to find out the thickness of the rivet. So, what we will do? First we have to find out the gross diameter. Now this length is 115, and this is 150; we have to find out the thickness of the plate which is unknown, right. Now what we will do? First, we have to find out the gross diameter of the hole means gross diameter of rivet hole; that is 20 plus 1.5, 21.5, right. Now deduction in width of hole along section one two three; means if we see it may fail like this, say one two three. This is one way it may fail; another is four five. This may fail one, two, four, five. So, there are two way of failure which has to be calculated one, two, three and one, two, four.

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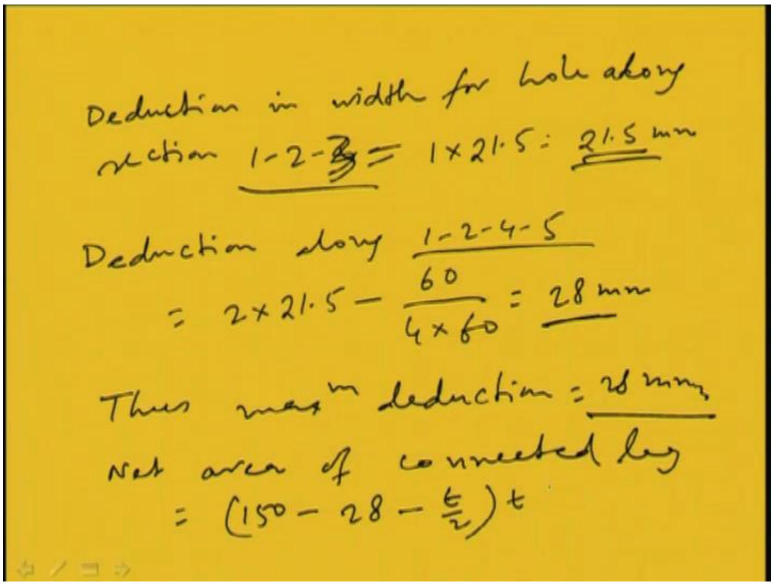

So, deduction in width not in area because area we do not know because of unknown thickness. So, deduction in width for hole along section one two three will be. So, along one one two three, this will be deduction of hole that will be 1 into 21.5. So, this is 21.5 millimeter because only one rivet is there along one two three. Similarly, deduction along one two four five; that means this one one two four five; so on this deduction will be how much? That will be two rivets are there.

So, 2 into 21.5 but a square by 4 g because of zigzag nature we have to make. So, s square s is 60 4 g, g is also 60. So, this value is 60, and this is also 60. So, s square by 4 g will be this. So, this will become 28 mm, right. So, deduction in width for hole along one two four five is 28 mm and along one two three is 21.5 mm. So, thus maximum deduction will be 28 mm, 20 mm, 28 mm. So, this is the weakest section means one two four five will be the weaker one. So, now we have to find out the area. So, net area of connected leg, this will be how much? Net area of connected leg that is 150 minus 28 minus t by 2 into t; this will be net area of connected leg.

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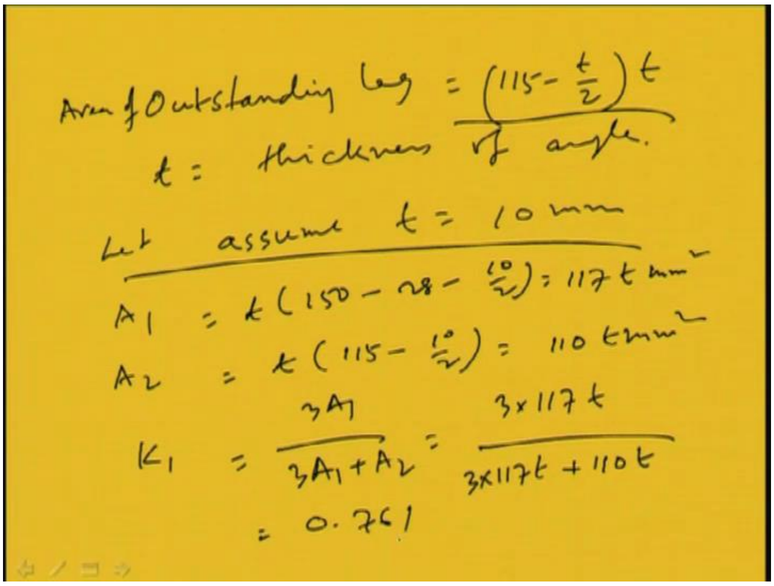

And similarly net area of outstanding leg. Outstanding leg means area of outstanding leg will be one one five minus t by 2 into t, where T is nothing but thickness of angle which we have to find out. So, we have now net area means A 2 we have and A 1 we have. So, now let us assume because now we will see that this is coming quadratic means unknown t square by 2 will come. So, to make it simplify, let us assume t as, say 10 mm, then what will happen? Then A 1, A 1 we have calculated as A 1 was 150 minus 28 minus t by 2 into t.

So, this t actually if we assume 10, then it will not change much, because the deduction will not be much. If we make 10 or 8 or 12, the deduction is not going to affect much; that is why we are assuming for the sake of simplicity. So, that we can make t into 150 minus 28 minus 10 by 2; so in this way I can find out, say 117 t. Similarly, A 2 we can make t into 115 minus t by 2 means 10 by 2. So, 110 t this is millimeter square, okay. Now we can find out K 1. So, K 1 will be 3 A 1 by 3 A 1 plus A 2. So, 3 into A 1 means 117 t by 3 into 117 t plus A 2 means 110 t. So, from this we are going to get 0.761, okay. So, the coefficient K 1 is coming 0.761.

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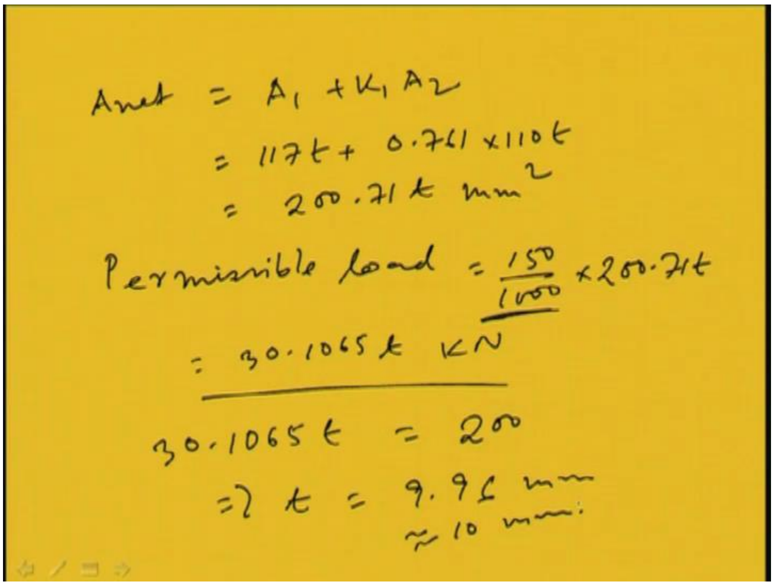

Now what we will do? Now area net we will find out. Net area will be A 1 plus K 1 A 2. So, A 1 is 170 plus K 1 is 0.761 into 110 t. So, this will become 200.71 millimeter square. So, net area of the section is coming 200.71 t. Now permissible load will be how much? On this basis permissible load should be 150 into 200.71 t. This is dividing by 1000 because of making change from Newton to kiloNewton. So, this will come 30.1065 t kiloNewton. So, permissible load is this one.

