Course on Design of Steel Structures
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Lecture 38
Module 8
Connection Design of Lacing System

Todays lecture will be the continuation of previous days lecture in previous day we have gone through a design example for designing of lacing system. So in last lecture we have discussed how to design a lacing system, how to provide the length of the lacing, width of the lacing, thickness of the lacing. Then what will be the spacing between two lacings, what will be the angle of inclination so all the details of lacing has been discussed.

Today we will be going to discuss on the connection part, connection part means the connection between the lacing and the column main column. So as lacing is taking certain amount of load, so we need to design the lacing with the column in such a way that the connection between these two can withstand the developed load, developed load how to calculate we have discussed, today also we will calculate the developed load that means the transverse shear what is coming 2.5 percent of the load which one of the compressive load which is acting on the main member main compressive member.

So from that we have to find out the value of the shear and then we can find out what will be the connection details, connection details again we will discuss today two type of connections one is bolt connection another is weld connections. So for bolt connection how we will be designing the bolt and how we will be designing the weld those things will be discussed today. So before going to do that first I will very quickly go through the the previous days example so that we can remind our earlier calculations which will be required for calculating the design design strength of bolt and number of bolt or weld weld length. So very quickly we will go through the earlier lecture whatever we have given part of that.

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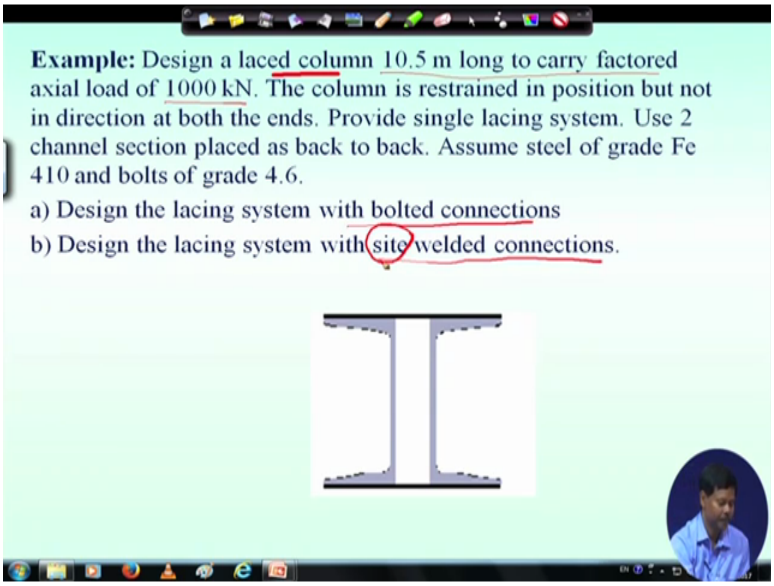

So example was this that is so example is this which is written here that design a laced column of 10.5 meter long to carry a factored load of 100 kilonewton the same example and here we will be using two channel section placed back to back and we will try to find out the design of the lacing system with bolted connections and design of the lacing system with weld weld connection and weld connection we will consider this case as site weld, we can consider shop weld also in that case that gamma mw value will be changed. So according to the weld type of weld whether it is site weld or shop weld the gamma mw has to be taken.

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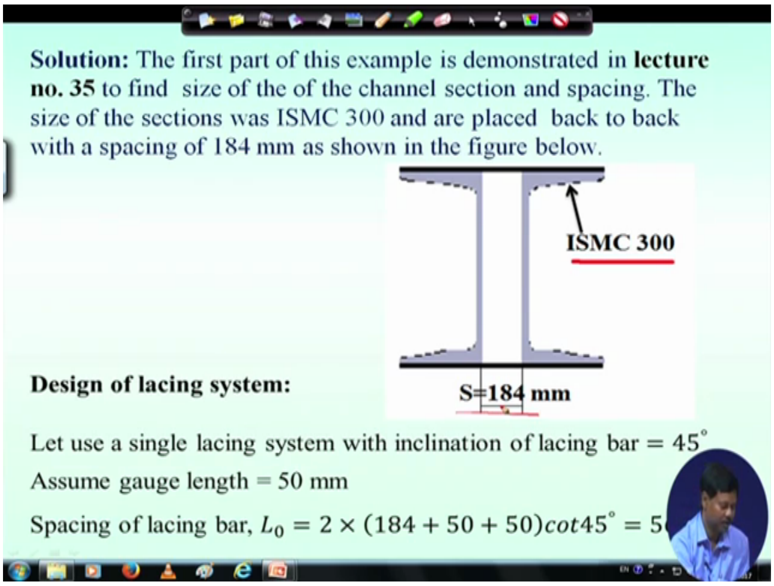

