Design of Steel Structures
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Module - 4
Lecture – 3
Tension Members
Design of tension member: Gusset plates Lug angles and tension splices

Hello. Today I am going to discuss about the gusset plates, lug angles and tension splices. These three additional members looks is required in case of design of tension members. These three members are used in various regions which I will discuss today, and how to design all those. We will be going through some examples, so that it will be clear.

Now, first we will know about gusset plate. In fact, already we have discussed about gusset plate in earlier lecture. So, we do not need to introduce this term gusset plate. A gusset plate basically is an extra plate which needs to introduce when a joint is consisting of more than one member. That means when a truss like structures where more than one members are meeting in a joint, in that case to make the joint properly, to make the load at a particular point in a proper position, then we need to introduce gusset plate.

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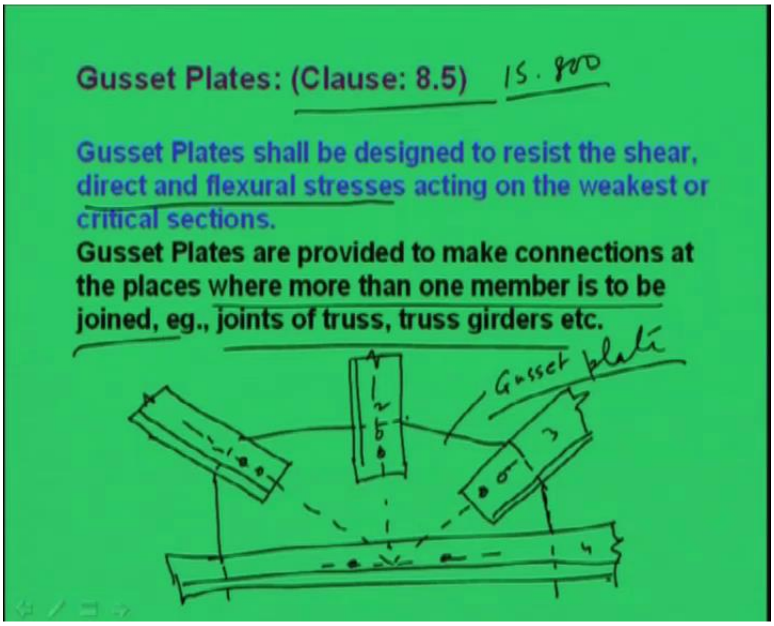

So, this gusset plate has been discussed means about the gusset plate has been told in clause 8.5 of IS800. So, in the clause, it has told that gusset plates shall be designed to resist the shear direct and flexural stresses acting on the weakest or critical section. So, we need to design the gusset plate because to resist the shear direct and flexural stresses. As we told that gusset plates are provided to make connections at the places where more than one member is to be joined. That means joint of trusses, truss girders, etcetera.

So, as we see how it looks like. Let us see that when suppose one truss member is inclined here, another truss member is say suppose are placed like this may be another truss member is placed like this. Suppose one bottom card is there. So, this is another truss member. Now, this truss member say 1, 2, 3 and 4 are to be joined in this joint. So, what we will do? We have to make the connections in such a way that all the cg of the load passes through this particular point. So, may be the rivet line will be like this. So, rivets are placed in such a way that the load on the joint is coming through its cg.

So, this is the gusset plate which we need to say like this. So, this is basically gusset plate. So, the function of gusset plate is just to hold the different members in proper position, so that the loader is being transferred properly from one member to another member through the joint. This is the joint where we have to make the connections properly. So, this is the gusset plate. Now, regarding gusset plate I will not discuss much because already we are familiar with this term gusset plate and whenever we are going for designing such type of connections, we generally use gusset plates. In fact, we have to design in such a way that it should be able to resist shear direct and flexural stresses. So, all these things we have to keep in mind.

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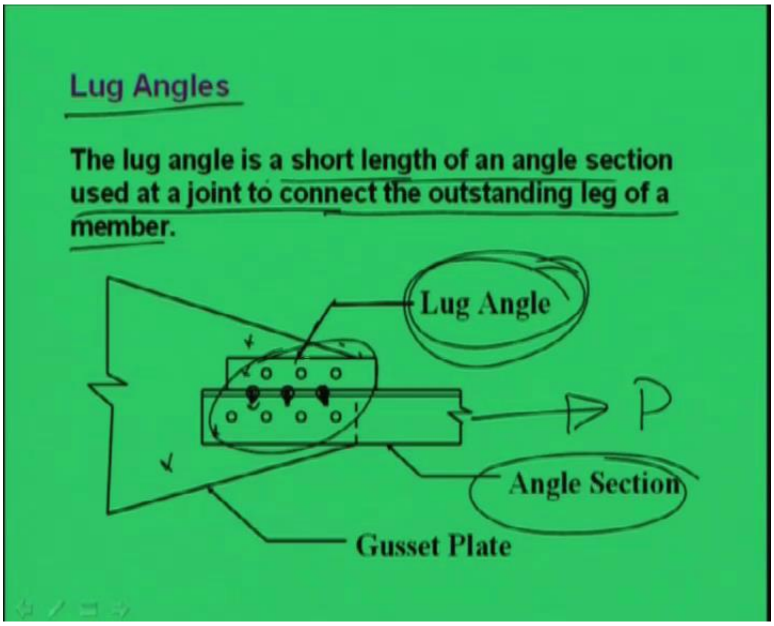

Another additional member which is required sometimes is called lug angles. What is lug angle? Lug angle is basically a short length of an angle section used at a joint to connect the outstanding leg of a member. Basically this is required when the length of gusset plate is limited. When the length of gusset plate is limited, then to transfer the load to connect the joint properly, we need lug angle which is an extra material, extra plate type of thing which is required. This is basically in picture. Whatever we are seeing this is basically lug angle.

So, lug angle basically connects means this is a rivet thread bolted joint. That means this is another joint. So, this is main member. This angle section is main member. So, main member is connected with lug angle through the rivets and rivets and the main member also is connected with this gusset plate as well as the lug angle is connected with the gusset plate. So, in this way the joints are made and the forces are being transferred. So, we will see how to design the lug angle, and before going to design, we will see what the aspects of lug angle in terms of codal provisions are.

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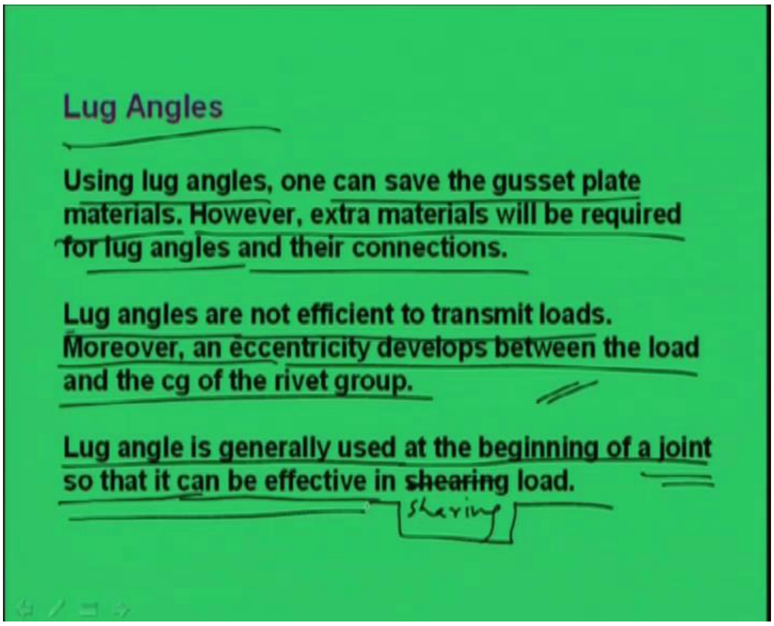

Before going to codal provision, let us know means some advantage and disadvantages of using of lug angles. Basically we can see that using lug angles, one can save the gusset plate materials. So, one can save the gusset plate material by the use of lug angle. However, extra materials will be required for lug angles and their connections. So, when we are going to save the gusset plate materials, we have to provide some lug angle and in that case for lug angle for providing lug angle, another set of materials will be required. So, that means it is balancing. Basically balancing means in terms of materials. So, if we have the restriction of gusset plates, then we can go for lug angle.

Another thing we should remember that lug angle are not efficient to transmit loads. This is very important. Lug angles are not efficient to transmit loads. Moreover an eccentricity develops between the load and the cg of the rivet group because this is the load and cg of the rivet groups will be different. So, a small eccentricity will develop. So, this is disadvantage you can say. Therefore, generally lug angle is not suitable and not advisable to use. However, lug angle is generally used at the beginning of a joint, so that it can be effective in load sharing.

So, lug angle generally we use at the beginning of a joint, so that it can be effective in sharing the loads. However, it is not efficient on transferring the load and also it develops some sort of eccentricity between load and the cg of the rivet group. So, generally unless it is very much required, we generally avoid this. Now, let us come to the codal provisions.