Now 200 kiloNewton load has to carry. So, permissible load has to be maximum 200 means 200 load has to be carried. So, we can make equal of 30.1065 t is equal to 200, right. So, from this I can find out t as 9.96 millimeter. So, we are going to find out t as 9.96 millimeter; that means we can use 10 millimeter, right. So, hence we can use 10 millimeter thickness; that means the section what will be section?

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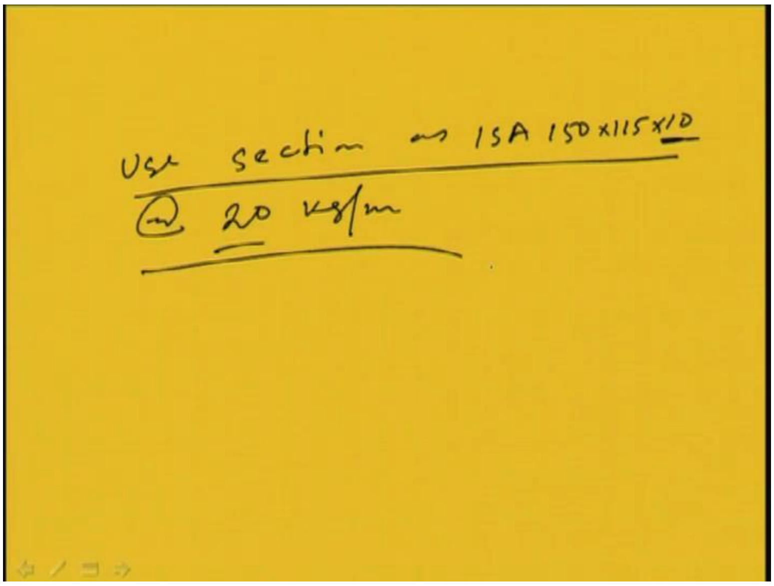

So, use section as say ISA 150 by 115 by 10, and its weight also was given in the code which can be find out for 10 millimeter thickness; this is 20 kg per meter, okay. So, the answer will be this 150 by 115 by 10 at the rate of 20 kg per meter; in this way we can make it. So, this example I have gone through because to see how to find out the thickness of the angle section; if everything is given, then how to find out the thickness? Section is given; we know how much load has to carry. So, what should be the thickness of the angle? So, the suitable thickness of the angle can be found out through this type of process. So, now I will go through one design example which I have discussed earlier, the different steps how to design an angle.

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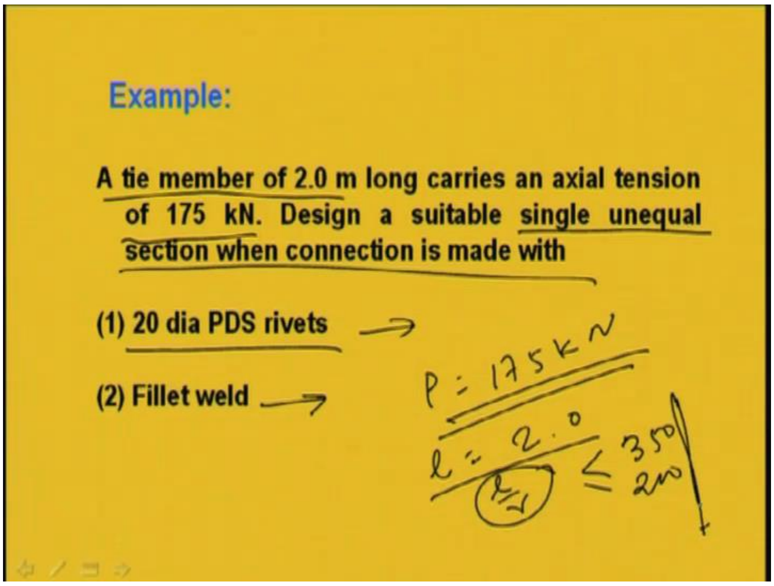

First, I will go through one unequal single angle section, say a tie member of 2 meter long carries an axial tension of 175 kiloNewton, right. So, axial tension is 175 kiloNewton. Now design a suitable single unequal section when connection is made with 20 mm diameter of power driven soft rivets and fillet weld. So, we will design through fillet weld, we will design through riveting 20 mm diameter of power driven soft rivet.

So, load is given here 175 kiloNewton. So, this much load has to be carried by the angle. And section has been told that this is single unequal section. And another thing is length is 2 meter; why it is required? Because we have to find out the l by r ratio, which should be less than or equal to 350 or 200 as per the codal provision, right; so let us see how to go through the step by step to find out the design section.

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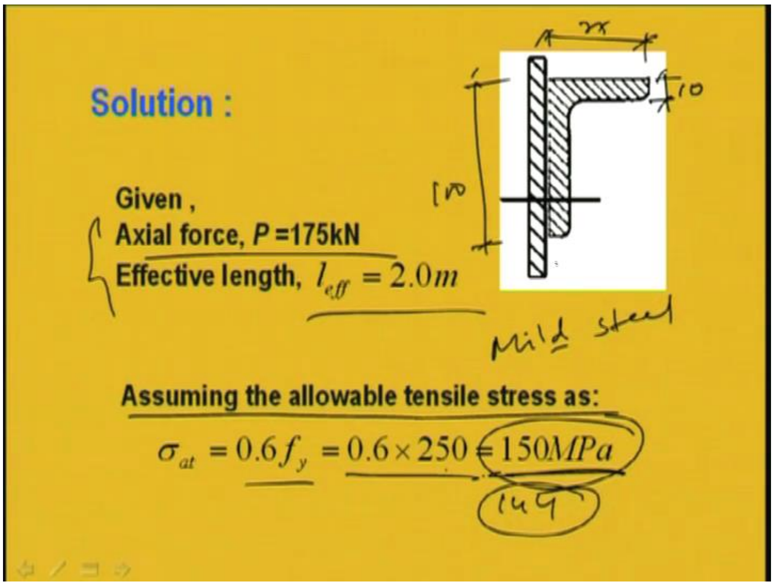

So, now we know the P is given which is 75 kiloNewton, effective length this is given; these are the two things which has been given. And now the type of steel you have to assume because it is not told. So, if you assume the allowable tensile stress as this if you assume the mild steel. Then the allowable tensile stress will be 0.6 into f y; f y will be 250. So, allowable tensile stress is 150 Mpa. And we know as per the codal provision that this will be less means 144 if the thickness is becoming more than 20 mm, right. So, let us assume that thickness is not going to become more than 20 mm which generally does not become. So, we are taking the sigma a t value as 150, okay.