So if we remind the earlier lecture we can see that we got already the solution of this that is ISMC 300 back to back we have provided with a spacing of 184 millimetre, right.

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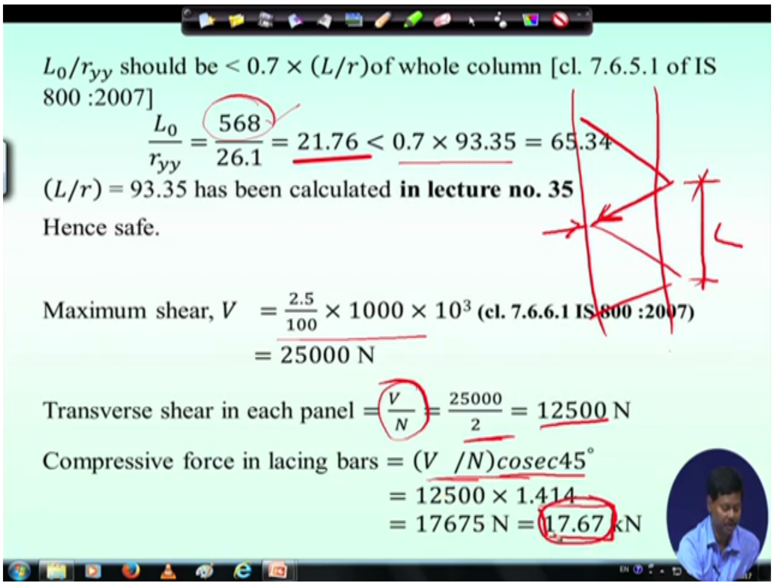

And also we found the L0 by ryy we calculated where L0 by ryy is coming this, where L0 value has been calculated in earlier slide and this is becoming less than the 0.7 times L by r or 50, therefore the L0 value whatever we have consider 568, L0 value means if we see the lacing like this then this is the L0 value, right so lacing is going like this so L0 value we have considered from this.

Now the maximum shear also we have calculated which is 2.5 percent of the compressive load and the transverse shear in each panel has been consider as there are two parallel phase so the value of N we have consider 2, therefore transverse force and transverse shear in each panel is coming this much. And compressive force in lacing will be transverse shear into cosec 45 degree, why cosec 45 degree that transverse shear is coming in this way and compressive force will be in this way. So while making the equilibrium equation we can find out this value.

So the compressive force in lacing bar we obtained this, this value will be required in todays calculation that is 17.67 kilonewton this value is the compressive force in the lacing bar and while designing the connections we have to design against this load, so we have to remember this load which are coming here.

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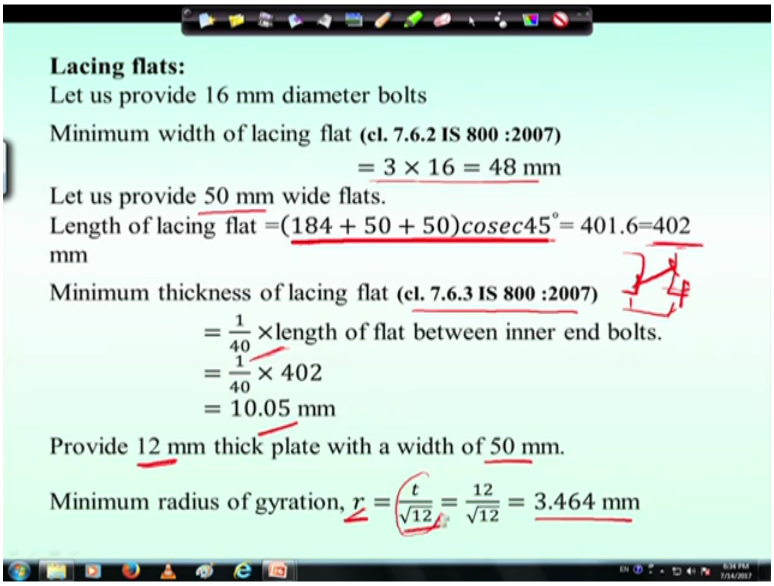

