Design of Steel Structures

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Module - 5
Lecture - 7
Compression Members
Design of Lacing System

Hello. Today my lecture will be focused on design of lacing systems. In fact, this is a continuation of the previous lecture. In previous lecture, we have discussed about different aspects of design criteria of lacing systems. In codal provisions, different guidelines have been given. So, according to that we have discussed what guidelines we have to maintain for design of lacing systems.

Today, first I will just give a short overview of the yesterday's lecture. That means the design steps which we have followed which we have discussed for designing of lacing system. Then, I will go through one example which you will be clear to understand how to design a lacing system. The example we will not only design the lacing systems, but also it will design first the built up sections means for a given load and for a given dimension. Dimension means the length of the column, what should be the appropriate built up sections and then, what should be the orientation, whether it is back to back or front to front, whether it is channel section or I section. All those things we will discuss. Then, we will design those built-up sections. After that we will design the lacing systems including the connection between the main frames with the lacing. I hope with this it will be clear that how to design a built-up section with the lacing.

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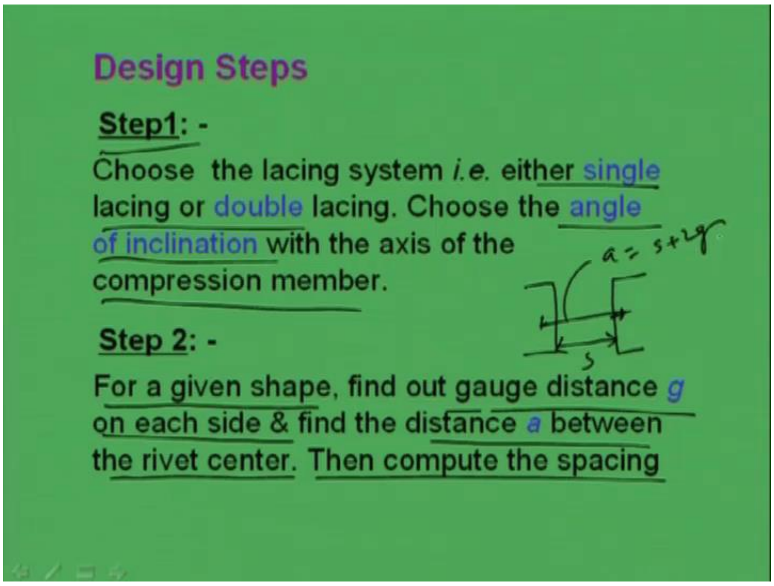

So, in last lecture we have discussed about design steps. Those steps, first I will like to remind again because these steps will be required for working out the example. First what step we are making that choose the lacing system. That means, either it is a single lacing or double lacing that we will first choose. Then, what we will do? We will choose the angle of inclination with the axis of the compression member. So, this is the first thing we will decide. That means first we will choose whether it is double lacing or single lacing and then, we will decide some angle of inclination. In fact, in codal provision we had seen last day that the inclination should be in between 40 to 70 degree. So, in between some angle of inclination we will choose.

In next step, what we will do that for a given shape, we will find out the gauge distance on each side and find the distance between the rivet center and then, compute the spacing. That means first we will find out some shape. That means, on the basis of the availability in the market or on the basis of the choice of the designers, we will find out the built-up section shape whether it is channel section or I section or combination of channel and I section, or say combination of angle section. That we will first decide. Decide means we will choose and then, we will find out the distance a. That means suppose if this is a channel section we are choosing say back to back channel section. Then, we know what the gauge distance is. We know gauge distance and we will find out the spacing for the optimum use of the material and then, we will find a. A mean basically a will be s plus 2 g. That we will find out, right.

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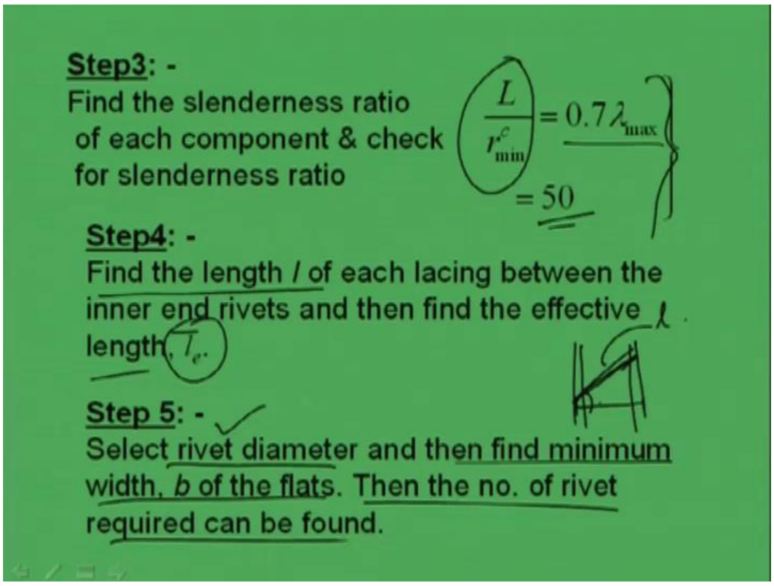

What we will do next? We will check that slenderness ratio whether L by rc minimum is exceeding 0.7 lambda max or not and 50 or not. That means we have to check this one that this should not exceed more than 50 or more than 0.7 lambda max. Then, in step 4, we will find out the length l of each lacing between the inner end rivets and then, find the effective length. Length l means suppose two main frames is there. Now, if we have to find out the length, this will be the length. So, the moment we know this distance a, we can find out the length l because we know the angle of inclination. So, length l we can find out and then, as per the boundary condition, n condition we will find out the effective length and this has been guided in the code.

Then, in next step 5 what we will do? We will select some rivet diameter and accordingly, we will find out the width of the lacing which is given in the codal provision. So, we will find out the minimum width and then, we will adopt some width through which we will go on designing, right and then the number of rivet required that also we can find out, right.

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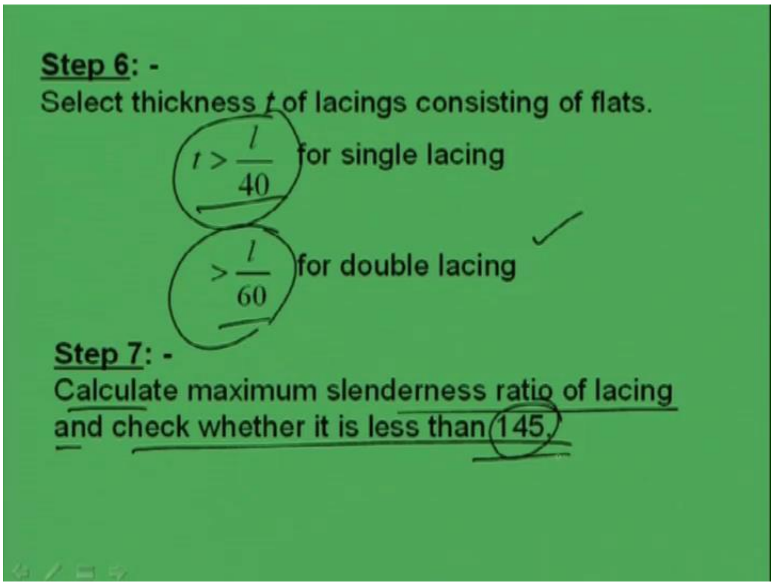

Next what we will do? Next we will find out the thickness. As we know from the codal provision that thickness should be greater than l by 40 for single lacing system and l by 60 for double lacing system. So, accordingly we can find out the thickness t and then, what we will do is, we will calculate the maximum slenderness ratio of the lacing and check whether it is less than 145 or not, right. That means the slenderness ratio how do we calculate. We will calculate the radius of gyration of the section which we are going to adopt. Radius of gyration means we know t and b thickness and width of the lacing. So, we can find out the radius of gyration. That means, i by a root over I by a. So, from that we will see whether it is exceeding 145 or not and accordingly we will adopt. If it exceeding 145, then we have to increase the dimension, so that l by r ratio, the slenderness ratio becomes less than 145.