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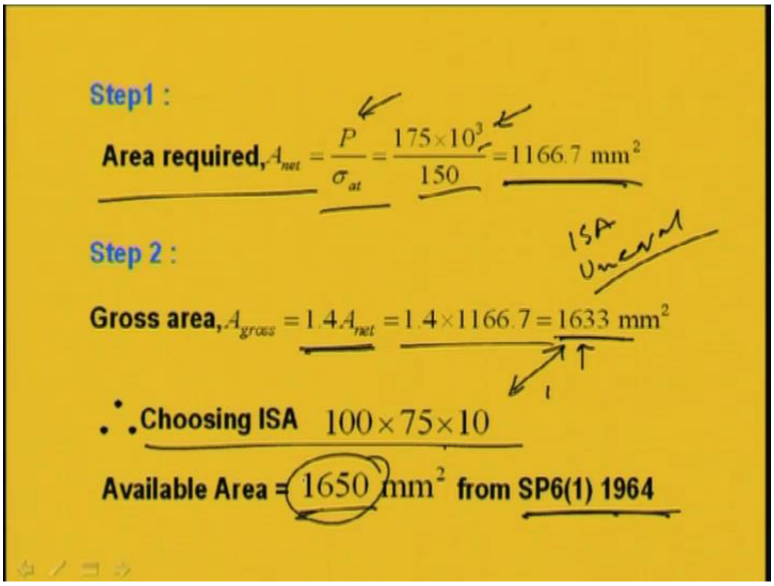

Now as we have discussed, what is the steps one? In step one, first we will find out the required net area. Net area required will be P by sigma a t, where P is the force applied and sigma a t is the allowable tensile stress on the member. So, load is 175 kiloNewton; we are making it Newton, and this is 150 Newton per millimeter square. So, net area required is 1166.7 millimeter square.

In next step what we will do? We have to increase the area for finding out the gross area and let us, say increase 40 percent, okay. So, gross area we can find out from this 1.4 into 1166.7. So, the gross area we are going to get as 1633 millimeter square. Now let us choose some angle because how do we choose because we need this 1633 millimeter square.

Now we will go to the SP 16 of 1964. We will see which section is matching towards this section, okay. It is told that ISA an unequal. So, in ISA unequal table that we will go through the table and we will see which one is the closest 266.33 millimeter square. That we have seen that if we choose 100 by 75 by 10, then it is coming 1650 millimeter square, right. It should be means available area should be more than this preferably, okay. So, 1650 millimeter square available area will be if we choose ISA 100 by 75 by 10 angle section, okay. So, in this way we can find out.

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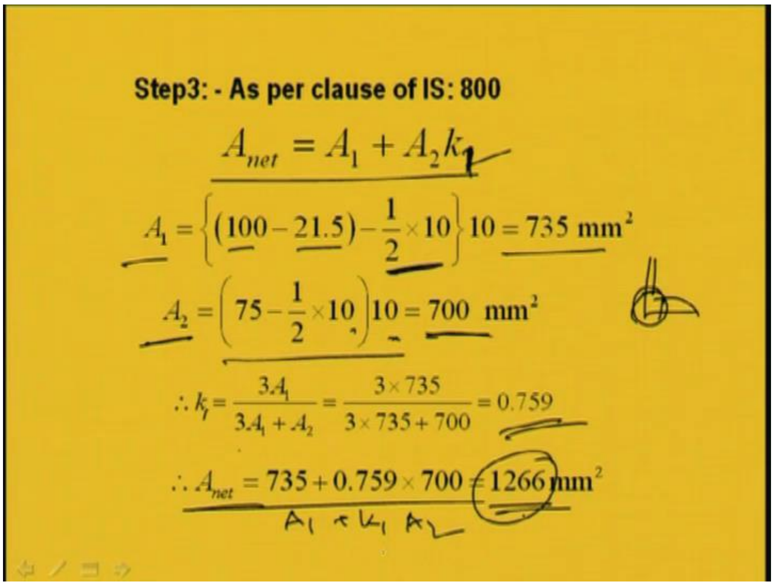

Next what we will do? Now we will find out as per the codal provision net area. What will be net area as per the clause of IS 800? The net area will be A 1 plus K 1 into A 2.

Now A 1 is the area of the connected leg. So, A 1 will be how much? 100 because this is the connected leg; this is 100; this is 100, and this is becoming 75, right and 10; this thickness is 10, right.

So, this will be A 1, and this will be A 2. So, A 1 and A 2 we have to find out now, right. So, A 1 is the area of connected leg which will be we are assuming that one rivet is going to be used. So, 100 minus 21.5 and minus this because of this corner one this common one, so half into t. So, A 1 we are going to get 735 millimeter square. Similarly, A 2; A 2 is nothing but the area of unconnected leg; area of unconnected leg will be simply 75 minus half of 10 into 10. So, this will be 700 millimeter square.

Now I can find out K 1. K 1 is equal to 3 A 1 by 3 A 1 plus A 2. So, I can find out the value as 0.759 K 1. Now what we will do? Net area can be found out A 1 plus K 1 A 2; from this formula I can find out. Now all the values are derived. So, we can find out the value net area as 1266 mm square, where A 1 is 735 millimeter square, A 2 is 700 millimeter square, and K 1 is 0.759, right. So, net area we are going to get 1266 millimeter square.

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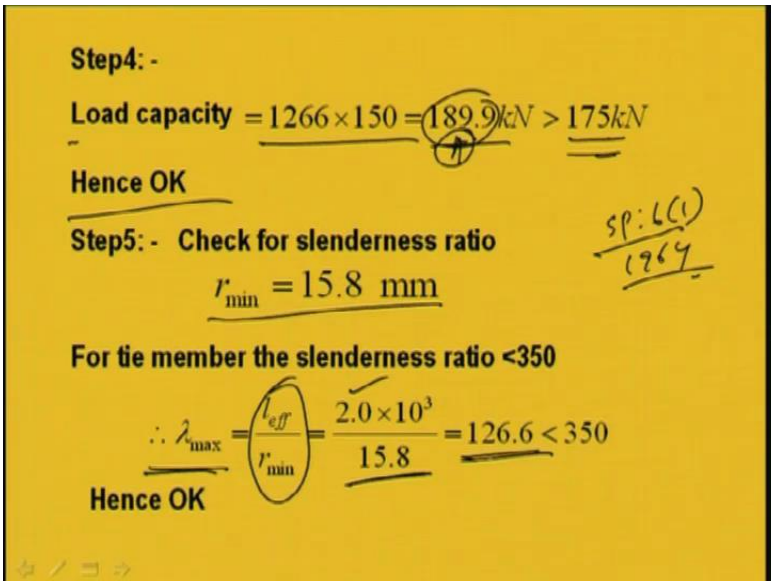

So, 1266 millimeter square and we need require as 1166.7 millimeter square. Net area is required 1166.7 millimeter square. And available net area we are going to get 1266 which is greater than the net area required. So, we can go with this section, right. Load carrying capacity also we can find out; load carrying capacity will be 1266, the net area available into 150. So, this is coming 189.9 which is greater than 175 kiloNewton.

The load acting is 175 kiloNewton, and the member can carry the load as 189.9 kiloNewton, which is greater than the 175; that means this is safe, it is okay. If this is coming less than the 175, then we have to increase the next section; we have to increase for next section, we have to check again same thing, okay. Now what we will do? So, this check is okay.

Now we have to check the slenderness ratio. Now from SP 6 1964, we will get all the member properties sectional properties of the angle. So, from that we can find out the angle of whatever we have considered this angle. That is ISA 100 by 75 by 10. For this angle, r minimum is 15.8 mm which has been given in the handbook. So, maximum lambda will become l effective by r minimum which is becoming this. Effective length of the member is 2 and minimum radius of gyration is 15.8. So, we are getting 126.6 which is less than 350 as per the codal provision. That means this is also okay; from slenderness point of view this is also okay.