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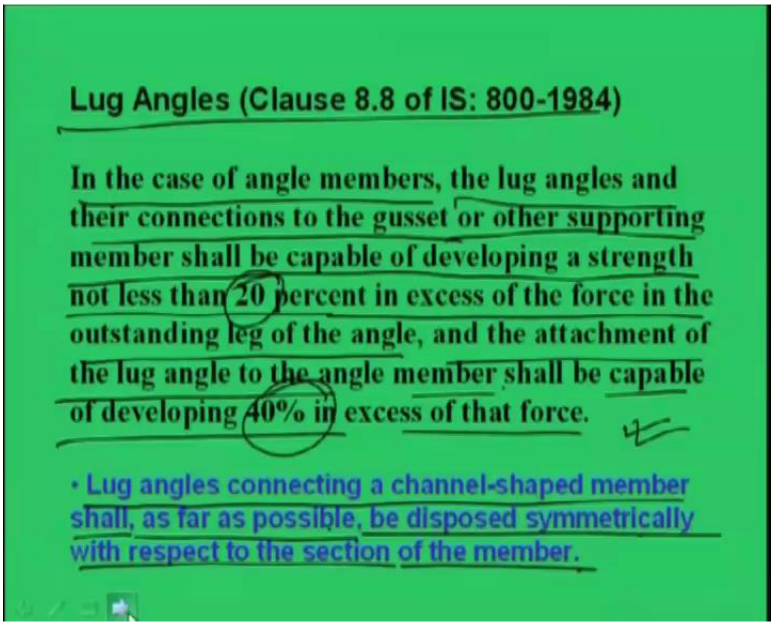

In IS: 800-1984, in clause 8.8, some provisions has been given about the lug angle. So, while going for designing of lug angle, we have to remember this clause means this codal provision is given in the clause 8.8. What it this? Let us see one by one.

First is in the case of an angle member. The lug angles and their connections to the gusset or other supporting members shall be capable of developing strength not less than 20 percent in excess of the force in the outstanding leg of the angle, and the attachment of the lug angle to the member shall be capable of developing 40 percent in excess of that force. So, we have to design the lug angle in such a way that it can develop 20 percent more strength, so that it can carry 20 percent more and the lug angle to their angle member shall be capable of 40 percent more. This will be clear when we will go through one example in detail. We will discuss all this.

Another thing is lug angles connecting a channel shape member shall as far as possible be disposed symmetrically with respect to the section of the member. So, this is important. When lug angles connecting a channel shape member shall as far as possible be disposed symmetrically with respect to the section of the member. This is another provision.

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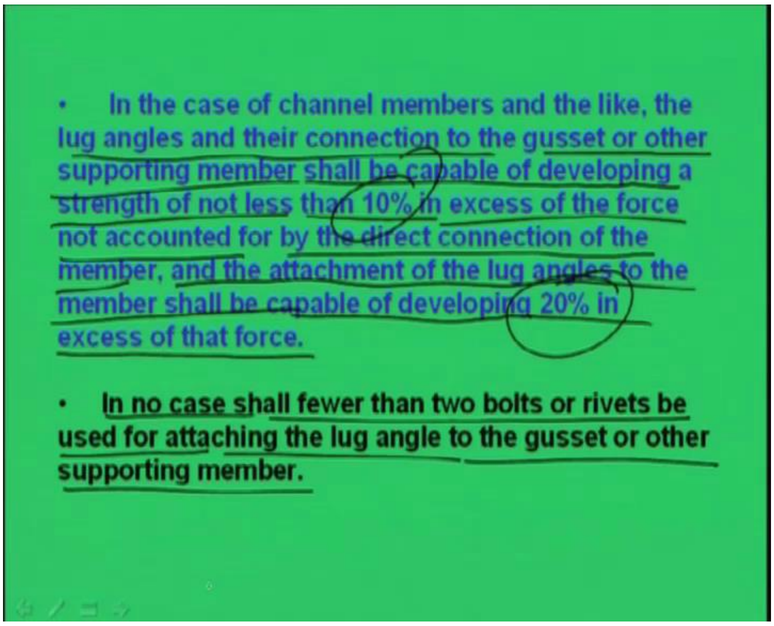

Other provision is in the case of channel members and like the lug angles and their connections to the gusset or other supporting member shall be capable of developing strength, not less than 10 percent in excess of force not accounted for by the direct connection of the member. The attachment of the lug angles to the member shall be capable of developing 20 percent in excess of the force. So, in case of channel section, this percentage of excess force we should be able to bear by the lug angle should be 10 percent and in between 20 percent. So, in case of angle section, it was 20 and 40.

In no case shall fewer than two bolts or rivets be used for attaching the lug angle to the gusset plate or other supporting members. That means minimum two numbers of rivets or two numbers of bolts are required to attach the lug angle with the main member or with the gusset plate. So, that has to be also remembered well designing the lug angle.

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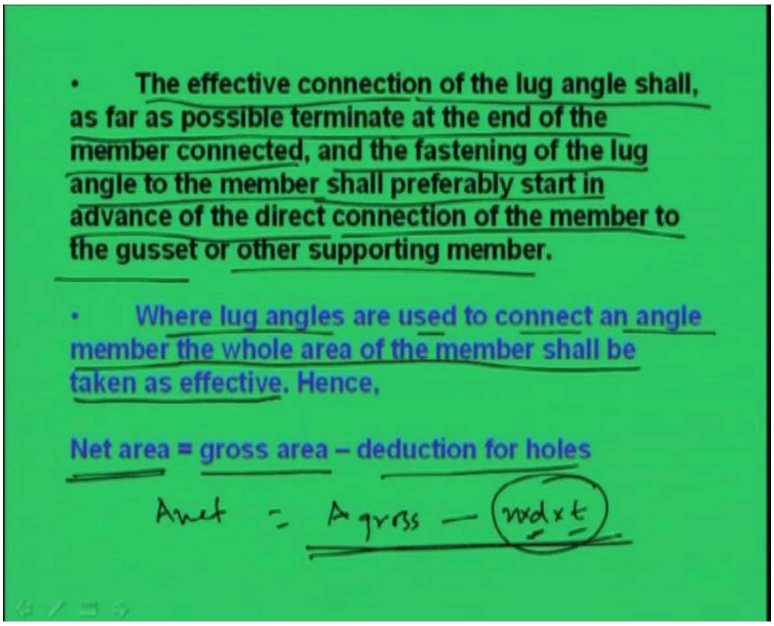

Another thing is the effective connection. The effective connection of the lug angles shall as far as possible be terminated at the end of the member connected, and the fastening of the lug angle to the member shall preferably start in advance of the direct connection of the member to the gusset or other supporting member. This is also important where lug angles are used to connect an angle member. The whole area of the member shall be taken as effective. Therefore, the net area can be calculated as gross area minus deduction for hole.

So, net area we can find out A net as A gross minus deduction of hole. Deduction of hole means n number. Suppose n numbers of whole are there n into d into t. This will be the whole area n into d into t. So, A gross minus hole area. Whole area means if number of whole are in number of rivets are in the diameter of rivets is d, and t is the thickness of the plate, then net area will be this. So, in this way we have to calculate.

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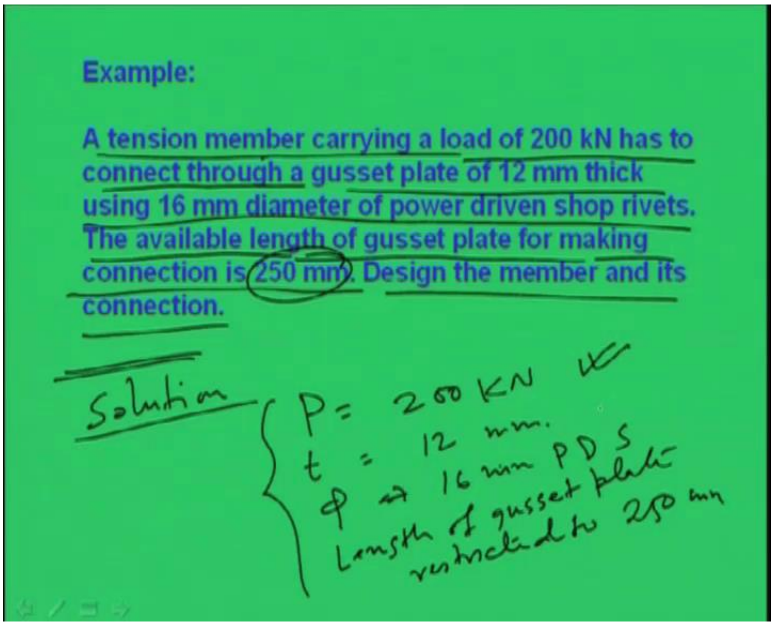

Now, with all these provisions, it will be clear if we go through one example. That means here the example has been made, so that the provisions given in the code can be followed and how to design the lug angle and why it is required and in what case it is required. That will be understood if we go through this example. So, what is this example? That a tension member carrying a load of 200 kilo Newton has to connect through a gusset plate of 12 millimeter thick using 16 mm diameter power driven soft rivets. The available length of gusset plate for making connection is 250 millimeter. Design the member and its connection.