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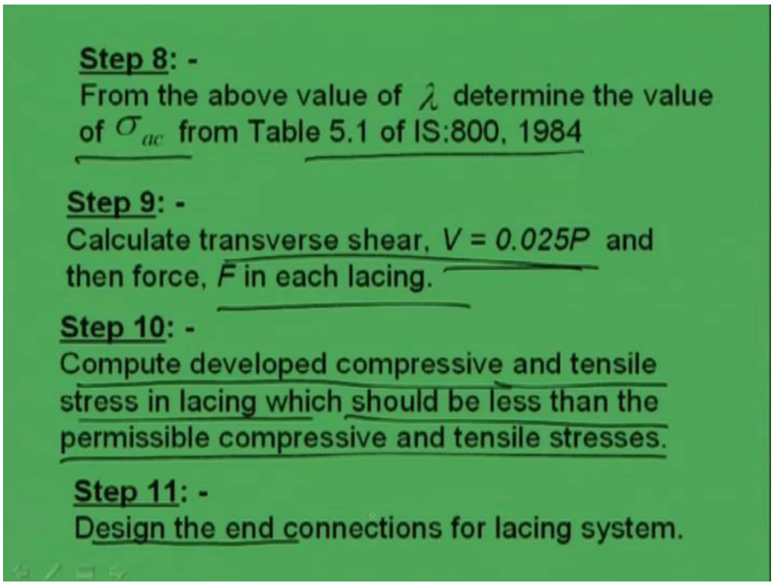

In step 8, what we will do? We will find out on the basis of the calculated lambda, we will find out sigma ac. Sigma ac from where? It is from table 5.1. In table 5.1 of IS: 800-1984, we will get the allowable compressive stress sigma ac on the basis of lambda and the type of steel we are going to use. So, on that basis we will find sigma ac. Then what we will do? Then, we will calculate the transverse shear. Transverse shear V which is 2.5 percent of the axial compression. So, transverse shear we can find out and then, we can find out F in each lacing whether it is double lacing or single lacing. Accordingly, F we will find out as we have shown earlier. Then what we will do?

Then, we will find out the compressive stress and tensile stress, and we will check whether it is exceeding the permissible compressive and tensile stress. If it is exceeding permissible compressive or tensile stress, then we have to increase the dimension. Otherwise, it is right. In step 11 what we will do? Then, this is the last step where we will design the end connections. End connections means whether we are going for welding connections or riveting connections. So, accordingly we will design number of rivets. How many would be that? We will find out and what type of riveting we are doing. Riveting means what type of means what is the configuration of rivet joints. Accordingly, the force will come and accordingly the number of rivets can be found out, right. So, with these steps we can design a lacing system.

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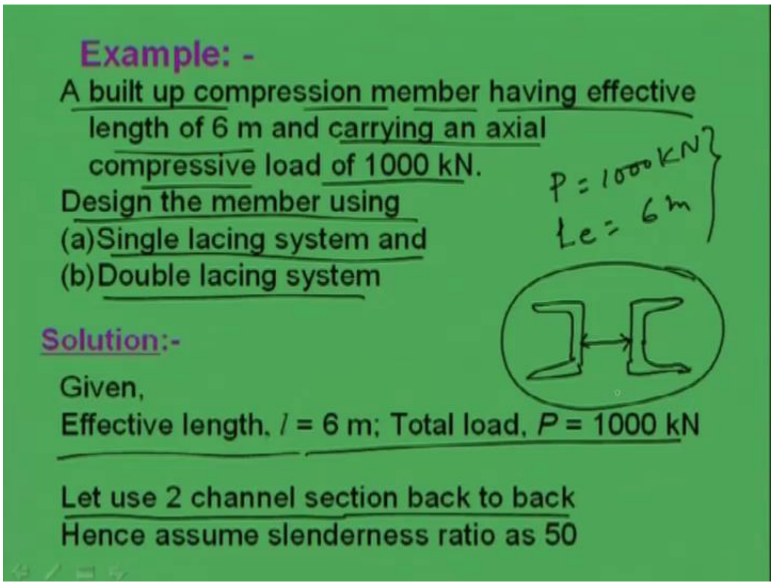

So, in this example let us see how to design the lacing system. That a built up compression member having effective length of 6 meter and carrying an axial compressive load of 100 kilo Newton. That means axial compressive load is 100 kilo Newton. This is given and effective length Le of the compression member that is given as 6 meter. These are the two things which have been given. Now, we have designed the member using first single lacing system and then, double lacing system. Two things we will see. If we use single lacing system, how design we are going to follow and if we use double lacing system, how it is differing from the single lacing system design procedure. That we will see.

So, to differentiate the two things or to understand properly both the things, we will do, right. For the same problem we will first design using single lacing system and then, using double lacing system. So, these are given effective length and total load is given. Now, it is the choice of the design engineer what type of section he is going to adopt whether channel section or angle section or I section. It is up to him and it is of course up to the availability of the section in the market which is available in the market. On that basis we generally use to choose what type of things we are using.

Now, let us say we are choosing two channel sections back to back. So, let us first use the two channel sections we are using and that we are using back to back. So, this is the first criteria we are assuming. Now, from this what we have to do? Now, we have to find out the spacing through which the applied load can be carried out without any problem, and second is whether it will be back to back or front to front. Now, generally back to back channel is preferable from the design point of view. From the maintenance point of view, we had shown earlier that why channel section back to back is preferable. So, we prefer this one and another thing is we have to assume the slenderness ratio because on that basis we have to find out the size of the section.

Now, in the codal provision, it is given that if we assume slenderness ratio around 50, then we can find out an optimum size of the section. So, at the starting point we are choosing the slenderness ratio as 50 because for built-up section, generally slenderness ratio will become less, right.

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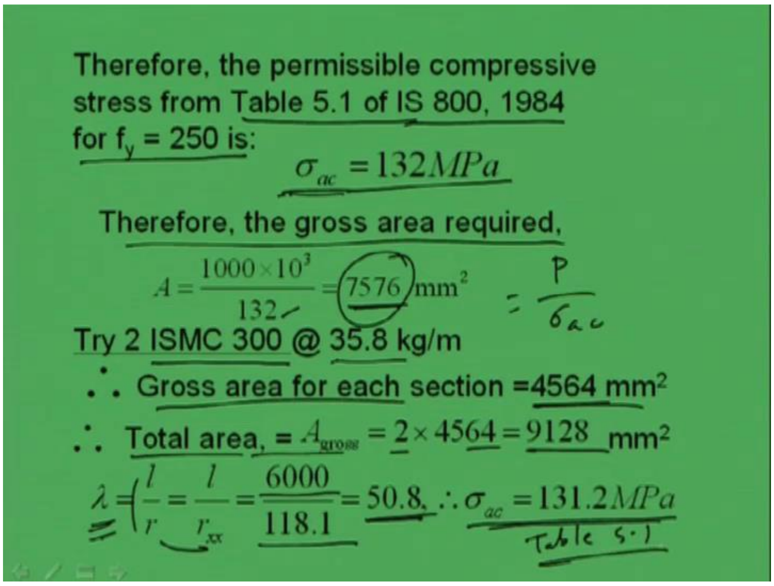

So, with this we can find out the value of sigma ac that is the permissible compressive stress which we can find out from table 5.1 of IS: 800-1984 for a particular grade of steel. Suppose grade of steel we are going to use as fy is equal to 250, right. So, from table 5.1, I can find out sigma ac. The compressive stress allowable is 132 Mpa, right. Now, the allowable stress as we are getting we can find out the gross area required. The area required for the section is this. So, this is basically P by sigma ac. P is 1000 kilo Newton and sigma ac is 132. So, from this we are getting 7576 millimeter square. The area required is 7576 millimeter square.

Now, we will see two channel sections as we are going to use. So, what channel section will be preferable to adjust is this much area, right. So, if we use say ISMC 300 with a weight of 35.8 kg per meter, then we see the gross area of each section is given as 4564 millimeter square, right. So, total area we can find out as 2 into this is equal to 9128 square millimeter. So, we are going to use 9128 millimeter square area whereas, we need 7576. That means we are using little higher size. Now, with this channel section we have to check whether the allowable stress means allowable stress is greater than the developed stress or not. So, for this now actual section we know. So, we can find out the lambda which is slenderness ratio. So, slenderness ratio is l by r. In this case, r will become rxx and this is l is effective length is 6 meter and r is 118.1 millimeter which we can find out from IS: 800-1984 and then, it is coming lambda as 50.8.

Remember we have assumed lambda as 50 and now it is becoming 50.8, right. So, actual lambda is becoming 50.8 and the sigma ac, the allowable compressive stress is becoming 131.2 Mpa. This we can find out from table 5.1, right.