Then what we have calculated is the thickness of the lacing plate and using so this thickness of the lacing plate will be calculating before that we have to calculate the length of lacing flat and lacing flat we got like this because the minimum width of the sorry for lacing flat we will be calculating because the spacing between these two was this and and gauge distance was 50, so according to that the length of lacing flat which is this has been calculated, right.

Another thing is the minimum width of lacing flat is 3 into d that has been calculated 48 and so we have provided 50 mm wide lacing flat and 402 mm length and thickness well we will be calculating as per clause 7.6.3 we can calculate the minimum thickness of lacing flat as 1 by 40 into length of flat and we know that for double lacing it will be 1 by 60. So lacing thickness we are finding like this, so we can use 12 mm thick plate and width as 50 mm.

And now we have to check the slenderness ratio for checking the slenderness ratio we will be finding the minimum radius of gyration which is for lacing flat it will be t by root 12 that we can find out like this, remember that minimum radius of gyration if we consider angle section then we can find out the minimum radius of gyration from the IS code means SP: 6, from SP: 6 the minimum radius of gyration rvv of the angle section we can find out and from that we have to calculate, right and as we are using lacing flat we directly found this value.

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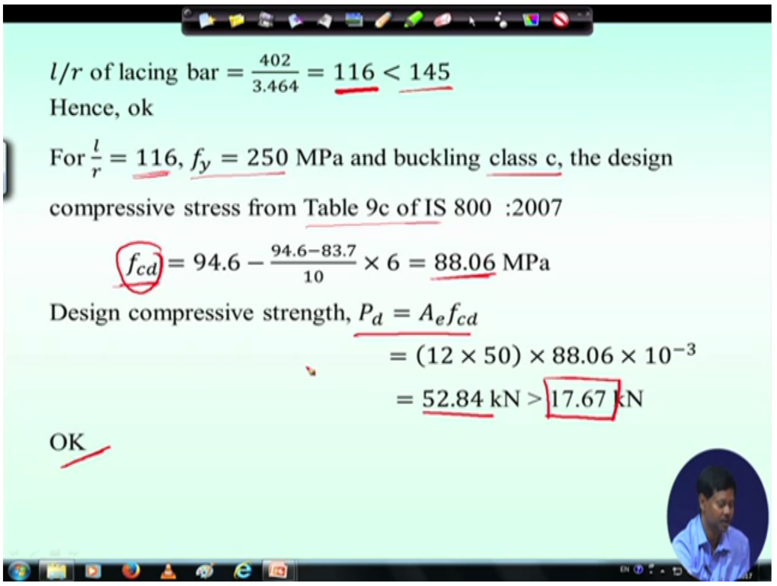

So radius of gyration we are getting 116 and which has to be less than 145 that means the lacing length is fine, right. Next what we will go we will do the we will find out the fcd value, fcd value means compressive stress of the lacing member. So for l by r is equal to 116 which we have found and we are using fy 250 grade of steel and for flat plate the buckling class will be c, so according to that condition we can find out the value of compressive stress from table 9c which will be this 88.06 and this can be found from interpolating results for l by r is equal to 110 and l by r is equal to 120, so this is how we can find out the fcd value, right and the design compressive force also we can find out.

And this design compressive force has to be greater than the force acting on the lacing member the compressive force acting on the lacing member which we have calculated as 17.67 kilonewton so this is the design compressive strength which is more than the external compressive force on the lacing member. So that means the design is okay, right.

In every case I have told that if the criteria is not satisfying then we have to increase either the thickness of the plate or the width of the plate means case to case we have to check, sometimes we may have to reduce the length of the lacing plate by changing the angle of inclination, so in this way we have to we have to find out which one means which dimensions and which orientation the design will be means lacing will be provided so that the design of the lacing will be safe.