So, what is the difference from the other example? Other example means in previous lecture we have shown one example. So, what is the difference here? Difference is this restriction that the gusset plate for making connection is restricted to 250 millimeter length available. Length of gusset plate is 250 millimeter. So, when we go for solution, we have to see that what are things are given.

First is the tensile force P is given. This is 200 kilo Newton, and second thing is the gusset plate thickness. Thickness of the gusset plate that is given 12 mm, and rivet diameter is 16 mm power driven soft rivets. Diameter of rivets which will be used for the connection is 16 mm or driven soft rivets, and length of gusset plate is restricted to 250 millimeter. So, these are the things which have been given. Now, we have to design the member, right. So, let us see how to design means first what we will do. First we will design the member and then we will design the connections.

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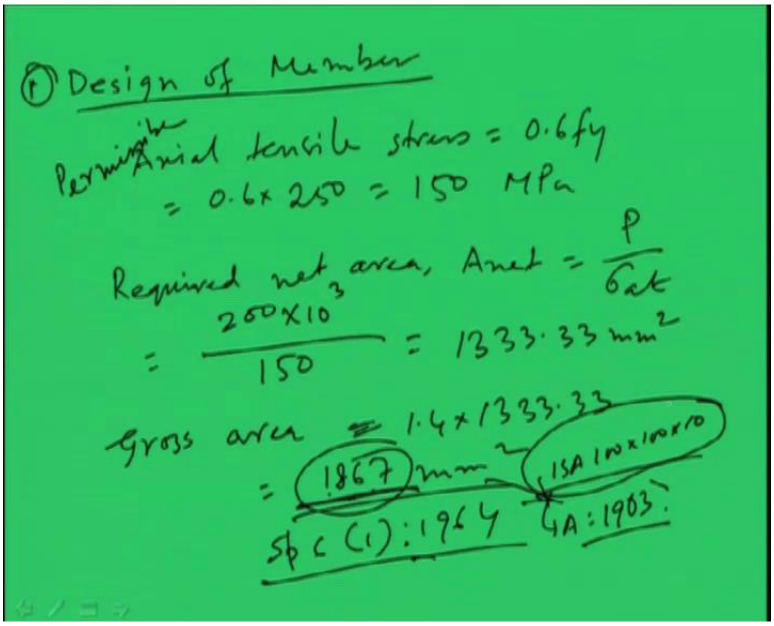

So, first we will go for the design of member. This is the first thing we have to. So, first we know axial tensile stress which is given. Tensile stress if it is not given, we have to assume the type of steel which we are going to use, say if we use the mild steel, then 0.6fy. So, this will become 0.6 into 250 for mild steel fy is 250. So, this is 150 MPa. So, this is given you can say.

Now, we can find out the required net area A that will be basically P by sigma at. So, P is given as 200 kilo Newton. So, 200 kilo Newton means if we make Newton, we have to multiply with 10 cube and sigma at it is nothing, the permissible stress which is 150, right. This is permissible axial tensile stress. So, after calculating we will get the area as 1333.33 millimeter square. So, now we can find out gross area. So, in case of angle we have told earlier that it is around 40 percent more than the net area because of the deduction first hole and other things.

So, we have to take gross area little more that is 20 to 40 percent. So, let us take 40 percent. So, this will become 1.5 into net area is this one. So, this will become 1867 millimeter square. So, gross area is required 1867 millimeter square. Now, what we will do? Now, we will go through the table given in the SP-6. SP-6 is the handbook of 1964 where the properties of angle section and other sections are given. So, from there we will find out a suitable section. We need the gross area as this. So, if we go through the angle section table, we will see. If we use ISA say 100 by 100 by 10, and then we will get more or less nearer to that area 1867. So, this area is becoming 1903 which is closer to this one. So, we have to find out the closer section having area nearer to 1867, but not less than this. So, the nearer means closer section we are getting as ISA 100 by 100 by 10.

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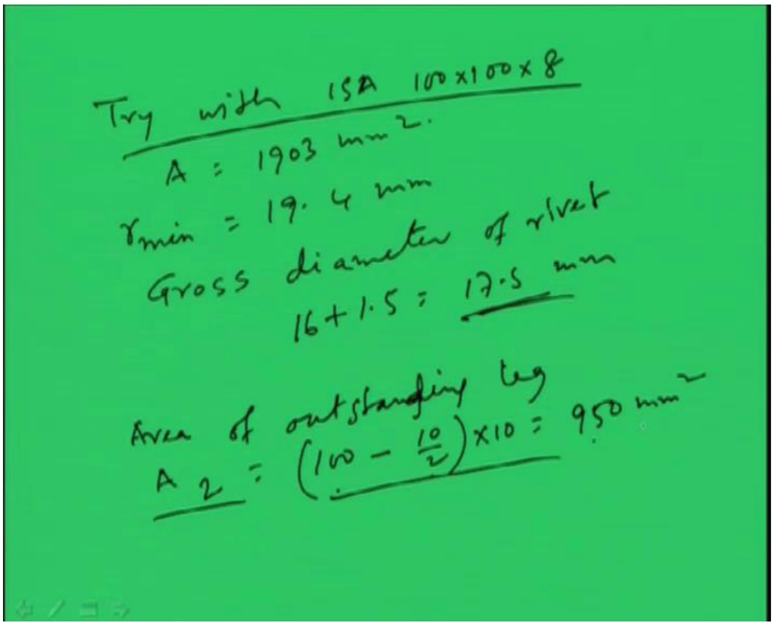

So, let us try with ISA 100 by 100 by 8. With this angle we will try. So, area is coming 1903 millimeter square. Now, from the table also we will get minimum radius of gyration which is given in the table that is 19.4 millimeter. This is required to check the slenderness ratio. Whether it is more or less than the slenderness ratio we have to check. Another thing is we have to find out the gross area means gross diameter of rivet because we are going to use rivet as 16 mm diameter. So, 16 plus 1.5 which is 17.5 millimeter. So, gross diameter of rivet also we have calculated. Now, this will be required for connections. So, these are the things which are required in later we are calculated.

Now, area of outstanding leg is because we have to find out the net area, then area of standing leg which is called A 2. A 2 will become 100 minus thickness is 10. So, area will be becoming as 1915 millimeter square. So, area of outstanding leg which is denoted in general A 2 will become 100 minus thickness into thickness. So, this will become 950 millimeter square.

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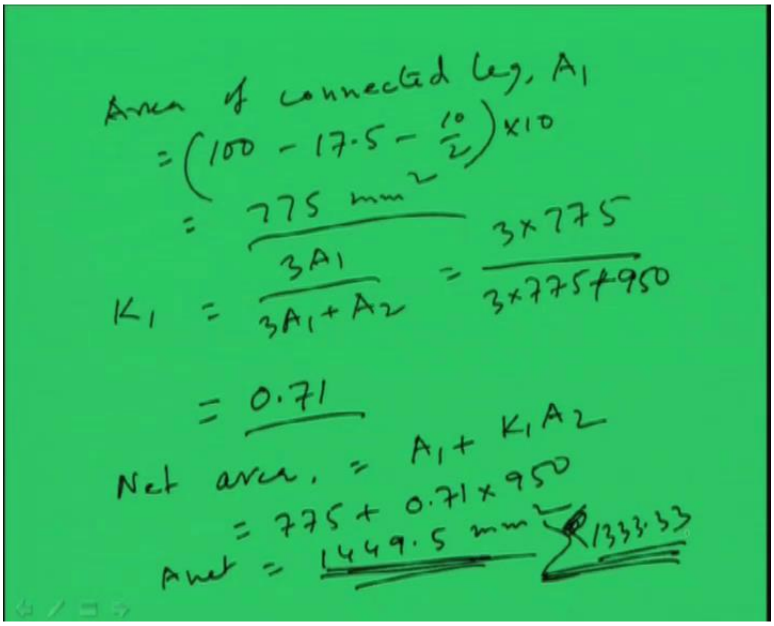

Similarly, area of connected leg which is denoted as A 1, this will become 100 minus 17.5 is the gross diameter minus thickness is 10 into 10. So, this will become 775 millimeter square. So, we got value of A 1 and also value of A 2. So, with this we can find out the value of K 1. K 1 is basically we know 3A 1 by 3 A 1 plus A 2. So, the coefficient can be found out. Now, 3 A 1 by 3 plus A 2, A 2 is 950. So, plus 950 we can add. So, this is coming after calculation as 0.71. So, the coefficient K 1 we got as 0.71.

Now, the net area we know that will be A 1 plus K 1 A 2. So, if we put the values, this will become A plus K 1 is 0.71 into A 2 is 950. So, after calculating this is becoming 1449.5 millimeter square. So, net area A is becoming 1499.5 millimeter square, right. So, net area which is less than the required area, sorry this is greater than the required net area which is 1333.3. So, what we are seeing that net area means available net area is greater than the required net area.