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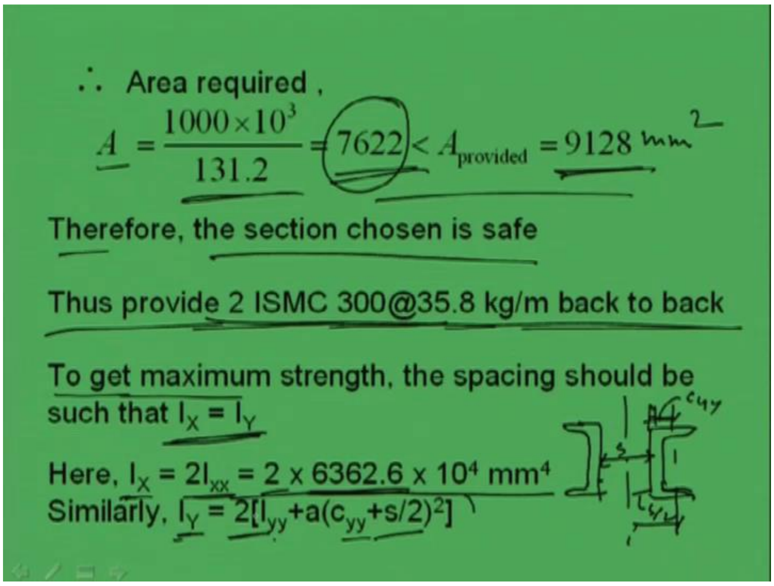

So, now what we will do? Next we will find out the required area because now we know what the slenderness ratio actual is and what the actual load is. So, what should be the required area? So, required area will be the actual load by the allowable compressive stress. So, that is coming 7622. This is the area required and we are going to provide 9128 millimeter square. So, this is perfect. That means the required area is 7622 millimeter square and we are going to provide 9128 millimeter square. So, in this way it is.

So, we can say that the section chosen is safe. Thus, we are providing 2 ISMC 300 at 35.8 kg per meter back to back. So, this is fixed now, right. So, this is one thing unknown that is what the built-up section configuration is and what will be the size of the built-up section. These two things we have decided. One is we are going to use channel section back to back and size is ISMC 300. The size we are going to use. Now, we have to decide what the spacing between two channel is, right. So, for spacing what we will do that we will try to find out the maximum strength. That means the spacing should be such that Ix will be equal to Iy, so that the maximum strength in both the direction we can find equal, right.

So, if we make Ix is equal to Iy that means Ix is basically 2 into Ixx 2 into individual Ix, right. 2 into this is the moment of inertia about x direction of an individual section. So, this is Ix. Similarly, Iy we can find out. What will be Iy? If we see the orientation of the member, we will see what will be the Iy. Let us see. This is two channel placed in back to back. So, what will be Iy? Iyy will be the individual Iyy plus this is cy and this is S by 2 because total is S, right. So, cyy plus S by 2 whole square into a. That means Iyy plus a r square into 2. So, this will become total Iy.

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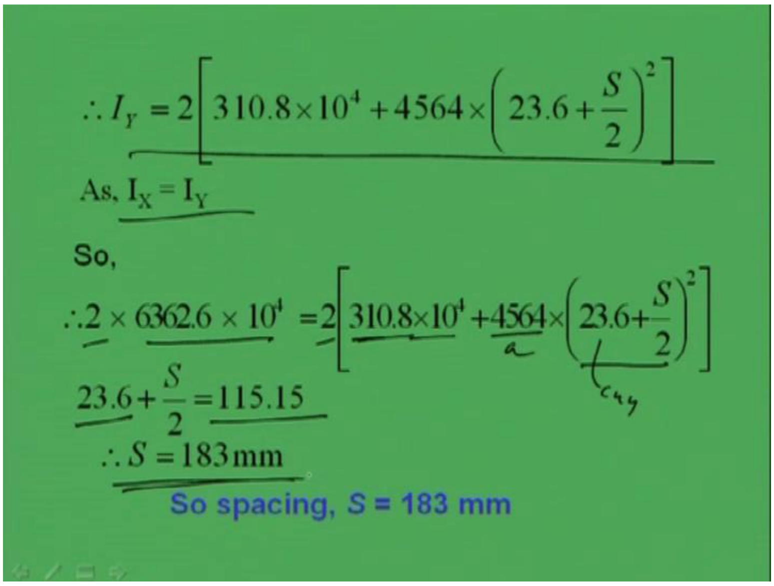

So, now if we make Ix equal to Iy, then we can find out the value. So, Iyy we are getting this, where S is unknown and if we make equal, we can find out the value of S which is coming 183 millimeter because Ix is 2 into 6362.6 into 10 to the power 4 and Iy is 2 into

31 means 310.8 into 10 to the power 4 which is Iyy plus area a r square r means cyy. This is cyy into S by 2 whole square. So, from this I can find out 23.6 plus S by 2 is equal to this and from this S is equal to be coming 183 millimeter, right. So, in this way we are getting spacing as 183 millimeter.

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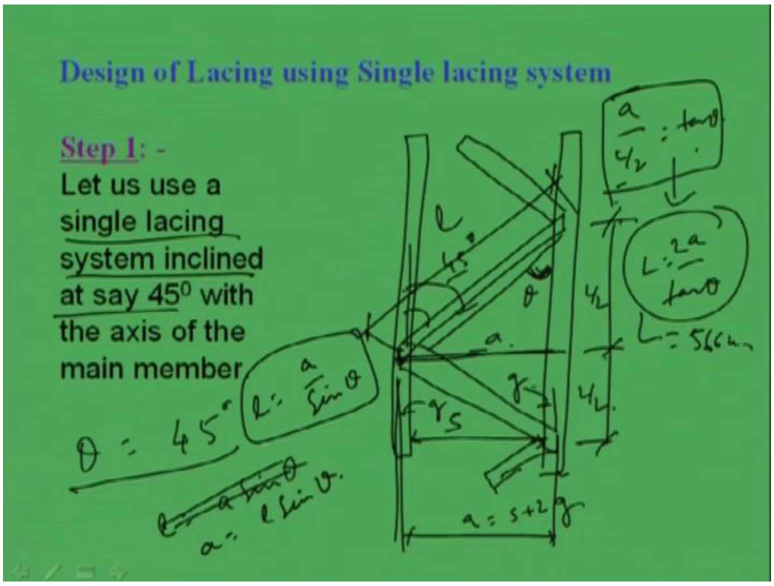

Next what we will do? Now, we will design the lacing using single lacing system, right. So, if we see the two sections is given and we are providing lacing, right. Let me draw first and then, it will be easy to understand and we say it is going on. So, first we are using single lacing system inclined at 45 degrees. So, this is 45 degree, right. We are assuming the angle of inclination theta as 45 degrees, right. So, these two things in first step we are assuming. One is that single lacing system and then, theta is equal to 45 degrees, right.

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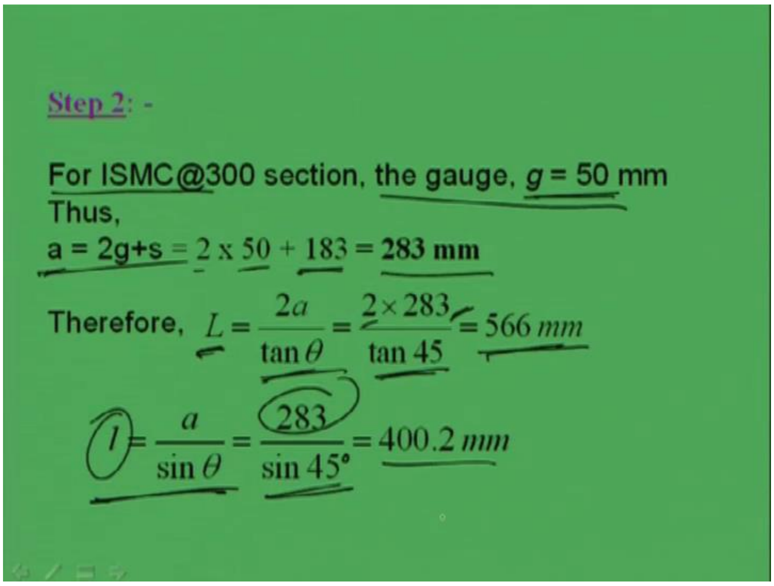

In next step, what we will do? As we know we are using ISMC 300, so from the handbook that SP 6 we can find out the gauge distance g which is given in the table in SP 6. So, in SP 6 we can find out g. So, we can find out a. A means which one a will be basically this one, this distance. So, this distance into this distance is a. That means, this is becoming s means clear distance between two sections and this is g which is given in the code. This is g. So, a will become s plus 2 g, right. So, s plus 2 g we are making. So, we are getting 2 into g is 50 and s was 183 millimeter. So, it is becoming 283 millimeter, right. Now, we have to find out L. L means this. This is the L, right. So, how do we find out?