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Now what we will do? Next step is design for end connection. So, we are using 20 mm diameter of power driven soft rivet. So, what we will do? So, nominal diameter will be 20 and gross diameter will be 20 plus 1.5 that is 21.5 And as per table 8.1 for power driven soft rivet, tau v f is this and bearing strength sigma p f will be 300 Mpa and tau v f will be 100 Mpa. Now we have to find out the rivet value. How do we find out rivet value?

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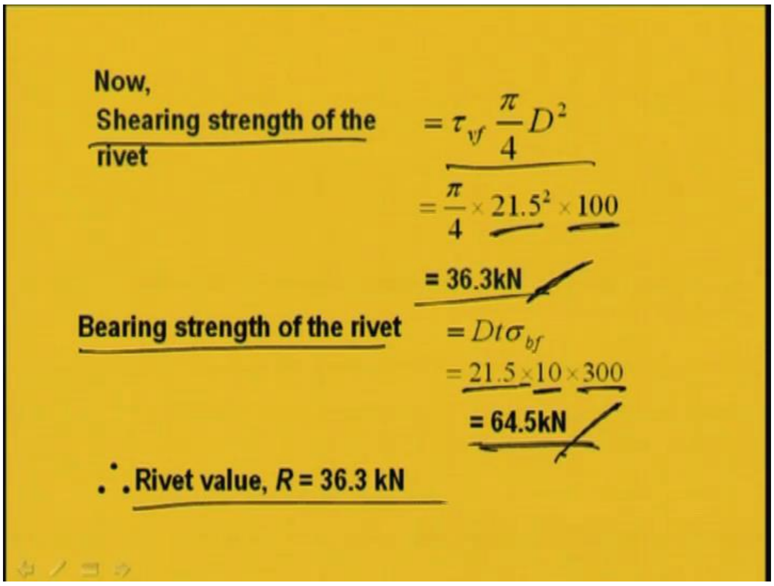

We know rivet value for shearing will be tau v f into pi by 4 D square. So, pi by 4 into tau v f is 100, and D is 21.5. So, after multiplication we are going to get 36.3 kiloNewton. And from bearing strength of rivet means from bearing point of view, it will be D into t into sigma p f. So, D is gross diameter of the rivet that is 21.5, thickness is 10. And sigma pf the bearing strength is 300 Mpa. So, after making this, we are going to get 64.5 kiloNewton. So, rivet value in shearing this is 36.3 kiloNewton rivet value in bearing, this is 64.5 kiloNewton. So, the minimum one has to be taken. So, the rivet value will be 36.3 kiloNewton because failure will happen due to shearing first, okay. So, rivet value can be found as 36.3 kiloNewton.

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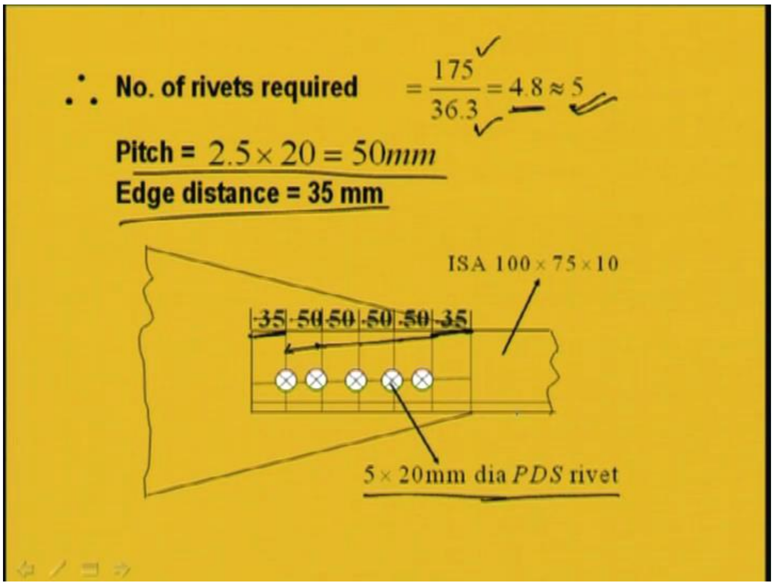

Next what we will do? Now number of rivet required; so number of rivets will be load by rivet value; load is given as 175kilo Newton, and rivet value is 36.3 kiloNewton. So, number of rivet required will be 4.8; that means 5. So, five number of rivets can be used for this, right. Now pitch, pitch from the codal provision we know minimum pitch will be 2.5 into D that is around 50 mm. So, we can make 50 mm. And edge distance, say let us consider 35 mm, right.

So, with this we can arrange the riveting like this. Say, this will be 35; edge distance will be 35, and pitch distance will be 50 each, and five rivets will be there. So, five rivets of 20 mm diameter power driven soft rivets will be used, and we can find out accordingly all the details. So, in this way we can design a member and we can make its connections also. So, this is the way we can make; this is the simplest design we have gone through. Next we will go one by one complicated one, okay.

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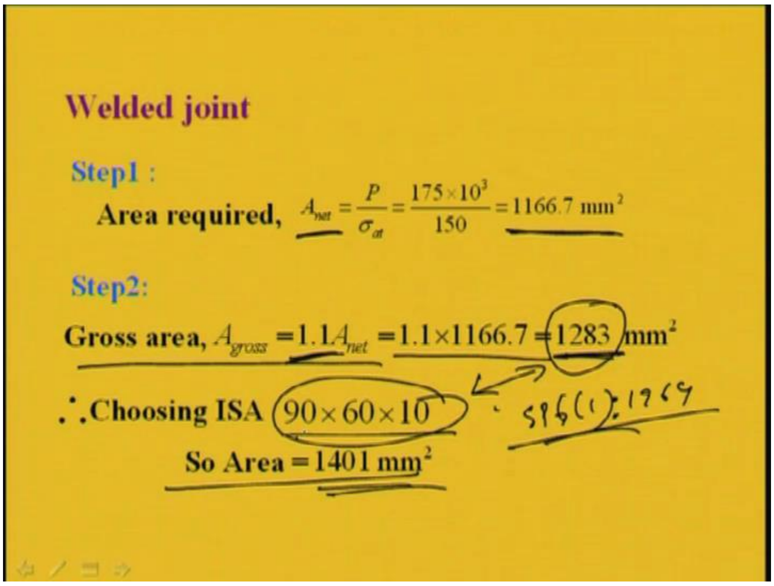

Now we will go for welded joint. So, same problem we will go through welding joint. So, in case of welded joint again we will see how to find out. First, what we will do? That net area we have to find out P by sigma a t which is 1166.7 millimeter square. Now gross area for welding joint because gross area will not be much, because in case of welding joint, there is no scope of deduction of hole. So, net area and gross area will be almost nearby.

So, gross area code has suggested means from experience also it has seen that 10 percent if we increase sufficient. So, gross area we are increasing 10 percent; so this one 1283, right. Now choosing 90 by 60 by 10, the area is becoming 1401 millimeter. As I told that from SP 6 1 in 1964, from this handbook we can find out the sectional properties. Now gross area required is this much 1283. Now we have to see which one is nearby. So, you have seen that this will be nearer to this area. So, we can choose with this 1401 millimeter square; that means the section is 90 into 60 into 10.