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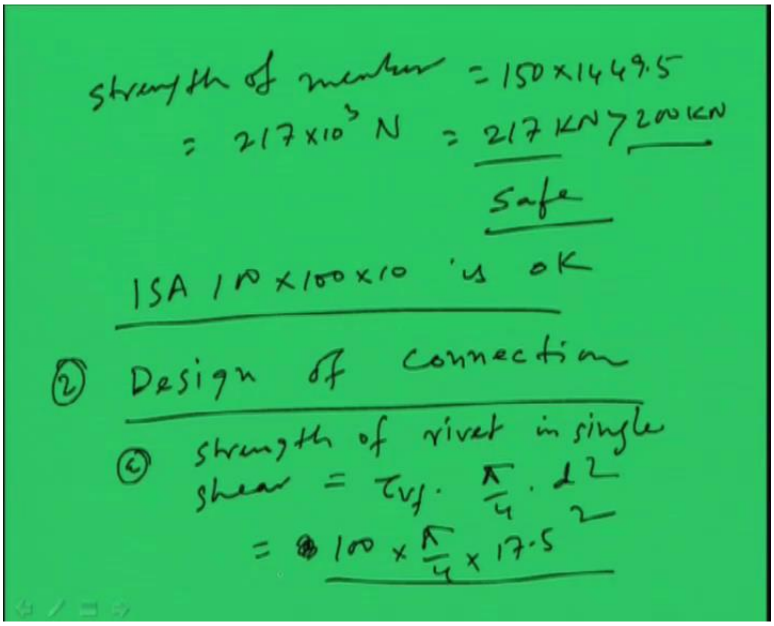

Now, the strength of the member we can calculate. So, 150 mean sigma 80 into net area. Net area available is 1449.5. So, this is becoming 217 into 10 cube Newton. That means 217 kilo Newton. Now, the applied load was 200 kilo Newton. So, applied load was 200 kilo Newton and strength of the member is 217 kilo Newton. So, this is completely safe. That means the angle section whatever we have chosen which is ISA: 100 by 100 by 10 is. So, the section whatever we have chosen is completely right. So, in this way we can design.

Now, what we will do? Now, we will go for connection design. Member design is over. So, we will go for connection design. So, for connections, first we have to see what the strength of the rivet is. That means rivet values. So, first is strength of rivet in single shear. First we will strength of rivet in single shear and then, bearing whichever will be lesser will be the rivet value. So, strength of rivet in single shear will be that is tau vf into pi by 4 into d square. That means we are using power driven soft rivets. That means, tau vf will become 100 and pi by 4 and we are using 16mm diameter of rivet. So, it is 17.5.

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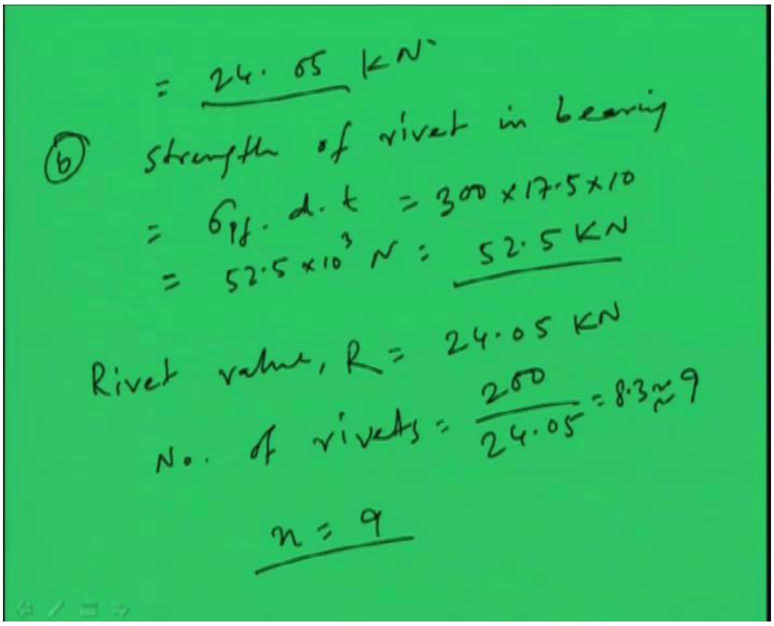

So, this will after calculating will become 24.05 kilo Newton, right. So, rivet value in single shear is 24.05 kilo Newton. Now, strength in bearing also we have to find out. Strength of rivet in bearing, this can be calculated from this formula sigma pf into d into t. Now, sigma pf is the bearing stress. Bearing stress is 300 for power driven soft rivet, and gross diameter of the rivet is 17.5 and thickness is given as 10 mm because angle we have chosen is 10 mm thickness. So, after calculating this, this is becoming 52.5 into 10 cube Newton. That means 52.5 kilo Newton.

So, a rivet value in single shear is 24.05 kilo Newton and rivet value in bearing is 52.5 kilo Newton. That means, we can find out the rivet means we can consider the rivet value as lesser of this two. That means 24.05 kilo Newton. So, rivet values we obtain now. Now, we can find out the number of rivets required to bear the load of 200 kilo Newton, so 200 kilo Newton by 24.05. So, this is becoming 8.3. That means, around 9 numbers of rivets will be required to bear 200 kilo Newton load for as tensile force. So, numbers of rivets are becoming 9. Now, we have to place in properly this 9 number of rivets.

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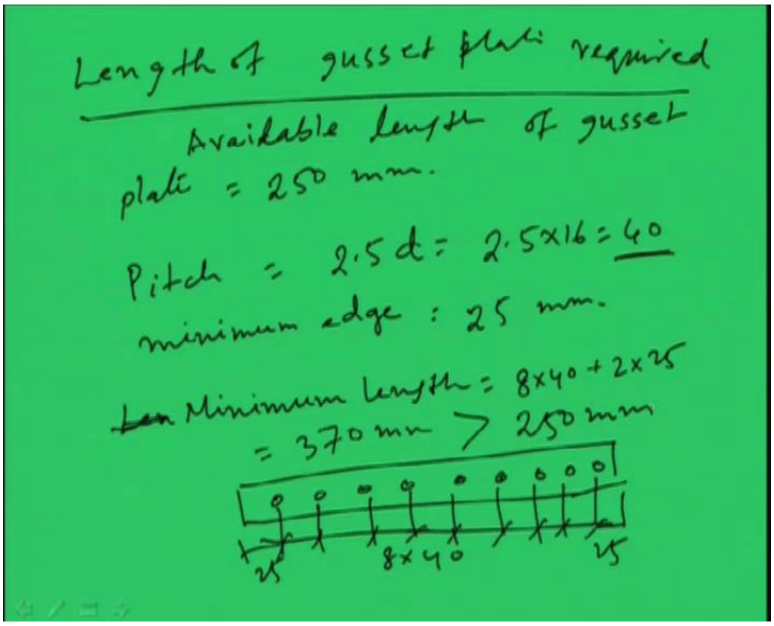

So, for placing this, we have to see length of gusset plate required because the length of gusset plate is restricted. So, we have to see whether it can take that much or not because length of gusset plate was 250. Available length of gusset plate is given as 250 millimeter. So, whether it can adjust all the rivets here or not, that we have to check. Now, to place the rivets, we need the pitch. So, minimum pitch we know as 2.5 d. So, 2.5 into 16 is the diameter of the rivet. So, this is 40 millimeter. So, minimum pitch at least we have to provide 40 millimeter, and minimum edge distance which is required as per the codal provision will be for 16 mm diameter of rivet. For this case, it will be 25 which is given in the code. So, it is 25 millimeter.

Therefore, to place 9 rivets, the length required will be means minimum length we should say because you can use more also. Minimum length which is required will be 8 into 40 plus 2 into 25 because if 9 rivets are placed, so 1, 2, 3, 4, 5, 6, 7, 8 and 9. So, this pitch distance will be 8 means 8 into this one. So, this will be 8 into 40 plus this edge distance to 25 here. So, it is 8 into 40 plus 2 into 25. So, this is becoming 370 millimeter which is greater than 250 millimeter, right. So, what we are seeing here that minimum requirement of length of gusset plate is 370 millimeter where the available length of gusset plate is given as 250 millimeter. Therefore, we cannot place the rivets here that is why the lug angle is required.

I think now it is understood that why lug angle we have to provide because lug angle providing we have several disadvantages like chances of eccentricity, it cannot transfer the load properly. So, there are lots of problems. Still why we are going for lug angle because the restriction of the length of the gusset plate in any case. If the restriction of gusset plate is there, then only we can provide lug angle as an alternative, right. So, now let us provide the lug angle.