We will find out first. So, this is a. We know right. So, we can find out L by 2. What will be L by 2? Here if we see this is 45 degrees, so this will become 45. So, a by L by 2 is equal to tan theta. So, we can find out L is equal to we will get a by 2 a by tan theta. So, in this way we can find out L is equal to 2 a by tan theta, right. The way we have find out L is equal to 2 a by tan theta, this is total L and this is L by 2 and we are finding from this a by L by 2 will become tan theta. If this is theta, this will be theta, right. So, a by L by 2 is becoming tan theta. So, from this equation I can find out L is equal to 2 a by tan theta. So, L is equal to 2 a by tan theta. So, 2 into a is given 283 millimeter and theta is 45 degree. So, if we put these values, we will get L as 566 millimeter. That means L is becoming 566 millimeter, right.

What will be the length of the lacing? Length means which one? It is from this to this. This is the length, right. So, what will be the length of the lacing? L will become a if this is theta and then, l will become a sin theta, right. So, sorry this is a, and this is l. So, this will become a equal to l sin theta. That means l will become a by sin theta, right. So, length of the lacing will become a by sin theta. So, length we are going to find out a by sin theta. So, a is 23 and theta is 45 degree. So, we can find out from this the length of the lacing as 400.2 millimeter, right. So, in this way we can find out the length of the lacing. So, step by step we are proceeding to find out the dimension of the lacing, right. So, what we have done? First we have decided the angle of inclination, and then we have found the length of the lacing and the spacing, right.

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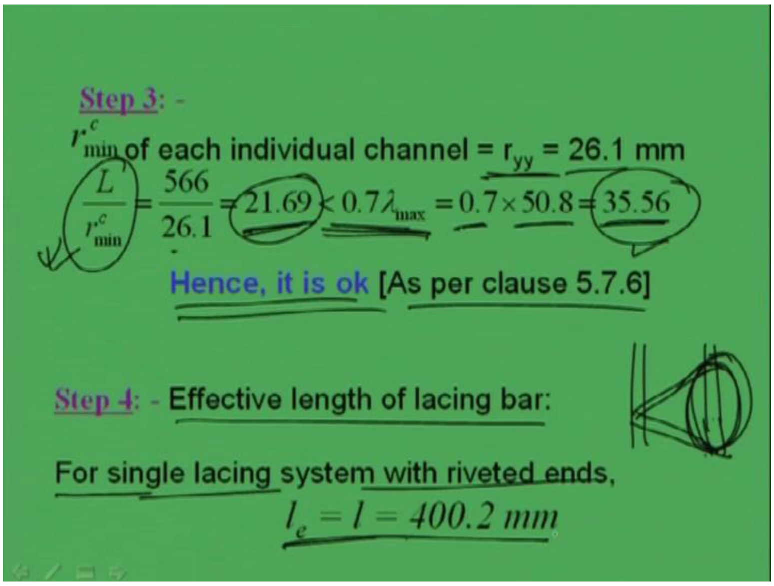

Next what we will do? Now, we have to find out what you call the thickness and width of the lacing, and before that we have to check as per the codal provision that this L by rc minimum should become this, right. Now, we know rc minimum which is for individual channel, this is ryy. It is 26.1 because we have to check and see if this is going like this. We have to check whether this is strong enough means local buckling should not occur. How to ensure that? From this the radius of gyration of this portion, right and this portion we can make ensure through this equation that L by rc minimum should be this and as per the codal provision, this should be less than 0.7 into lambda max and lambda max we got already earlier. Lambda max was 50.8.

Lambda max means the maximum radius of gyration, sorry maximum slenderness ratio of the main of the built-up section. So, in this way we are finding L by rc. Minimum is becoming 21.69, whereas it should be less than 35.56. So, we can say this is as per codal provision. In clause 5.7.6, it is told that L by rc minimum should be less than 0.7 lambda max and now 0.7 lambda max is becoming 35.56, and L by rc minimum is becoming 21.96. So, this is less than 0.7 lambda max. Now, what we will see that effective length of the lacing bar. We know the length of the lacing bar that is 400.2 millimeter length. So, for single lacing system with riveted joint, we know le becomes l effective length will become equal to l. So, the effective length in this case is becoming 400.2 millimeter, right.

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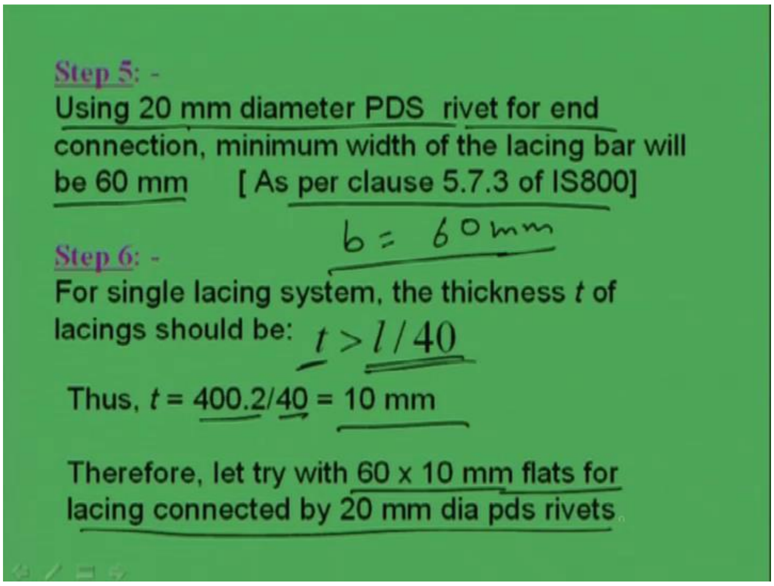

Next what we will do? In next step we have to do some rivet diameter. Let us use 20 mm diameter of rivet and power driven soft rivet. So, what we will get? We will get the minimum width of the lacing as per clause 5.7.3 of IS 800 as 60 mm. Minimum width for the lacing we are getting 60 mm, right. So, let us use b is equal to 60 mm of the lacing width and then, in next what we will do? We will find out thickness. The thickness should be for single lacing system l by 40 means it should be greater than l by 40. So, l is 400.2 and 40. So, we are getting 10 mm.

So, we can try with the lacing bar as 60 by 10 dimension and using 20 mm diameter power driven soft rivet. So, these are the unknown things what we suppose to get. Now, we are getting and that dimension of the lacing will become 60 by 20 using 20 mm power driven soft rivet, right.

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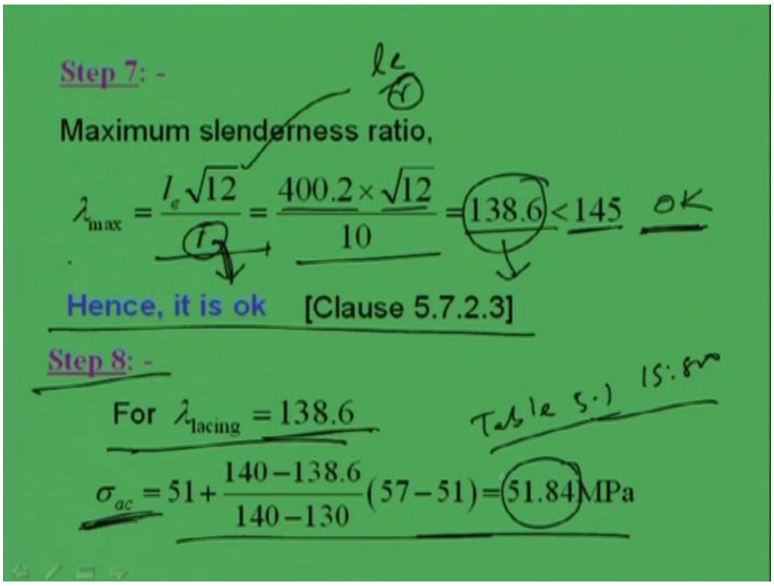

Next what we will do? Next we have to check the maximum slenderness ratio. Maximum slenderness ratio for the rectangular bar we know in earlier equation, we have seen that and that will become finally le root over 12 by t and for other type of section shape, suppose the angle section or some other section if we use as a lacing bar, then we have to find out lambda max from the equation that le by r where r is given in the table, right. So, from this we are going to get le as 400.2 and t as 10. So, if we put those value, we will get 400.2 into root over 12 by 10 is equal to 138.6 which is less than 145.

If the lambda max is greater than 145, then what we have to do is we have to increase the dimension of the lacing system. Dimensions mean here we are seeing that we cannot change other things, but the thickness because other things if we change, it has no meaning because this is fixed, right. So, thickness we have to increase if we cannot satisfy this one. So, to satisfy this one, we will do lambda max is equal to le root over 12 by t and accordingly, we will check what the value is coming. So, now we will check the maximum slenderness ratio. Slenderness ratio for rectangular type of bar we will get le root over 12 by t. Otherwise, if we have say lacing bar as angle like section or channel like section, then we have to find out le by r, where r is given in the code for a particular dimension of the section, right. So, here we are getting le root over 12 by t.