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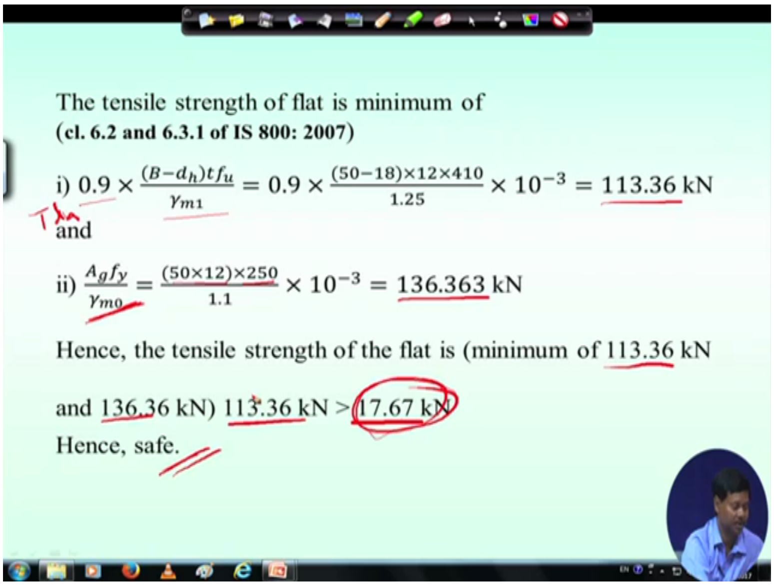

Now the tensile strength of the flat we have to find out because we will see the tensile strength or compressive strength both the cases this value will be same 17.67 because in lacing member the whatever axial force is coming that may be tension or compression. So for both the case means for compression and for tension we have to check whether the design strength due to tension or compression is more than this 17.67 or not.

So according to the tensile strength we can calculate the design tensile strength of the member due to yielding due to rapture of the critical section. So that we can find out this will be Tdn value so Tdn value we can find out from this formula that 0.9 into B minus dh into t into fu by gamma m1. So after putting this value we can find out the Tdn value as 113.36 kilonewton.

And similarly the Tdg value that is yielding due to gross strength due to gross yielding of the section that is Agfy by gamma m0 and by putting the gross area as 50 into 12 which is B into d B into t and fy then we can find out the Tdg value as 136.363 kilonewton. So the tensile strength of the flat will become minimum of this 113 and 136 that means 113.36 36 kilonewton and this is greater than the tensile force coming in the lacing bar, so this design is okay.

If I am I have already mention that if design is not okay then what we need to do we have to change the dimension of the lacing so that the design strength become more than this 17.67 kilonewton.

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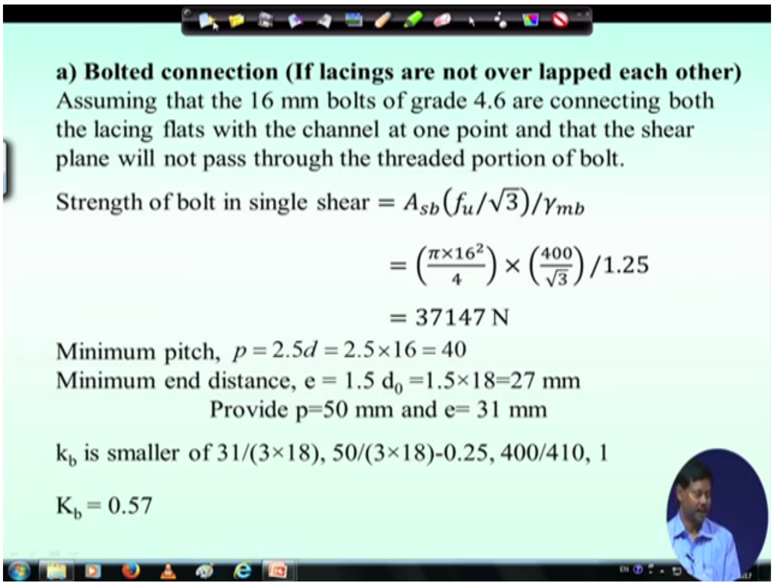

Now we will come to now we will come to bolted connections. Now first is we are going to consider the bolt connection when lacings are not overlapped each other.