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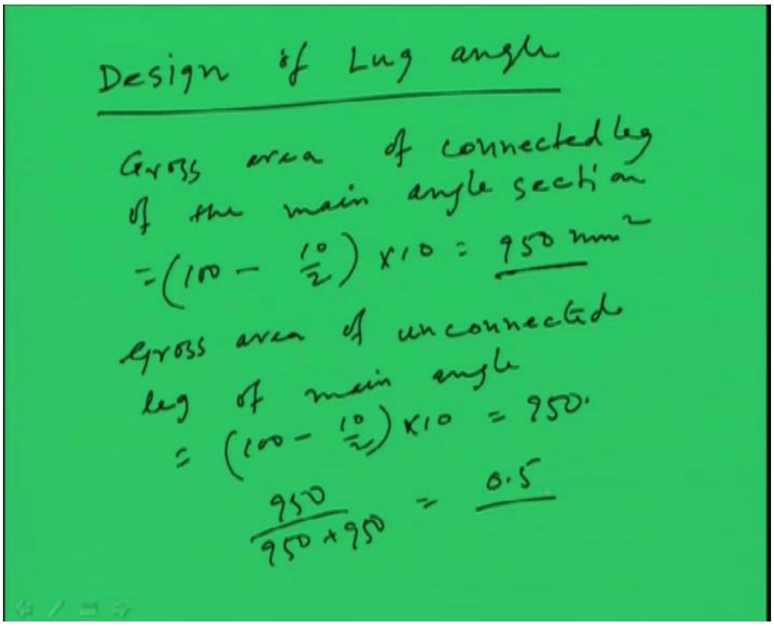

So, if we have to provide the lug angle, we have to design the lug angle. So, now the thing has come about the lug angle that as per the codal provision, how to design the lug angle. We will see. So, gross area of connected leg of the main angle section, we have to calculate, that is 100 minus 10 by 2 into 10 that is 950 millimeter square. Why we are calculating? We have to see the shearing of load between two lengths. So, area of connected leg is 950. Similarly, gross area of unconnected leg of main angle means outstanding leg also will become 100 minus 10 by 2 into 10. This is 950.

So, shearing will be basically 950 by 950 plus 950. That means 0.5-0.5. That means, as the angle is equal means equal length that is why 0.5. 0.5 means half of distribution will be there. However for unequal length, this distribution will be different and in that case distribution has to make in that way. Sometimes, it may be 0.6 0.4 means 60 percent, 40 percent, 30 percent, 70 percent, 45 percent, 55 percent, whatever it is coming. So, on that basis on that ratio we have to provide means we have to calculate the load and accordingly, load will be distributed to the different angle. One will be distributed to the connected leg, another will be to the outstanding leg.

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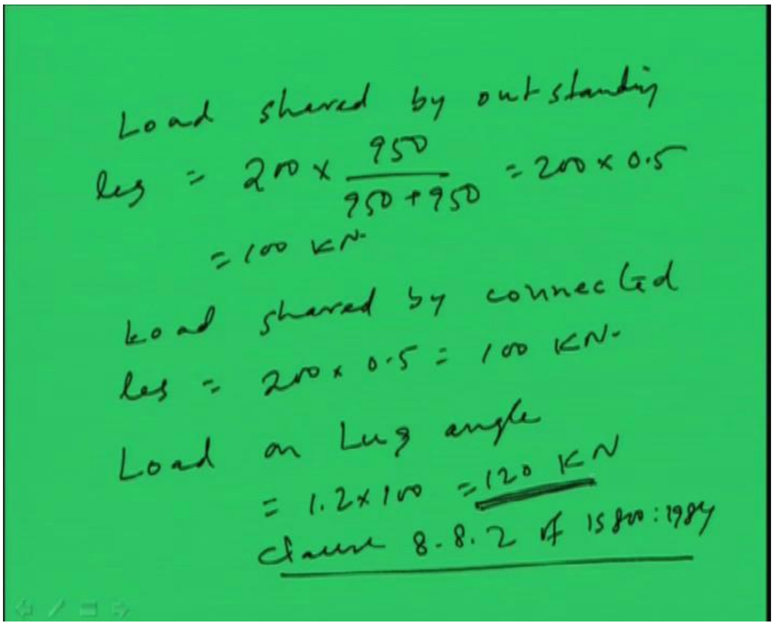

So, load shared by outstanding leg will be how much? 200 kilo Newton is the total leg. So, load shear will be 200 into 0.5. So, it is 100 kilo Newton. Similarly, load on another leg will be say load shared by connected leg that will be also 200 into 0.5. So, is equal to 100 kilo Newton, right. Now, we will see load on lug angle, how much it is load on lug angle. So, what we told in the hum means what we have studied in the case of this clause 8.8 which is given. That is that in clause 8.8, it was given the 20 percent load will be 20 percent extra loads have to be considered for the lug angle. So, it is 1.200 into 100. So, load on lug angle will become 120 kilo Newton, right.

So, this is basically given in the clause 8.8.2 of IS: 800-1984. In this clause, it is given that 20 percent extra loads should be carried by the lug angle. That is why when we will design the lug angle; we will design for not for 100 kilo Newton, but for 1.2 into 100 means 120 kilo Newton, right.

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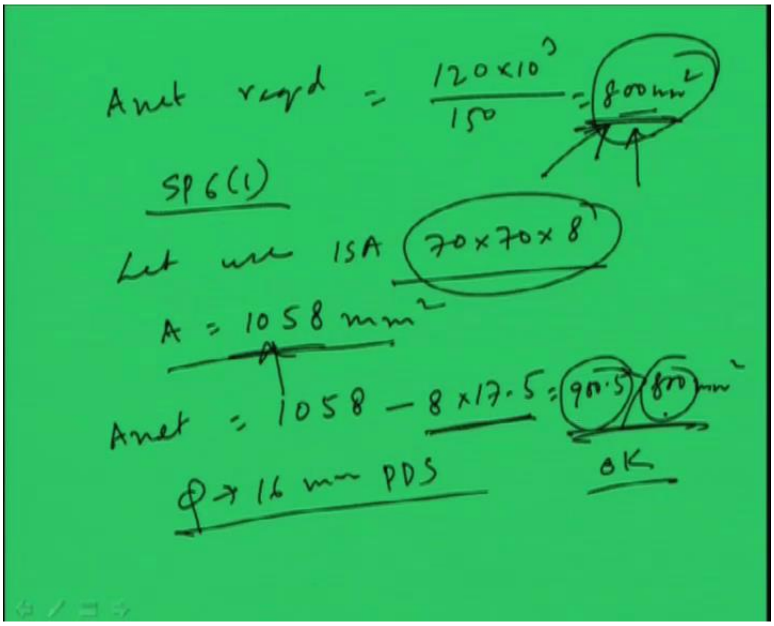

So, to carry this 120 kilo Newton load, the net area required A net this will be how much. It will be p by sigma at sigma at is 150. So, this is coming 800 millimeter square. So, 800 millimeter square is required. Now, we will see the code that SP-6 handbook. From there we will find out a suitable angle. So, let us say ISA 70 by 70 by 8, where the area is becoming 1058, right. We need area of 800 millimeter square and we are providing nearer to that which is 1058. Basically we will see which one is the closer value means which area is coming to closer to 800 millimeter, but it should not be in any case less than 800 millimeter, right.

So, if we choose 70 by 70 by 8, this area has this much. So, we can think about that and of course, we have to see what the net area is. So, net area will be this minus 8 into 17.5, right. So, this is the deduction of whole thinking that 16 mm power driven soft rivet is used and one rivet in each line has been used. So, net area will become this much. This is coming around 900 millimeters square which is greater than the area required. That is why we have taken little more because the net area required is 800 millimeter square.

Now, after deducting the whole area means after deducting whole, the net area should become more than 800 or at least 800. So, after deducting we are getting 900 millimeter square. So, that is why we can consider that this section is 70 by 70 by 8. Now, we have to find out the number of rivets for connecting lug angle. So, for connecting lug angles, first we have to find out the number of rivets and before finding out the number of rivets, we have to know what the rivet value is. So, rivet value means rivet value in single shear and rivet value in bearing.

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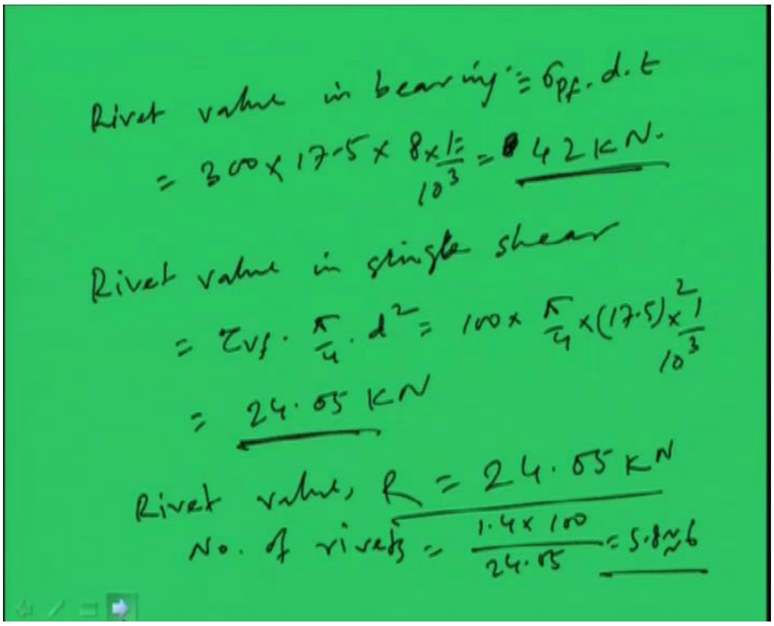

So, rivet value in bearing how much it is coming, this will be sigma pf into d into t. So, sigma pf is for power driven soft rivet. This is 300 d is 17.5. The gross diameter of the rivet and thickness of the angle is 8. So, this is coming and by 10 cube to make it kilo Newton. So, this is coming 42 kilo Newton. This is strength of rivet in bearing. Similarly, a rivet value in single shear will become tau vf into pi by 4 into d square. That means 100 into pi by 4 into d means 17.5 square and to make it kilo Newton, we have to divide it by 1000. So, this is coming around 24.05 kilo Newton.