So, if we put the value le as 400.2 and t as 10, we are going to get 138.6 which is less than 145. So, it is right. Now, if this lambda max is becoming more than 145, what we have to do? There will be only possibility is to change the thickness t because if we change width, there will be no meaning. That means we are not able to decrease. So, to decrease this we have to increase the thickness. So, if the lambda max is coming more than 145, then we have to increase the thickness, so that it becomes less than 145. So, in this way we have to adjust, right.

So, as per the codal provision in clause 5.7.2.3, we have to see whether lambda max is becoming less than 145 or not. Then, what we will do? Then, we will find out what the lambda lacing is and accordingly, what the permissible compressive stress is. So, for lambda lacing 138.6 permissible compressive stresses, we will get from this that is from table 5.1 of IS 800 that is given for different lambda. The value of sigma ac has been given. So, for 138.6 lambda lacing, we will get permissible compressive stress as 51.84 Mpa, right.

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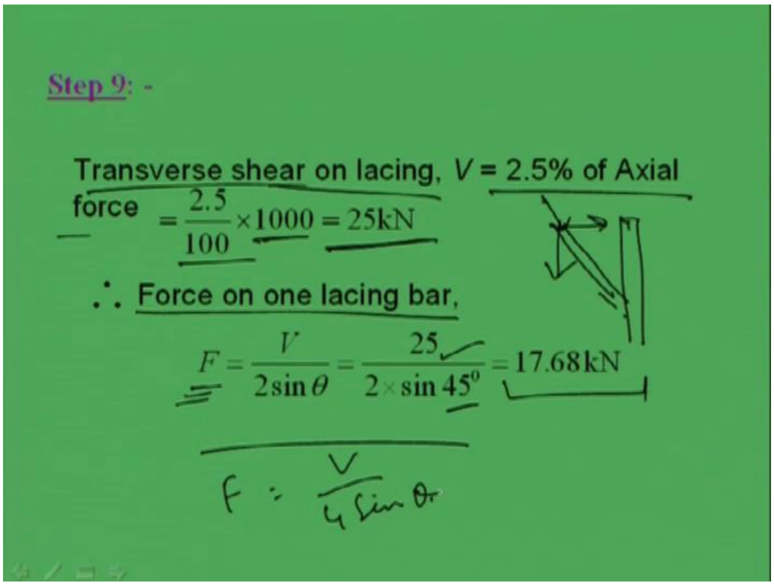

Next what we will do? Next we will find out the force. Shear force which is coming into lacing as 2.5 percent of the axial force, that is coming 25 kilo Newton because as per the codal provision we know that transverse shear on lacing will be 2.5 percent of the compressive force. So, 2.5 percent of the compressive force that is becoming 25 kilo Newton. So, now for a single lacing system, we know this force will become V by 2 sin theta because as this is in angle, it is there. So, if this is the main bar, then we know if this is there, we have one system is like this and another would be coming like this. So, F will become V by 2 sin theta, right. So, V is 25 and theta value is 45 degree. So, we can find out 17.68 kilo Newton.

So, in this way the force on lacing bar can be found out, but remember this will be different for double lacing. What will be the value means that F will become for double lacing as we remember that 4 sin theta because double lacing was here. We will come later when we will design the double lacing.

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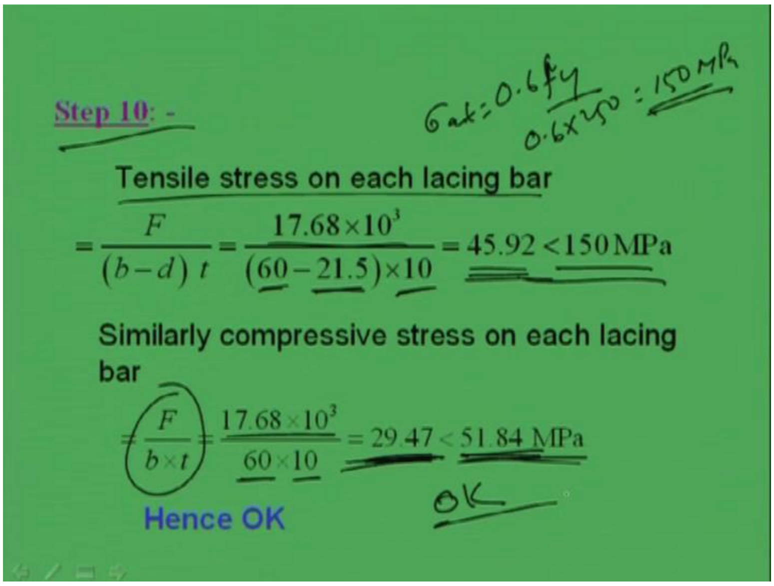

In step 10 what we will do? We will check the compressive stress and tensile stress. Tensile stress how much it will develop? This we know F by b minus d into t, right. So, F is 17.68 into 10 cubes. This is the force and b is 60 mm and d the diameter of the rivet that is 20 mm diameter of rivet. So, gross diameter will become 20 plus 1.5 mm. So, it is 21.5, right and t is given 10 mm. So, if we calculate this, we will get 45.92 MPa and allowable tensile stress in the member as we know is 150 MPa because 0.6 into fy. Fy is 250. So, 0.6 into 250 is 150 MPa. So, allowable compressive, sorry allowable tensile stress is becoming 150. That means developed tensile stress is less than the allowable tensile stress. So, the assumed dimension or calculated dimension of the lacing bar is complete.

Now, we will check for the compressive point of view. So, in compressive stress what will be? It will be simply b by means F by b into t F by b into t. So, F is this one that is 17.68 into 10 cube by b is 60 and t is 10. So, this is coming 29.47 and this is less than the permissible compressive stress. Permissible compressive stress we found from the table as 51.84. So, this is less than the permissible compressive stress. The developed compressive stress is coming 29.47 and allowable is 51.84. So, the assumed dimension is perfectly from all points of view. All point of view means from compressive point of view, from tensile point of view and from buckling point of view. So, we have checked as per the codal provision.

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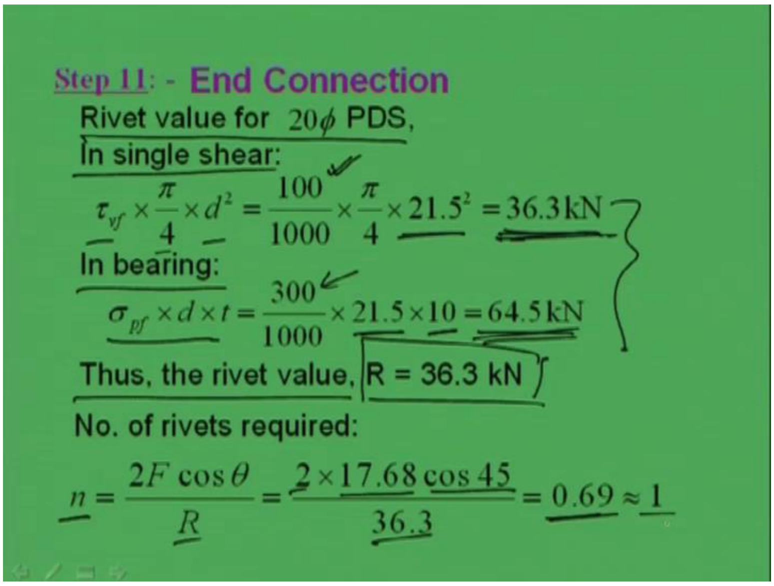

Next what we will do? Next is the last step that is in end condition mean end connection design of end connection in between lacing and the member, right. So, as we have assumed that rivet diameter as 20. So, we can find out the rivet value for single shear as tau vf into pi by 4 into d square. Now, tau vf is 100. We know the allowable shear stress tau vf is 100, right and gross diameter is 21.5. So, we can find out the rivet value for single shear as 36.3 kilo Newton.

Similarly, in case of bearing the rivet value will become sigma pf into d into t, where sigma pf is 300. This is d and t is the thickness of the lacing. So, this is becoming 64.5 kilo Newton, right. So, now the rivet value will become lesser of this 36.6 kilo Newton and 64.5 kilo Newton. So, lesser of this two is 36.3 kilo Newton. So, this is the rivet value and number of rivets will be required as per the formula 2 F cos theta by R. That also we have shown why 2 F cos theta in case of single lacing. So, 2 into F into cos theta by R, this is becoming 0.69. That means 1. That means the number of rivets is required 1. So, with this calculation let us see what will be the detailing of the lacing system.