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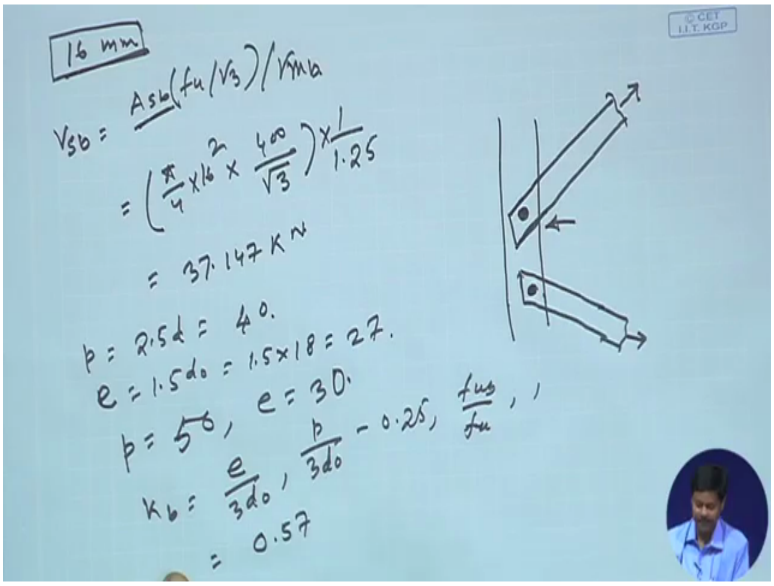

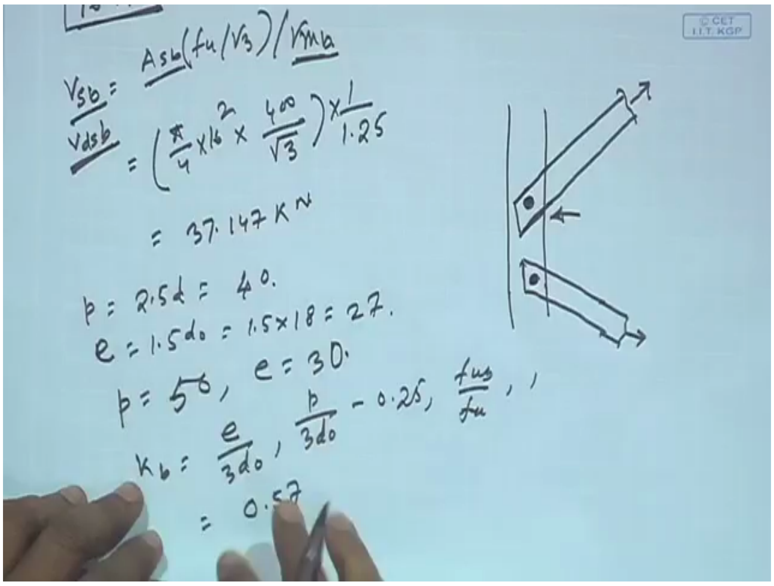

That means when our case is like this say suppose this is a column member vertical column member and lacing is provided in this way with a certain inclination and this is not overlapped that means separately it is it has been joint like this, right. So force we can find out what is the force are coming, right. Now for finding out the force means we will provide the bolt here and we know what is the force axial force is coming into picture on this single lacing, right that we have calculated earlier.

Now we have to find out first what will be the bolt strength which the bolt strength of the member, right. So if we use 16 mm bolt because in question it is given 16 mm bolt of grade 4.6, then what we can find out we can find out the strength of bolt in single shear because this is separately it is not overlapped separately it is joint, so this will be basically a single shear. So due to single shear Vsb we can find out, right Vsb will be Asb into fu by root 3 by gamma mb mb.

And here what we have considered the shear plane is not going to pass through the threaded portion so in place of Anb we are considering Asb. So if we consider that we will be getting pi by 4 into 16 square into 400 is the strength of the bolt yield strength ultimate strength of the bolt then this into 1 by gamma mb is 1.25, right. So if I consider this then I will get the value as 37.147 kilonewton.