So, now the rivet value will become lesser of these two. So, rivet value which is denoted as R, this will become 24.05 Newton, right. So, rivet value we are getting now, and now we can find out the number of rivets required. So, number of rivets required this will become number of rivets will be how much, that is 1.4 into 140 percent extra has to be made by 24.05. So, that is becoming 5.8. That means 6 numbers of rivets will be required for this. So, number of rivets required to connect this is 6.

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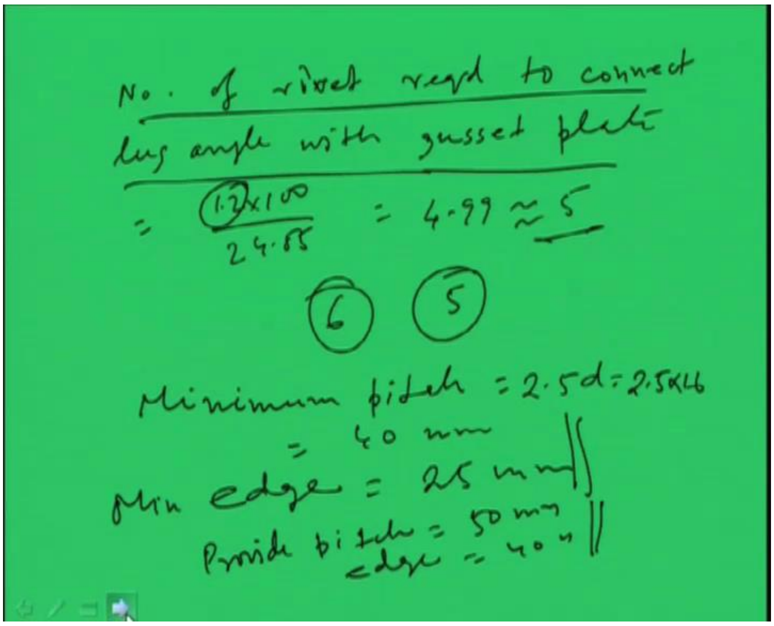

Again number of rivets required to connect lug angle with gusset plate that is 20 percent extra. That means 1.2 into 100 by 24.0, right. This is coming to 4.99. That means 5. So, observe this that number of rivets required to connect lug angle with gusset plate is 5 and number of rivets required to connect lug angle with main member is 6. That means 40 percent. So, for one case, it is 40 percent and another case for gusset plate, it is 20 percent and for main member, it is 40 percent, right. So, that is why here we are multiplying with 1.4 and there we are multiplying with 1.2. So, we are getting number of rivets which connects the lug angle with the main member is 6 and lug angle with the gusset plate is going to become 5.

Now, we have to distribute properly say first minimum pitch will be 2.5d. That means 2.5 into 16. This is becoming 40mm, right and minimum edge distance will become 25 mm as per the codal provision. So, from this we can provide this as minimum or we have sufficient length. So, let us provide pitch as say 50 mm and edge distance as say 40 mm. With this we can distribute the rivets properly. Another thing is number of rivets required to connect main angle with gusset plate that also we have to find out.

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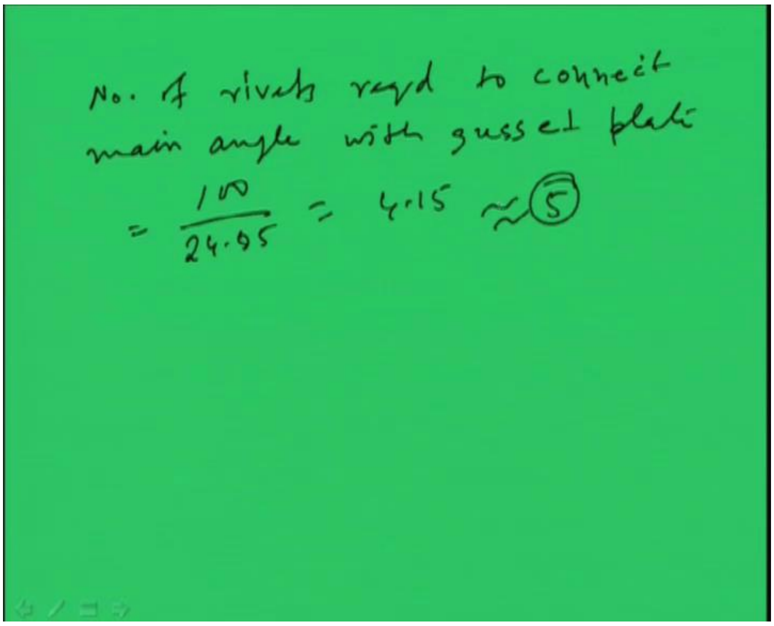

Number of rivets required to connect main angle with gusset plate. Here also we are providing same diameter of rivets. So, this will become 100 by 100 kilo Newton load is transferred into hum through this gusset plate, and the main angle that is 100 by 24.05 kilo Newton. So, this is becoming 4.15. That means this is also 5. So, three interfaces are there. One is gusset plate with main member, another is main member with lug angle and another is lug angle with gusset plate, right. So, three interfaces are there. So, if we draw, then I think it will be clear, right. Let us draw and make the details.

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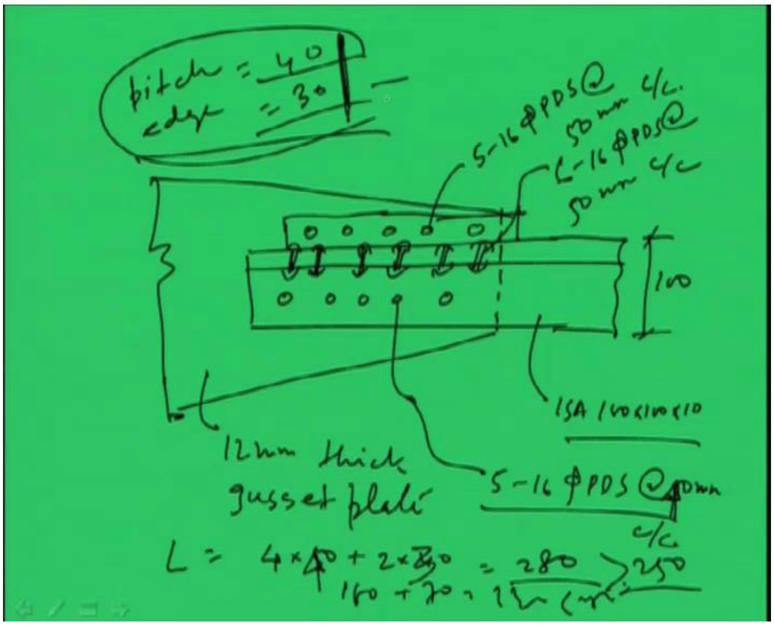

Suppose this is the angle, right and this angle section is 100 by 100 by 10. So, the gusset plate is there. Again the lug angle has been provided here, right. So, lug angle is there. Then, this is the gusset plate. So, this is 12 mm thick gusset plate. This is 1. Second thing is this is ISA 100 by 100 by 10. The section of the angle, the main angle is 100 by 100 by 10. Now, the main angle is connected to the gusset plate with a number of 5. So, 1 2 3 4 5, five numbers of rivets are there, and the lug angle and the gusset plate having also five numbers. The number of rivets between the main angle and the lug angle are 6 as we wrote.

Now, these are basically 5 number of 16 phi PDS power driven soft rivets say at 50mm center. To center this is the distribution, and here this is 5 number or 16 phi PDS at 50 millimeter center to center. Here this is 16 numbers of 16 PDS at 50 millimeter center to center, right. So, in this way we can make it. Now, let us see the length of gusset plate required. To make this length, gusset plate will be required. That is we have five numbers. That means 4 into 50 plus 2 into 40. So, this is coming 280, right and we have in fact 250. Total length was 250. So, what we can do? Now, we can reduce the pitch. So, if we reduce the pitch to 40, I think we can make it say 40 and let us make the edge as 30.

So, in that case 160 plus 70 means 230 which is less than 250. So, the pitch let us make for this one as 40 pitch which is connected to the gusset plate. Let us make 40 and edge let us make 30 to include that 5 numbers of gusset plate. Sorry 5 number of rivets into the gusset plate. So, we can redesign means reorient the rivets, so that the required length which is given 250 millimeters for the gusset plate can be adjusted in this. So, in this way we can make. Otherwise, if we want to provide the pitch say 50 and edge say 40, then again we have to redesign it. That means we have to go for another sort of rivet, so that number of rivet become less. So, we can place properly, right.

So, in this way I think we can design the lug angle. So, what I told in the beginning of design of lug angle is that lug angle is necessary when the length of gusset plate is restricted. So, in that case to accommodate that many number of rivets for high load, heavier load, we have to go for lug angle providing angle type plate extra plate with additional to gusset plate and design considerations as given in the clause 8.8 of IS: 800-1984. We have to follow those things and accordingly we have to design.