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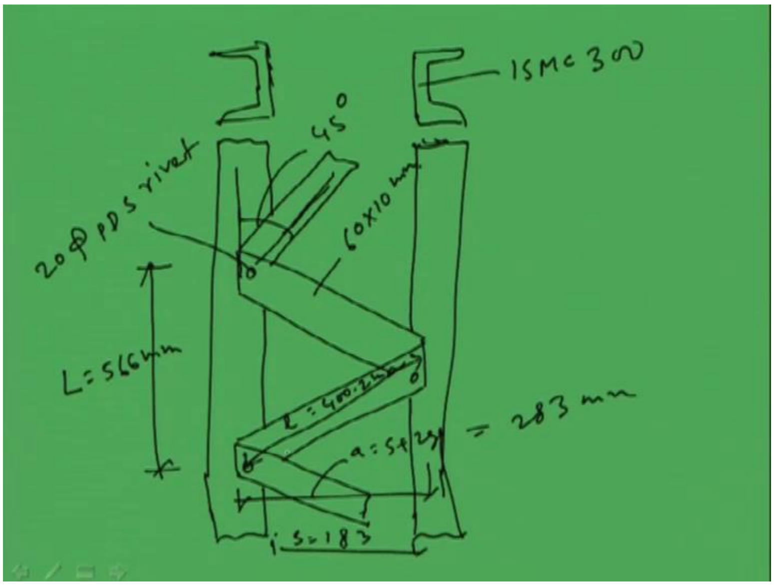

So, what we have seen that one lacing is here means main member and say this is the lacing system. Now, this is the lacing and this is main frame member. It is not going to be means according to a scale. I am not able to draw here. I am giving a free body diagram. Now, this is the lacing. So, this is one channel section say it is placed like this. This is ISMC 300, right. Similarly, another channel section is placed shear cross-section. This is another channel section. So, this is also ISMC 300 and this distance is 183, that is the spacing 183 mm, right. Now, this is called L which is 566 mm and this distance is l that is 400.2 mm, right.

Other thing is now one rivet we are going to provide in this joint. So, this rivet is 20 mm diameter power driven soft rivet, right and this angle is we have designed considering this angle as 45 degree and the dimension of this lacing is 60 by 10 mm, right and this also we know this gauge distance we know is equal to s plus 2 g that is becoming 283. So, these are things which in a. So, in this way we can finalize the design. So, from means when one is told to design the lacing system means the built up section that means this will be the answer. That means we have to show in drawing means in turns drawing we have to show what are the detailing, right.

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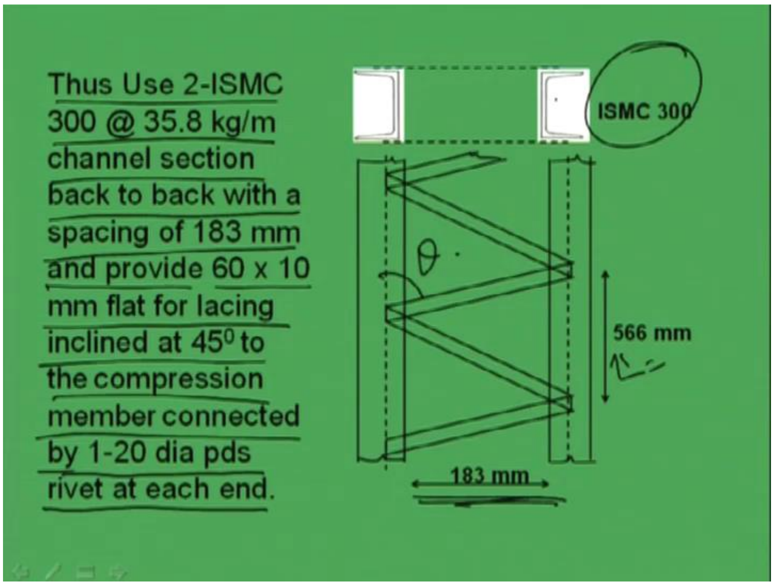

So, we can see here in short we can say that use 2 ISMC 300 at 358 kg per meter channel section back to back with a spacing of 183 millimeter and provide 60 by 10 mm flat bar for lacing inclined at 45 degree to the compression member connected by one number of 20 diameter power driven soft rivet at each end, right and if we show the drawing, we have to show that what the spacing is, what this l value is and of course, this theta and other things we have to show the section as such.

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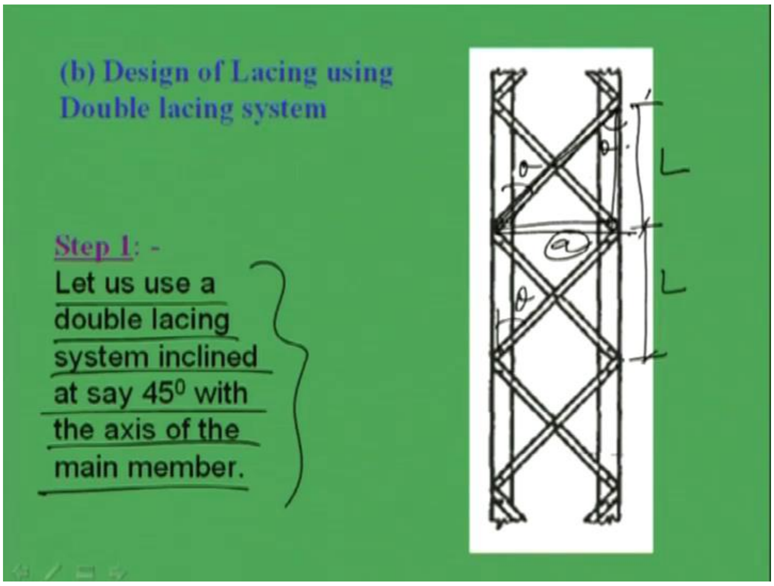

Now, the same problem we will design by the use of double lacing. That means in first half what we have seen that first we have found the built up section, appropriate build up section to carry the required amount of load that is 1000 kilo Newton. Then, we have designed the built-up section using single lacing system. Now, we will do the same thing using double lacing system. The purpose of showing this is what the difference in design of lacing system for using single lacing and using double lacing just to know what the differences are we used to follow. So, if you see here L will become this one, right. This is L and this is theta we have to assume.

So, in first step what we will do is that we will assume that we are going to use double lacing system and we are using with theta of 45 degree. That means angle of inclination we are using 45 degree. So, in first step in earlier case we used same thing. Using just single lacing system with 45 degree angle here double lacing system, but 45 degree angle let us see what the differences we are going to get, right.

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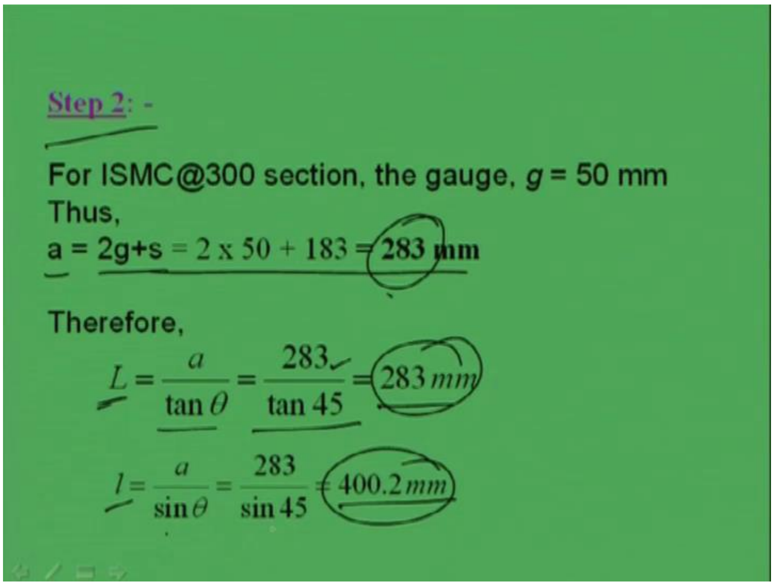

In step 2 what we will do? We will find out in similar way that two g plus s and this is coming 283 millimeter and similarly, we can find out L. Here what will be L? L means this one. That means, if this is total means 2 L; this is again L, right. So, we can find out L as from this triangle if this is theta, this is becoming theta and this is a. So, from this triangle, we can find out the value of L which will be L is equal to a by tan theta, where a is 283 millimeter and theta is 45 degree. So, we can find out a is equal to 283 millimeter, right and similarly the length of the lacing can be find out that will become a by sin theta that is 400.2 millimeter. So, difference with single lacing system is that only this one.

Other things are same. A was 283 millimeter and L was also same right. Now, let us see what other differences we are getting.