Now as 16 mm diameter of bolt we are using, so I can assume the pitch as 2.5d minimum pitch so it will be 40 mm and minimum and edge will be 1.5d0 that is 1.5 into 16 plus 2 that is 18 is equal to 27. So we can provide say pitch as say 27 sorry 50 mm we can increase little bit and say e as say 31 mm because or 30 mm, right. So now Kb will be the smaller of this e by 3d0, p by 3d0 minus 0.25, fub by fu and 1 so if we consider this we will get the value of Kb as 0.57, right.

Now considering value of Kb as 0.57 we can find out the bearing strength bearing strength Vdpb if fact this I can make sorry this Vsb actually Vdsb because we have divided by gamma mb Vdsb design shear strength, right.

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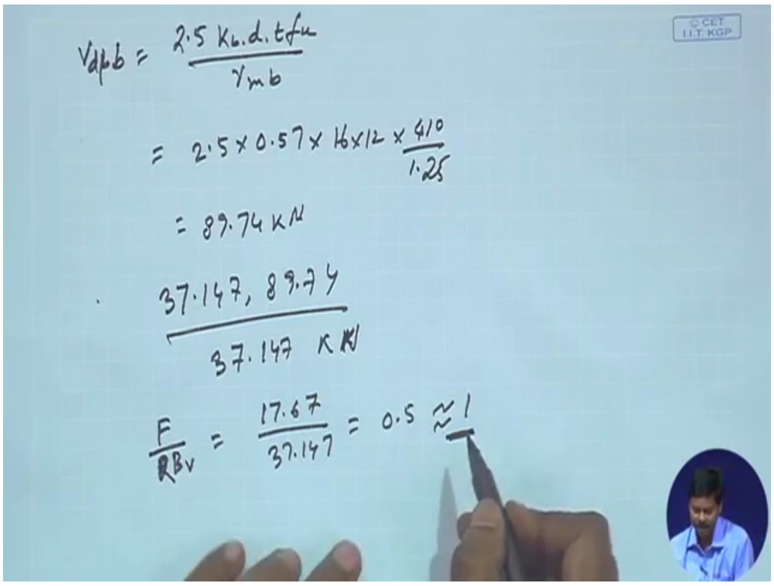

So bearing strength Vdpb will be 2.5 Kb dtfu by gamma mb, right. So if I provide this value I can find out that is 2.5 into Kb is 0.57 into 16 into 12 into fu is 410 by 1.25, so this is becoming 89.74 kilonewton, right. So strength of the bolt I can find out as 37 means lesser of these two 37.147 and 89.74, so lesser of these two the strength of bolt will become 37.147 kilonewton, right kilonewton.

So the number of bolts required will be the force by by bolt value say R or Bv bolt value, so force is 17.67 kilonewton which we have calculated earlier and the bolt value is 37.147 so this is becoming 0.5 that means at least one bolt has to be provided at each end, right so one bolt we are going to provide, so this is one case and another case will be that if the bolts are sorry if the lacings are overlapped each other.

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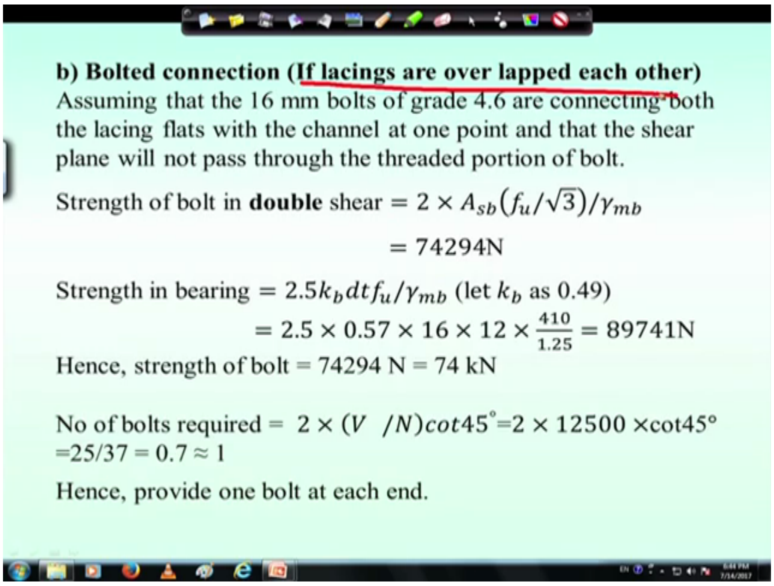

This case if lacings are overlapped each other.