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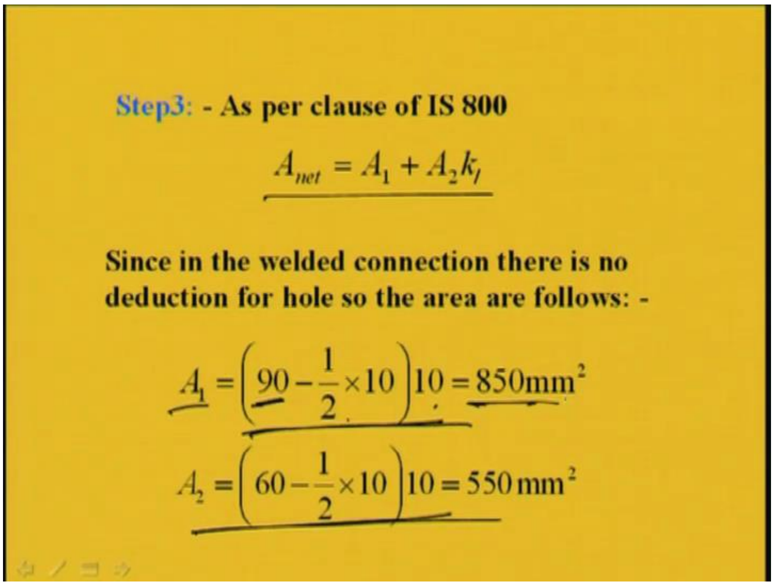

So, with this now we have to find out as per clause of IS 800 that A net is equal to A 1 plus K 1 into A 2, okay. So, since in case of welding joint there is no deduction for hole. So, A 1 will become simply the area of the connected leg, and A 2 will be simply area of the unconnected leg, okay. So, A 1 and A 2 simply can be find out from this because this is 90 the longer leg which is connected 90, 90 minus thickness by 2 10 by 2 into thickness; this is the area 850 mm square. Similarly, A 2 is the area of unconnected leg; that means area of the smaller leg that is 550. So, from this I can find out K 1.

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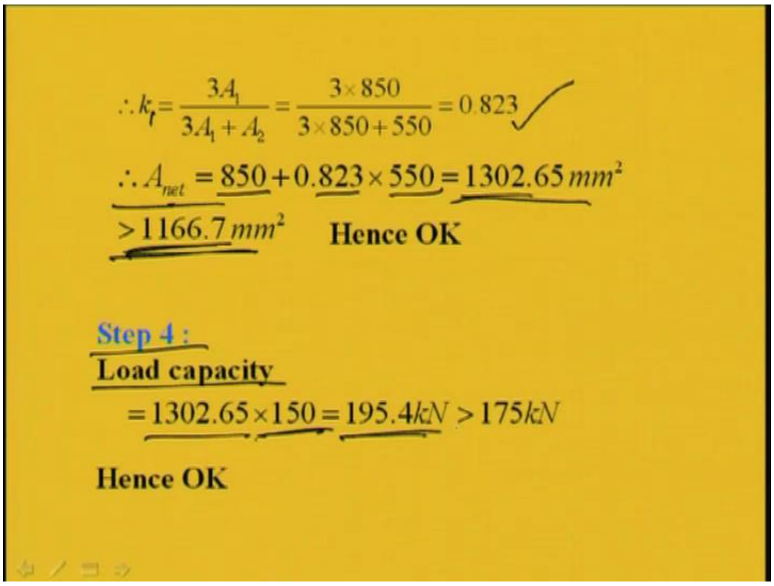

K 1 is equal to as we know 3 A 1 by 3 A 1 plus A 2. So, providing the value of A 1 and A 2, we can find out the magnitude of K 1 as 0.823. Now area net, net area will be becoming A 1 plus K 1 into A 2. So, A 1 is 850, K 1 is 0.823, A 2 is 550. So, after calculating this we are going to get 1302.65 which is greater than the required area; required area was 1166.7 millimeter square. So, it is okay.

We are getting the net area as 1302.65, whereas the required area is from the load point of view, it is 1166.7 millimeter square. So, it is okay. Now what we will do? Now we will find out load capacity. Load capacity we know the area which is 1302.65 and permissible stress in the steel. So, after multiplying we are going to get 195.4 kiloNewton which is greater than 175 kiloNewton. So, this is okay; that means load carrying capacity also we are going to find out that is 195 kiloNewton. So, considering this section, the section will be carry to 195.4 kiloNewton load.

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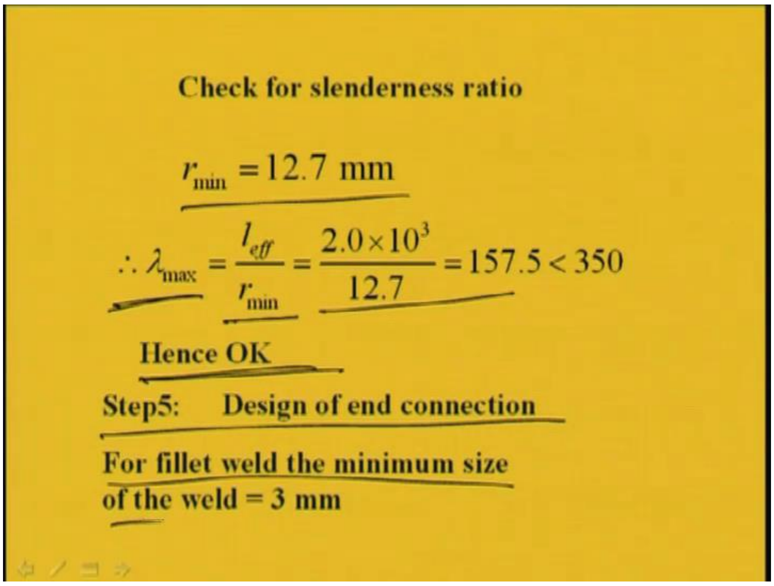

Now again the slenderness ratio has to be checked. So, for that section from the SP 6, we will get the minimum r is 12.7 millimeter; for a particular section, the radius of gyration minimum maximum along with all the member properties has been given in the code SP 6. So, lambda max will be l effective by r minimum. So, this is becoming 157.5 which is less than 350; that means it is safe.

If it is greater than 350, then we have to increase the sectional area increase the sectional properties; that means we have to increase the section dimension to make under this condition. Now if it is okay, then we can go for the next step that is design of end connection. So, we have to connect the end. So, for fillet weld, we know the minimum size of weld can be used as 3 mm, right.