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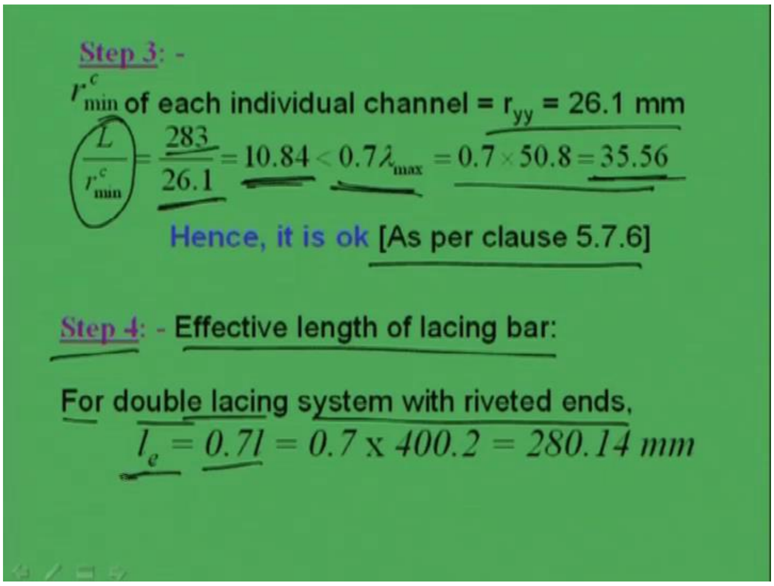

In step 3, what we will do? We will check L by rc minimum ratio which should become less than 0.7 lambda max. Here L is 283 and rc minimum is 26.1 because ryy is 26.1 from the table we got, and from this we can find out that L by rc minimum is 10.84 which is less than 35.56. So, it is completely right as per the clause 5.7.6 of IS: 800-1984.

Now, in step 4 means in next step we will find out the effective length and in case of double lacing system with riveted ends, we know effective length will become 0.7l. In single lacing system, it is l and double lacing system it is 0.7 l for riveted joint. For wielding joint, for single lacing system, it will be again 0.7 l remember. So, all these are given in the code. We have to follow the code itself. We do not have to remember much. Only thing we have to codal provision in 5.7 cross. All details have been given, right. So, the effective length we are going to get is 280.14 millimeter.

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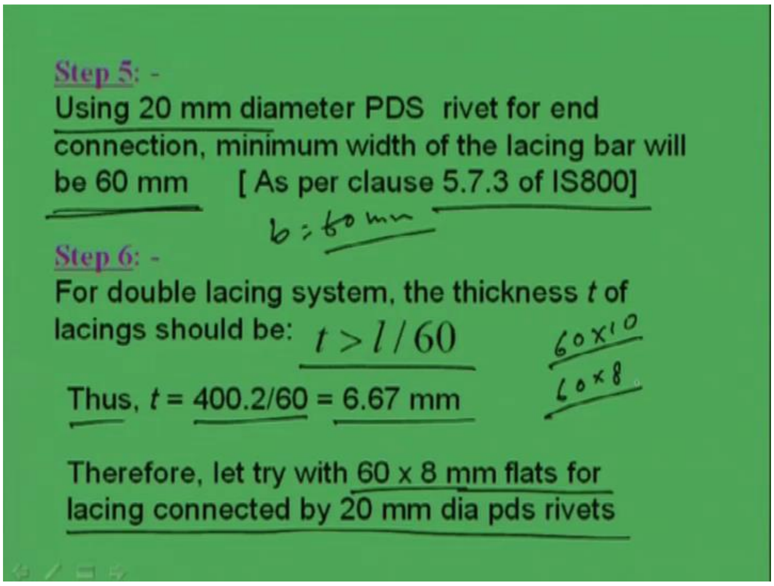

Next what we will do? Next we will assume some diameter of the rivet say same diameter of rivet. We are going to use say 20 mm diameter of power driven soft rivet we are going to use. So, if we use we know the minimum width of the lacing will be 60 mm as per the clause 5.7.3. So, the width we are going to fix as 60 mm and then thickness. Thickness for double lacing system, this should be greater than l by 60. In case of single lacing system, it was l by 40. So, this is the difference. So, thickness we are going to get is 400.2 by 60 is equal to 6.67 mm. So, we can use 60 by 8 mm flat bar for lacing connected by 20 mm diameter power driven soft rivet. So, earlier casing in single lacing system, it was 60 by 10 and here we are going to use 60 by 8. So, in double lacing system we are using that thickness.

Now, let us see from other point of view from buckling and other point of view whether it would be able to carry that much load or not. The compressive stress, the tensile stress whatever we will come whether this will be this dimension will be able to carry that much stress or not, those things we have to check.

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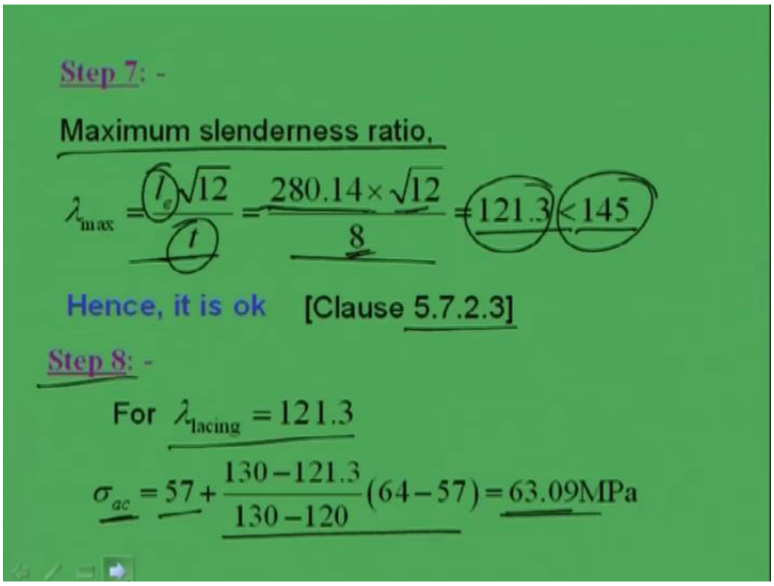

Now, maximum slenderness ratio for this we will find out, that is le root over 12 by t that is becoming le is becoming 280.14 into root over 12 by 8. So, this is becoming 121.3 which is less than 145. So, this is also as per the clause 5.7.2.3. Lambda maximum should become less than 145. Now, here you observe that le as le is less. So, if I am going to reduce the thickness also, finally the ratio is going to be less than 145, right. So, some advantage is there for double lacing system, but material will be required more. So, we have to see what the load is and we have to make use of material from economic point of view whether we will be going for double lacing system or single lacing system. We have to see what the amounts of material we are going to use for the lacing system from that we will make.

In step 8 what we will do? We know lambda lacing is this. So, what will be the value of sigma ac? Now, sigma ac means that allowable compressive stress which we will get from table 5.1 of IS: 800-1984, right. So, sigma ac we can find out from this table 5.1 that is 63.09 allowable compressive stresses or lacing.

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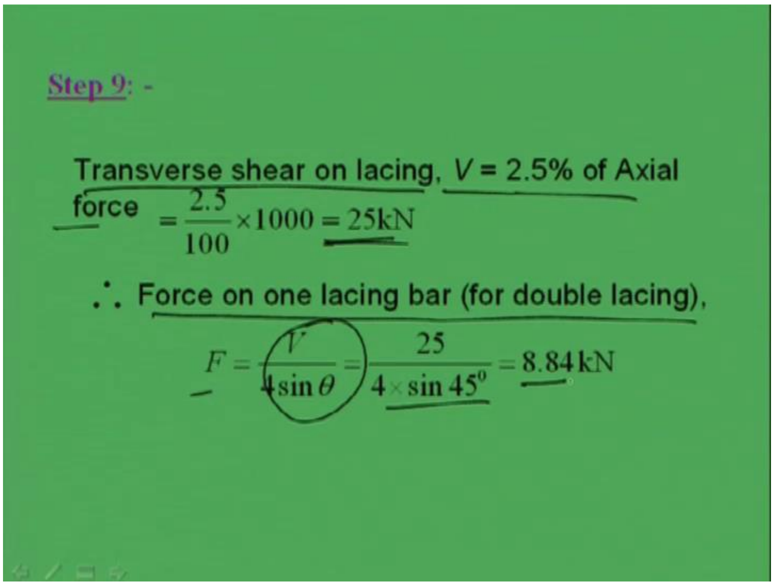

In next step what we will do? We will find out the transverse shearing force on lacing. Transverse shear will be 2.5 percent of axial force. So, that will become 25 kilo Newton and force on one lacing bar will become F equal to V by 4 sin theta whereas, in case of single lacing system, it was V by 2 sin theta. So, force definitely will become very less. That means, the size of the lacing system can be made very less. However if we use the 20 mm diameter of power driven soft rivet, then the width is fixed minimum 60 mm. So, we cannot reduce the width of the lacing. Only we can reduce the thickness, right. So, all these things we have to see. Unless huge load is coming, we do not generally go for double lacing system, right.