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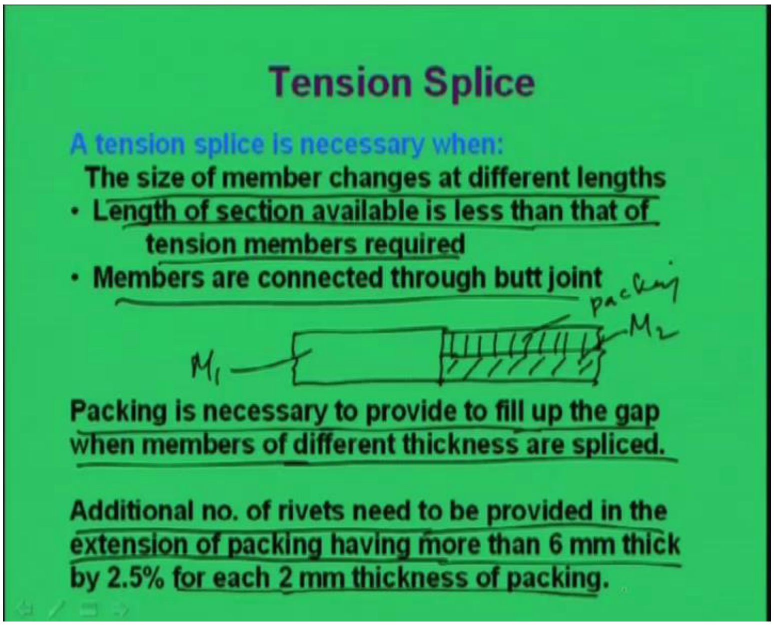

Another thing is tension splice. So, when tension splice is necessary, basically when the size of member changes at different lengths, that means if a member is like this and another member is say suppose like this. So, in that case say this is your member 1, member 2 and member 1. Now, here we need some tension splice. Another thing is when members are connected through butt joint. If the size of member thickness of member is same, then also it is required if it is butt joint and when the length of section available is less than that of tension member required in this case, also the tension splice is required.

When the two types of member thicknesses have to be connected to fill up the gap, we need another extra material which is called packing. This is called packing.

So, packing is necessary to provide to fill up the gap when members of different thickness are spliced. Members of different thickness are spliced; in that case packing is necessary. So, here the codal provision is that the additional numbers of rivets need to be provided in the extension of the packing having more than 6 millimeter thickness by 2.5 percent for each 2 millimeter thickness of packing. So, this is the codal provision which has been given. That means extra rivet is required to make the packing by that 2.5 percent. If the thickness is more than 6 mm for each 2 mm thickness, 2.5 percent extra will be required. So, in this way we have to calculate. Now, I think this will be clear if we go through the example means when we will go through the example, how the rivet is required for packing also will be understood, right.

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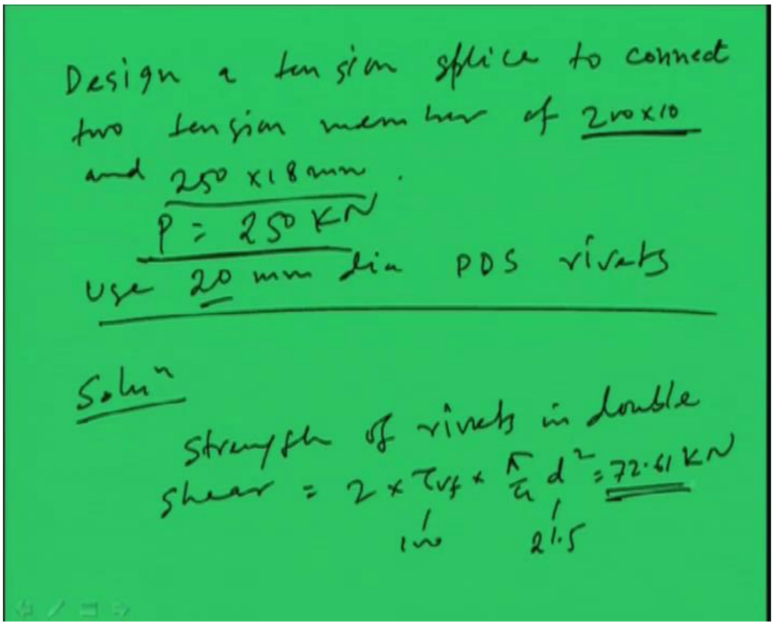

So, now let us go through this example. Design a tension splice to connect two tension members of 200 by 10 and 250 by 18 millimeter. The member is subjected to a pull of P is equal to say 250 kilo Newton, and use say 20 mm diameter of power driven soft rivet. So, what to do that design a tension splice to connect two tension members? The member size is 200 by 10 and 250 by 18 mm, and the force acting on that member is 250 kilo Newton tensile force. Now, use 20 millimeter diameter of power driven soft rivets. So, with this let us design the tension splice.

So, what we will do for the solution? First we will find out the strength of rivets. Strengths of rivets in double shear I am coming on why double shear is required. So, this will be 2 into tau vf into pi by 4 d square. So, this will become 72.61 kilo Newton. This is 100 and this d will be 21.5. So, after putting this value, we will get 72.61 kilo Newton.

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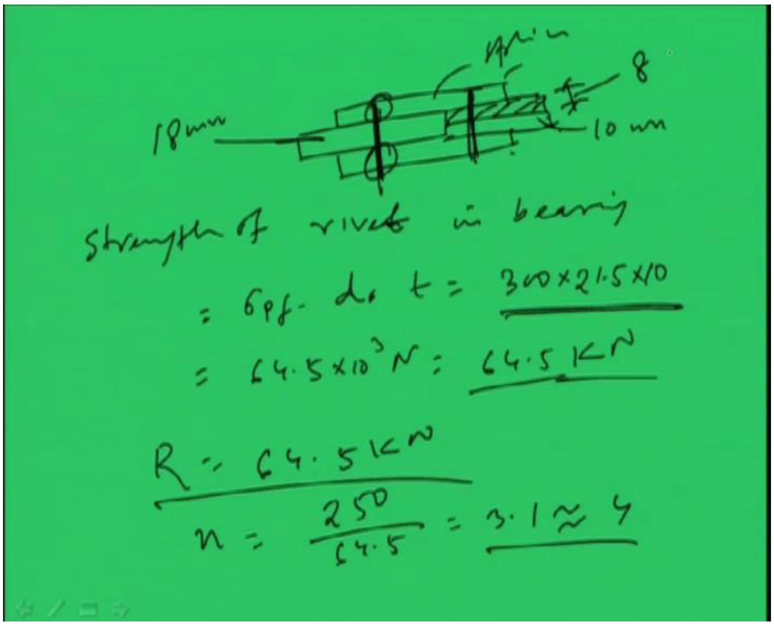

Now, why it is required because when these two members are spliced, say here one packing is given, then we need this is the tension splice. So, when the rivets are providing here, what we are going to get rivets are under double shear. So, that is why strength of rivets in double shear we have calculated. Now, strength of rivet in bearing, so it will become sigma pf into d into t. So, 300 into d is 21.5 t is the thinner part of the plate. One is 18 mm thickness, another is 10 mm thickness. So, the lower one we will see is 10 mm and this is 18 mm.

So, strength of rivet in bearing is becoming this. So, after calculating this, we will get 64.5 Newton. That means 64.5 kilo Newton, right. So, the rivet value we can find out as the minimum of these two, one is 64.5 kilo Newton and another is we got here 72.61 kilo Newton. So, minimum of all these two will become 64.5 kilo Newton, right. So, rivet value we have. Now, what we will do is number of rivets. So, number of rivets n will become the load was 250 kilo Newton by 64.5. So, this will become 3.1 or equal to 4. So, number of rivets we are getting is 4, right. Now, thickness of packing. So, what will be the thickness of packing? We have to see this is 18 millimeter and this is 10 millimeter. So, thickness of packing will become 8 millimeter that is 18 minus 10. So, thickness of packing will become 8 millimeter.