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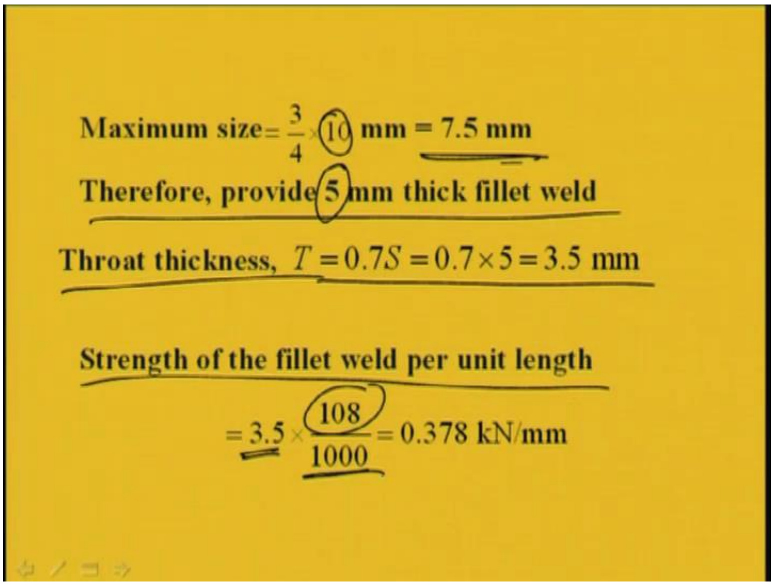

And maximum size for this case can be used three-fourth by t; t is the thickness of the angle which is 10, so 7.5. So, in between 3 to 7.5 mm, we have to find a fillet weld size. So, what we will do? Now fillet weld size we are providing in between as 5 mm. So, if size of fillet weld is 5 mm, then throat thickness can be found out from 0.707 or 0.7 S; that means 3.5 mm, right.

Throat thickness means effective thickness basically which is going to take care of the load; that will be .7 into S, S is the size of weld which is 5 in this case. So, 0.7 into 5, this is becoming 3.5 millimeter, right. Now strength of a fillet weld per unit length now we can find out as 3.5 into 108; 108 is the permissible stress in fillet weld 108 Mpa. And this is 1000; we are dividing to make it kiloNewton. So, this is becoming 0.378 kiloNewton per millimeter. So, strength of the fillet weld per unit length has been found. Now what we will do? Now we can find out the length.

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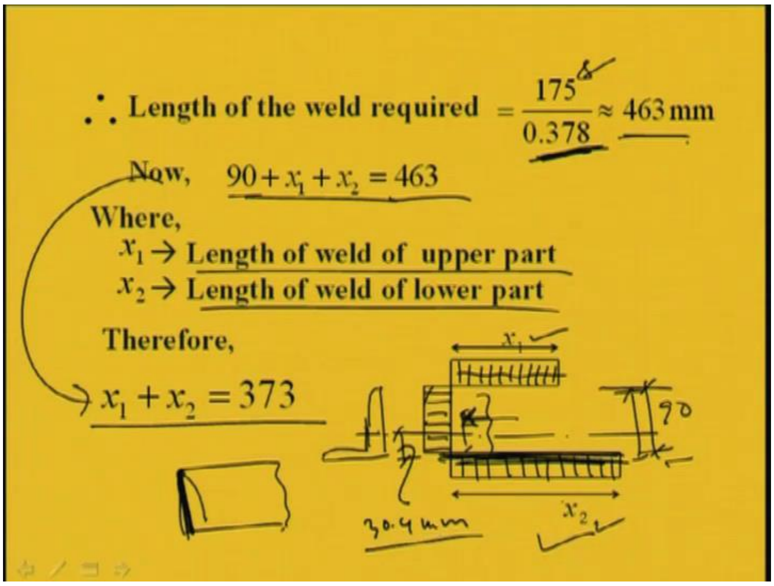

Length of the weld required will be this one because this is the load which has to carry by the weld and 0.378 kiloNewton per millimeter length is the strength of the weld. So, if we divide it, we are going to get 463 millimeter. So, length of weld is required 463 millimeter, right. So, 463 millimeter length has to be provided. Now how do we provide? Now we see when the member is here. So, what we will do? First, we can provide that this is the length of the connected leg.

So, this is basically 90. So, first we can provide this area, right. So, we can make and we do not know how much we have to provide here and how much we have to provide here, why? Because we have to make welding distribution in such a way that the CG of this weld should coincide with the CG of means load; that means CG of section, right. So, first 90 and if this is x 1 and if this is x 2, then 90 plus x 1 plus x 2 will become 463 mm, right, where x 1 is the length of weld of upper part, and x 2 is the length of weld of lower part.

So, from this we can make x 1 plus x 2 will become 463 minus 90 is equal to 373. Now as I have told that why this x 1 and x 2 will not become same because x 1 and x 2 has to be made in such a way that the CG of the weld has to pass through the CG of the section, right; so that is why we have to make in that way. Suppose CG of the section is here. So, CG of this section we know then we have to find out accordingly. So, distribution has to be made accordingly.

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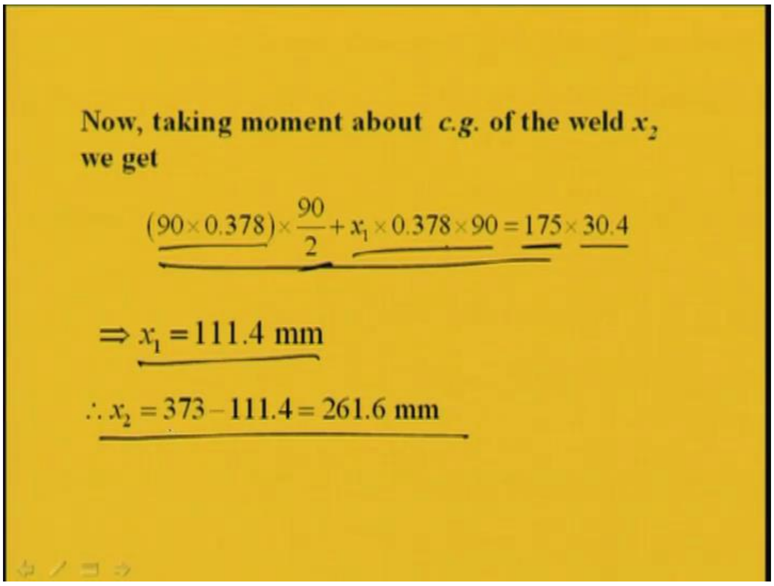

So, what we will do? Taking moment about the CG of weld x 2; so moment about CG of weld of x 2, if we take moment about this, what will happen? That means 90 into 0.378 into 90 by 2; this is one. This is 90, 90 into 0.378 is the strength per millimeter length of weld. So, 90 into 0.378 is the strength of this area. Then into 90 by 2 means half of this where the CG is acting. So, 90 into 0.378 into 90 by 2 plus.

Similarly, x 1 into 0.378 into 90 because at 90 mm distance from here, it is the x 1 is there, right, so into 90 is equal to the total load. Total load is 175, and this is at a distance of 30.4 millimeter; this is given in the code. This distance is 30.4 millimeter because this is the CG of the section. So, the CG of the weld should pass through the CG of the section; that is why we are making this equal to 175 into 30.4. So, from this I can find out x 1 as 111.4 millimeter, right. So, similarly x 2 I can find out then because x 1 plus x 2 was 373. So, x 2 will become 373 minus 111.4 is equal to 261.6 millimeter. So, the distribution now we can find out.