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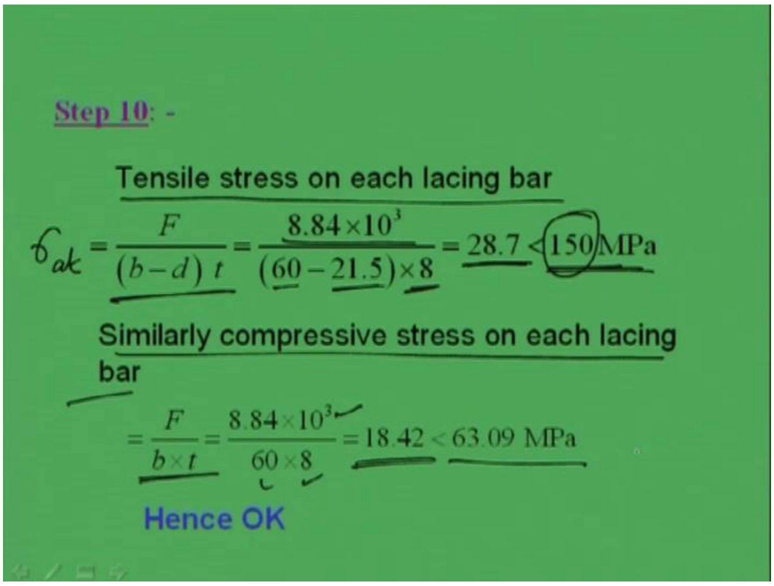

So, in next step what we will do? We will check for the tensile stress and compressive stress. So, in case of tensile stress, the sigma at will develop F by b minus d into t, where F is this 18.84 into 10 cube Newton, b is 60 and d is 21.5 and t is 8. So, if we calculate we will get 28.7 MPa which is less than 150 MPa. So, it is much safe, much below than the allowable stress that is 150 Mpa, right. Similarly, for compressive stress on each lacing bar we will get F by bt. F we know and b t. So, we are getting 18.42 Mpa. This is also much less than the permissible stress. So, the calculated thickness and width of the lacing bar for double lacing system is quite to carry that much load, right.

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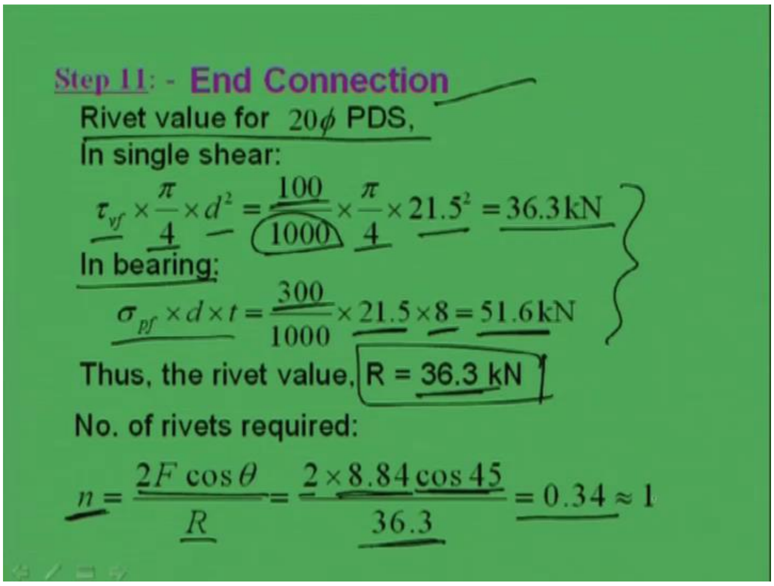

Next the end step is end connection. The final step, the last step, so what we will do? We will find out the rivet value for 25 power driven soft rivet in single shear that will become tau vf into pi by 4 into d square and tau vf is 100 and pi by 4 d square and this is coming Newton. So, if I divide by 1000, it will become kilo Newton. So, this is coming finally 36.3 kilo Newton. Similarly, in bearing you can find out that sigma pf into d into t. Sigma pf is 300 and d is gross diameter 21.5 and t is thickness of the lacing. So, if we calculate, we are going to get 51.6 kilo Newton. So, thus we can find out the rivet value as the lesser of these two that is 36.3 kilo Newton.

So, the moment we are getting the rivet value, we can find out the number of rivets required. Number of rivets will be 2 F cos theta by R. 2 F is 8.84 and theta is 45 degree and R is 36.3. So, this is becoming 0.34. That means at least one rivet will be required.

So, number of rivets is becoming one. So, here we are seeing that we are designing in a conservative way, right because everywhere we are seeing the allowable stress is much higher than the developed stress in terms of compressive stress, in terms of tensile stress, in terms of the slenderness ratio, in terms of number or rivet required. So, for this case at least we can say that if we use single lacing system, it will be convenient. However, it may vary case to case. It depends on the length of the built-up section, spacing of the built-up section and the loading compressive load because 2.5 percent load is going to carry by the lacing system which was for shear which has to be checked. So, all these things we have to see and we have to decide.

So, basically the design engineer can choose from their experience whether it will go for single lacing system or double lacing system.

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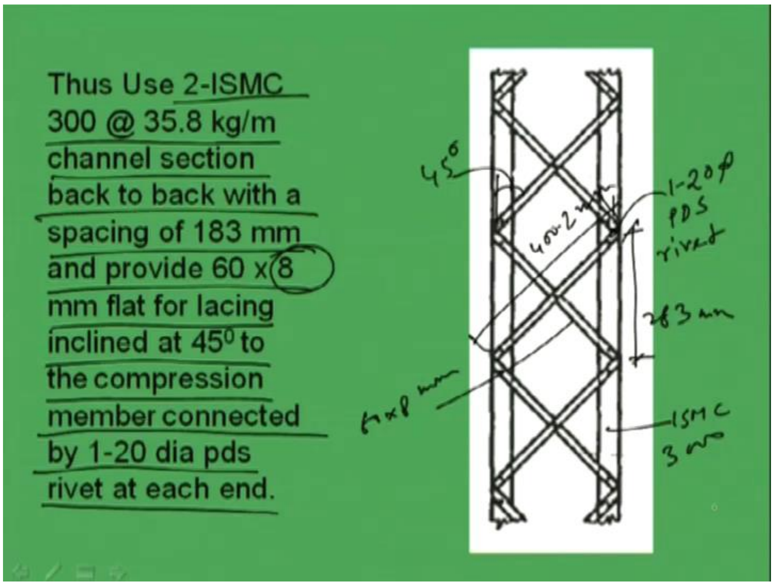

So, finally if we see that we can use 2 ISMC 300 at 35.8 kg per meter channel section back to back with a spacing of 183 millimeter and provide 60 into 8 mm flat for lacing inclined at 45 degree to the compression member connected by one number of 20 millimeter diameter power driven soft rivet at each end. So, only difference we are getting from single lacing system to double lacing system is the thickness. Just we have reduced the thickness. So, if we give the dimension, this will become 45 degree, this will become 400.2 millimeter and 125 PDS rivet will be required and then, this is coming 283 millimeter and the size will be 60 by 8 mm plate and this will be ISMC 300, right. So, when you will show in design, these are the necessary data which you have to show, right.

Now, you have seen that what the design steps we are going to follow for designing of lacing system along with the built-up section, right. So, what we have seen that we have to remember a lot of things in terms of codal provisions and we have to follow step by step method for designing this, and also we have seen that once we go for designing, again if we want to redesign for making economic, it is a lengthy process. There is a long process will be involved to design the same thing. So, if we have software like things which we can develop at our own, then we do not need to remember all these codal provisions.

So, in software if you can make that, first we will see what the steps are and accordingly, we will develop a software and all the codal provisions we will keep on checking in that software. Then, if we start designing a lacing, we do not have to remember anything about the codal provision, right. This is one thing the advantage of software. Another thing is that we will go on trial and error method means we will go on checking. Suppose we are giving some dimension, then we are checking whether it is or not. Then, again we can reduce the dimension, then you can check once again and if it is not, then we can increase the dimension. So, in this way again and again if we repeat, then we will get an economic size which is very much important for designing of an effective means lacing system.

So, with this I would like to conclude today’s lecture about the lacing and in the next lecture, we will start with the battening system.