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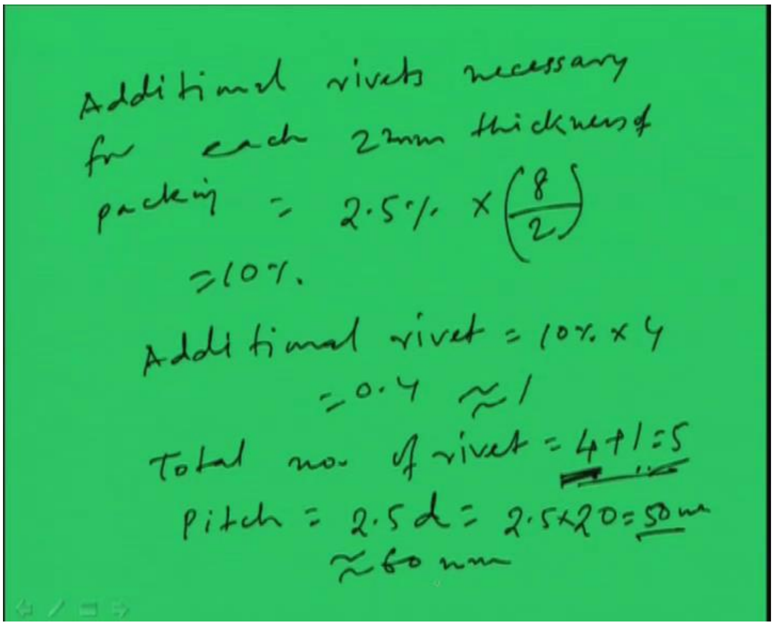

So, additional rivets necessary for each 2 mm thickness of packing as per the codal provision that is 2.5 percent for each 2 mm packing. So, 8 mm was the packing thickness. So, 8 by 2 means 10 percent. So, additional rivets will be required 10 percent. So, that means number of rivets was 4. So, additional rivet will become how many? Additional rivet will become 10 percent of 4 rivets. That means 0.4. That means 1. So, total number of rivets will become how much? That will be 4 plus 1. 4 is to join the tension splice and 1 is for packing. So, total number of rivets is 5. So, 4 numbers of rivets will be required in the splice and 1 will be required in the extension of packing and I will show in the figure. Now, pitch will be 2.5d. So, 2.5 into d is 10. So, that is 50 millimeter pitch, we can consider as 50, right. Now, another thing is minimum pitch is 50. So, let us make say 60 millimeter pitch say provide 60 millimeter.

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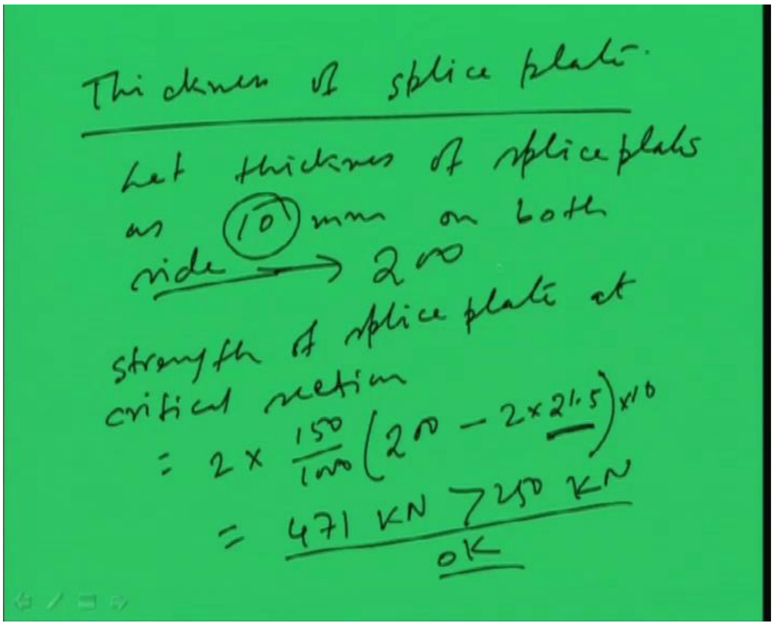

Now, the thing is that we have to find out the thickness of tension splice plate. That is two way. We can calculate the thickness of tension splice. One is, let us assume and we will check whether the splice can take that much load or not. First we will assume that say let thickness of splice plate as 10 mm on both side. 10 mm was the thickness of the plate also. So, that is why let us consider say 10 mm on both sides. That means if we provide both side tension splice with 10 mm, then strength will become strength of splice plate at critical section will be 2 into 150 by 100 per kilo Newton. 200 is the width.

So, if we consider thickness of means, sorry width of splice as 200 millimeter which is given in one plate. If we consider accordingly, then 200 and minus 2 into 21.5, this is the diameter of the rivet. If we consider that the two rivets are in a section, it is given, so this into 10 mm thickness. So, if we provide this is becoming 471 kilo Newton which is greater than 250 kilo Newton. That means the tension splice thickness whatever we have is considered. So, tension splice we have considered is 10 mm thickness and in fact, the width we have considered 200 mm width. So, 200 by 10 is sufficient to carry this much load. In other way also, we can find out the thickness of the tension splice.

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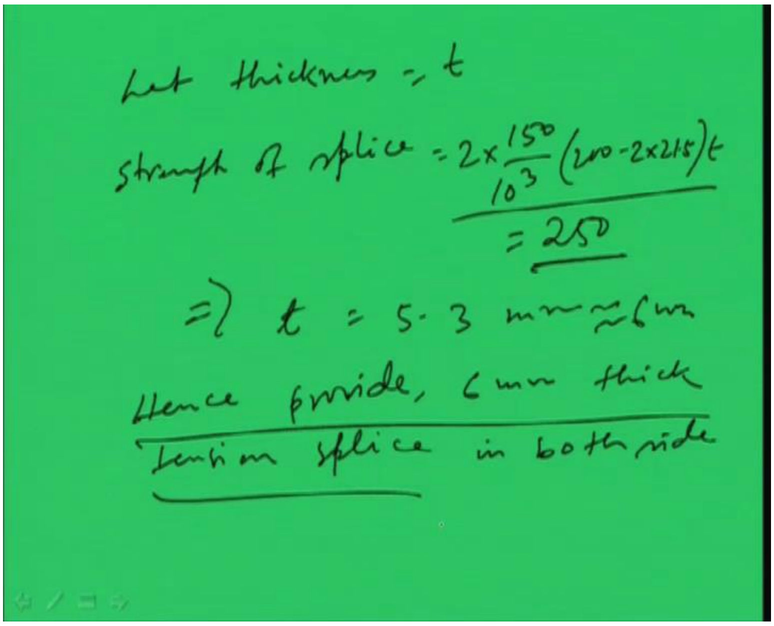

Thickness is equal the t we do not know. So, if thickness is t, then strength of splice will become 2 into 150 by 10 cube into 200 minus 2 into 21.5 into t. This has to become 250 because the strength of the tension splice has to become equal to the applied load which is 250. That means, tension splice should carry the load which is applied in the member that is 250 kilo Newton. So, if we make equal, we will get t as 5.3 millimeter. That means we can use 6 mm. Hence, we can provide in place of 10 mm, 6 mm thick tension splice can be provided. Hence, provide 6 mm thick tension splice in both sides. So, in this way we can make it.

So, both the way we can find out, either we can assume the thickness of the tension splice and then, we can check whether it is or not. Otherwise, we can make it equilibrium that makes it equal to the applied force which is equal to the strength of the tension splice. From that we can find out the thickness, right. Now, if we draw the figure means if we see the diagram, how it looks like let us see.

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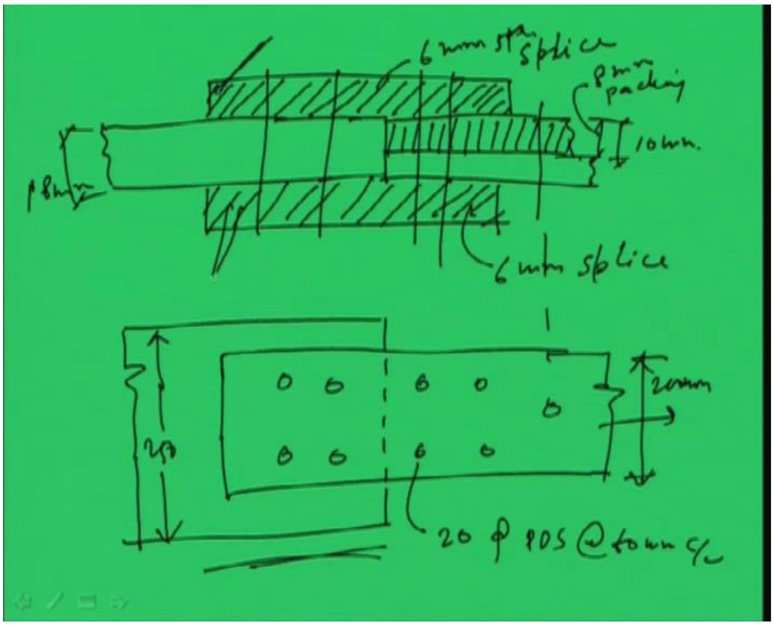

This is main plate, this is another plate and this is the packing, right. Now, tension splice we are giving one here, another here. So, this is the tension splice. This is the tension splice this is packing. So, this is 8 mm packing, this is 10 mm or 6 mm, say we are providing 6 mm splice. This is also 6 mm splice and this is this is 18 mm and this is 10 mm, right. Now, if we see in the plan, we will see another. So, if we see in the plan, this is basically 250 millimeter and this is 200 millimeter. This was 200 millimeter, right. So, now rivets will be basically we will provide rivets. This is one here, one here, one and another extra here.

So, we will get like this say 4 rivets are here, another like this. It will go on and one another extra will be here, this there. So, 25 PDS at 60 mm 100 percent. So, in this way we can plan the splice how it has been made can be seen. In the side view if we see the splice, one splice is provided at top and one splice is provided at bottom with same thickness of 6 mm thickness, right. So, this is the way how to design the splice. Tension splice why it is required and how to design all these, I think it is clear through this example. Now, with this I will like to conclude today’s lecture.

Thank you.