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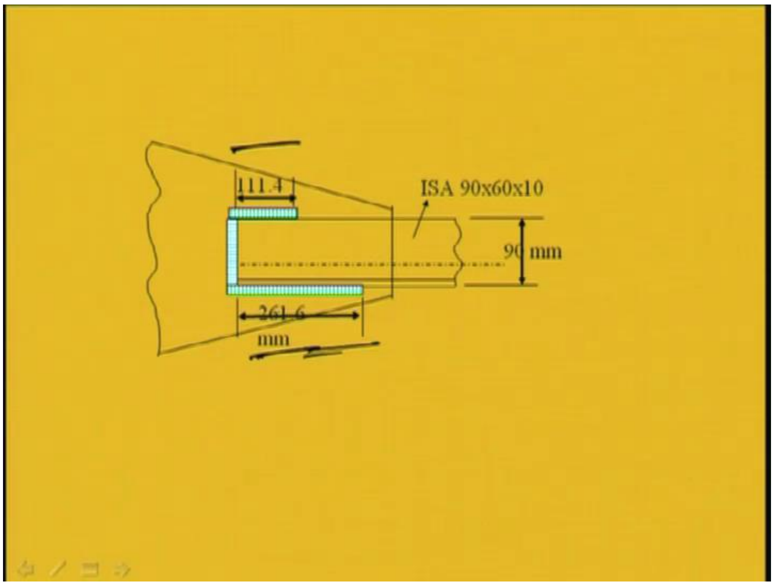

So, the design will be like this that this is 261.6 millimeter; this is 111.4 millimeter, and this is 90, right. So, the welding if we distribute in this way, then the CG of the weld and cg of the section will coincide each other. So, there will be no scope of eccentricity. So, in this way we can make design.

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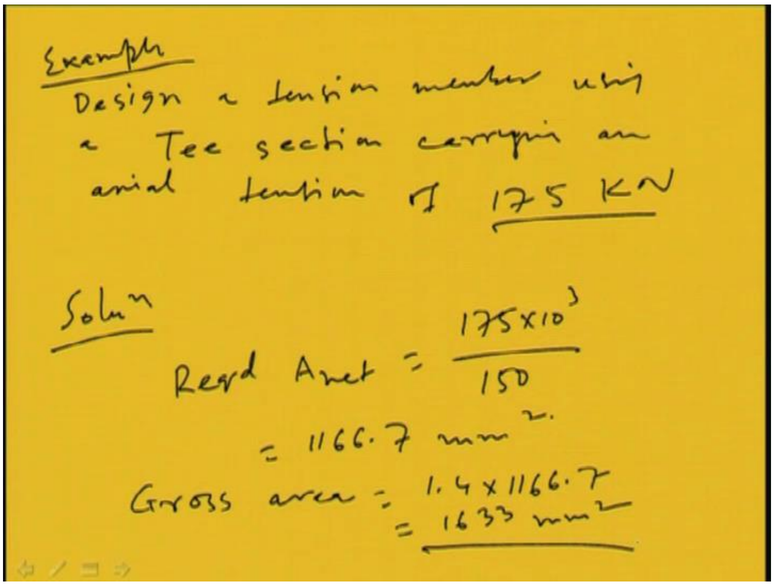

Now we will go through one another example through which we will be able to find out the design of a tee section. So, now we have to design a tee section which has to carry 175 kiloNewton axial tension. So, in this case what we will do? So, if we go through the solution, first what we will do? That first required area net, net area required will be 175 by the sigma a t; sigma a t is 150 which will become 1166.7 as we have done earlier. So, gross area, how do we find out gross area? Gross area will be around 40 percent more; that means 1.4 into 1166.7. That is coming 1633 millimeter square, right. So, this is the gross area which is required to provide.

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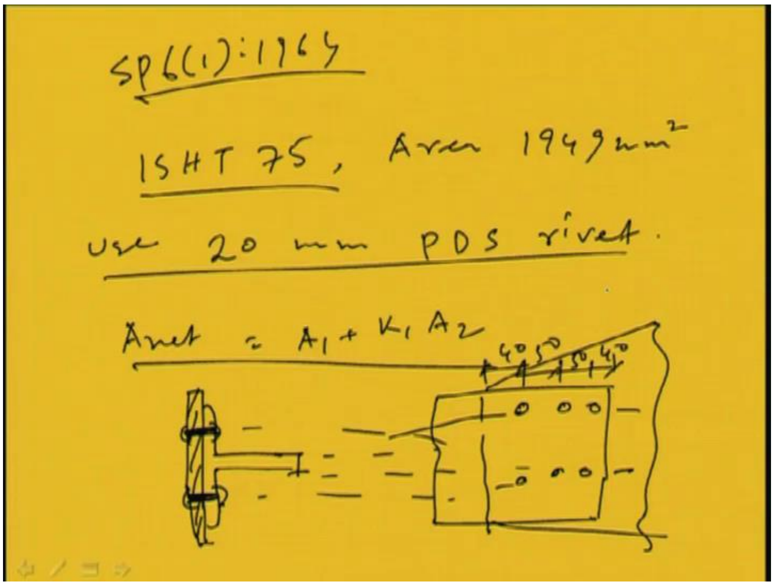

Now we will see the handbook that is SP 6 1 1964 which has the matching with the required area. Now, if we use ISHT is tee section 75, then the area is coming around 1949 which is closer to that. So, we will use ISHT 75. And also let us use because it is not told anything, say 20 mm power driven soft rivet, right. So, we can find out now; in next step we can find out the net area, area net which is basically A 1 plus K 1 into A 2. So, we can find out the net area. So, A 1 we can find out, okay.

Now let us draw the things then will be easier. Say, these tee sections is single t. So, it is connected like this. This is the gusset plate, and this is one rivet because two rivet has to be provided in the flange, okay. So, if we see gusset plate is like this. So, this will be two rivets. If it is chain riveting, then it will look like this, this is this, this is this, okay, and this distance we will be find out.

Now let us assume this as, say 50 and 40; say 40 edge distance and 50 pitch distance, right. So, this is 40, because 52.5 D, D where 20 mm diameter has been used. So, 20 into 2.5 is coming 50. And, say edge distance we are providing 40; however, it can be changed also. And now this flange width is as per the codal provision this has given for ISHT 75, this width is 150 mm, right. So, now I can find out the area A 1 and A 2 because now the area will be in this section will be lowest. So, critical section I can make in this way.

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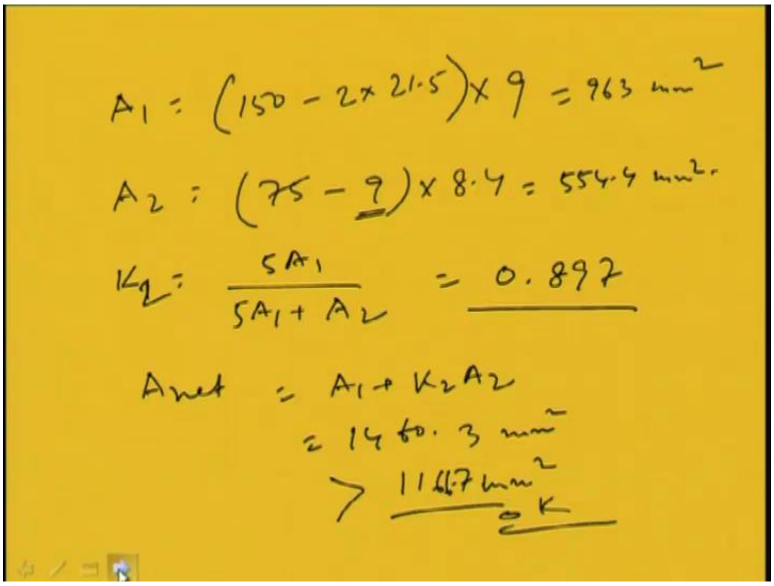

So, A 1 I can find out 150 minus 2 into 21.5. This is the two number of rivets has been provided and thickness has been given as 9. Thickness of flange has been given 9 for these particulars ISHT section. So, this is coming 963 millimeter square. Similarly, A 2 is the area of the web that is 75 minus 9 into thickness is 8.4. See, this thickness is 8.4, and this thickness is given 9.

So, when I am calculating this. So, I have to reduce this one for next one; that is why I have reduced nine. So, this is coming 554.5 millimeter square. So, now I can find out K 1 value which will be as per the codal provision 5 A 1, say this is called K 2 actually. K 2 is 5 A 1 by 5 A 1 plus A 2. So, after putting all those value, I will get this is as 0.897, where A 1 we will put 963, and A 2 we will put 554.4, so 0.897.

So, area net will become A 1 plus K 2 into A 2. So, this is coming 1460.3 millimeter square which is greater than the required area. So, we can find out this will be 1166.7 millimeter square. So, this is okay. So, area net we can find out which is 1460.3 millimeter square and which is greater than 1166.7 millimeter square?

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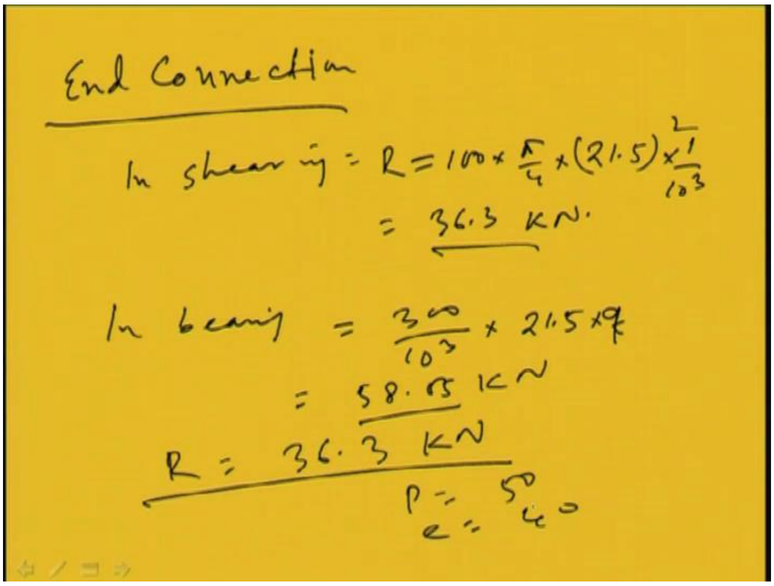

No we will go for end connection. So, the section whatever we have chosen is okay. So, for end connection what we will do? For shearing, in shearing we have to find out R value tau v f; tau v f is 100 into 5 by 4 d square. So, this into 1 by 10 cube for making kiloNewton. So, this is 36.3 kiloNewton. And for bearing, in bearing it will be 300 sigma p f into d into t; t is 9 millimeter. So, this is coming 58.05 kiloNewton. So, the rivet value can be made as 36.3 kiloNewton which is the lowest one of these two. So, rivet value we can find out. Now pitch and edge distance we have provided; pitch we have provided, say 50 mm and edge we have provided as, say 40 mm. So, in this way we can make. So, number of rivets we have to find out now.

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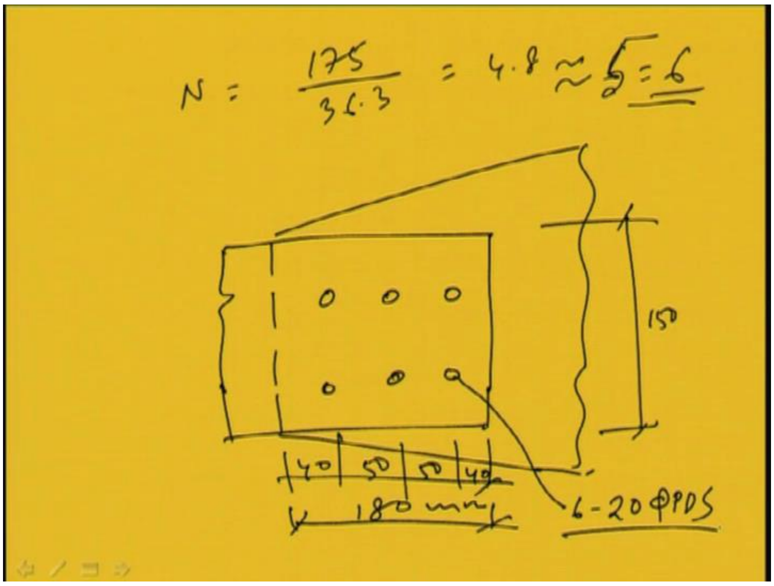

Number of rivets will be, say 175 kiloNewton load has to be provided; 36.3 is the rivet value is 4.8, say let us provide. Say, this will be basically 5. So, as two rivet in each row has to be provided. So, let us provide six rivets, right. So, provide six rivets and with a pitch distance of 50 and edge distance of 40 mm, right. So, number of rivets is becoming. So, what we are going to get that if we now draw. So, this will be now we can make one, sorry.

So, six rivets we are going to use. So, we can make simply a chain riveting, right. So, we are providing pitch and edge distance of, say 40, 50, 50 and 40, right. Now this is 150, and this totally is becoming 180 mm. And this is you can, say six rivet 625 PDS we have provided, right. Now in this way we can make it. So, what we have seen here? In case of design of tension member that a tension member can be designed as per the requirement of the load and when we are going to design the tension member first, we will find out the net area required for that section.

After going to find the net area, we will provide the gross area considering some additional percentage because of hole of the rivet because of the connections. So, that generally in the provisions I have told 40 to 60 percents can be increased in many cases 20 percent, in case of weld 10 percent also we can increase. So, it depends case to case it varies.

So, after increasing the gross area, what we will do? Now we will calculate what should be the net area considering riveted joint or weld joint. So, we will find out the net area, which should be more than the required net area which have been calculated from the force. After this, we will find out the radius of gyration of that section from the handbook that SP 6 1964, right.

Then what we will do? Then we have to see whether it is beyond the limiting value of the same l by r, whether it is more than 350 or 200 as per the codal provision we have to check. If it is okay, fine; if it is not okay, then we have to increase the section. If the section is okay, then what we will do; next we will go for end connections. End connections what we will do? We will provide number of rivets which can be found out from the load by the rivet value, type of rivet we have to assume or it is given i. So, from that, we will find out again the number of rivets.

After finding out number of rivets, we will place properly with the edge distance and pitch distance whatever is given in the codal provision, as per that we will face the rivet properly, or if it is welded joint, then welding has to make in such way that the CG of the weld joint should coincide with the CG of the section, so that the eccentricity due to the connection does not occur. So, after making all this, we can draw the detailing of the joint as well as the member, then it will be okay. So, with this, I like to conclude here today’s lecture. And in next lecture, we will discuss about other member like gusset plate, lug angles, tension splice; what are those things additional things, how it has been designed, and why it is required; all these things we will discuss in next class.

Thank you.