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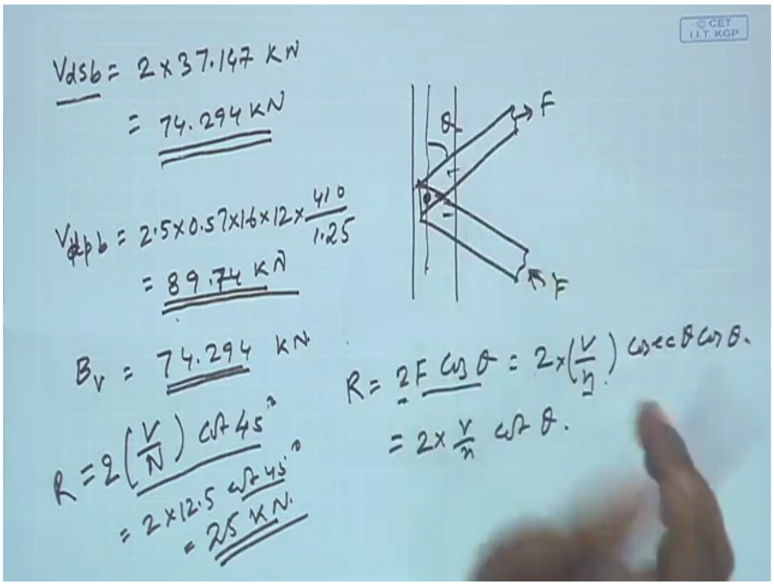

So if lacings are overlapped each other means this will be means connections will be like this say for example this is the main member and we have a lacing here and another lacing is so like this, right right. So bolting will be done here and that means the lacing in this orientation we are making lacings are overlapped each other. So in this case the design shear strength of the bolt Vdsb will become twice the shear strength of the due to single shear because this is acting as a double shear, so whatever shear strength we got earlier that will be double of that, right double of 37 kilonewton so 37.147 kilonewton, right. So this is becoming 74.294 kilonewton because in this case it will be in under double shear, right.

Now strength in bearing will be same we can find out the strength in bearing (Vpb) Vdpb that will be same 2.5, Kb was 0.57, d is 16, t is 12, then fu is 410 by 1.25 gamma mb this is coming same as earlier 89.74 kilonewton. So what we could see that the strength of bolt in double shear is coming 74.294 and strength of bolt in bearing is 89.74, therefore the bolt value we can consider as 74.294 kilonewton, right.

Now number of bolts required, so here we can see that what will be the force resultant force acting on the bolt that will be we can find out the resulting force will be V by N right into cot 45 degree, how we are getting this because you see if we result this this is theta, right so if this is theta then we can find out 2F cos theta is equal to 2 into sorry 2F cos theta so 2 into F means V by N, earlier we got cosec theta, right.

So the resultant force R will become in this bolt will be F cos theta plus F cos theta, right so both will act acting in together vertically F cos theta and F cos theta so 2F cos theta again F is equal to V by N cosec theta, so 2 into V by N cosec theta into cos theta. So this will become 2 into V by N cot theta, right 2 into V by N cot theta. So we can find out the resultant force as R is equal to 2 into V by N cot 45 degree therefore therefore this value will become 2 into 12.5 into cot 45 degree that means 25 cot 45 degree is 1 so 25 kilonewton, right. So resultant force is coming 25 kilonewton and the bolt value is coming 74.294 kilonewton remember this is different from the earlier one, in case of earlier orientation our bolt value was different because of the single shear and the resultant force was also different because here resultant force will be the means cos component of these two force, right.

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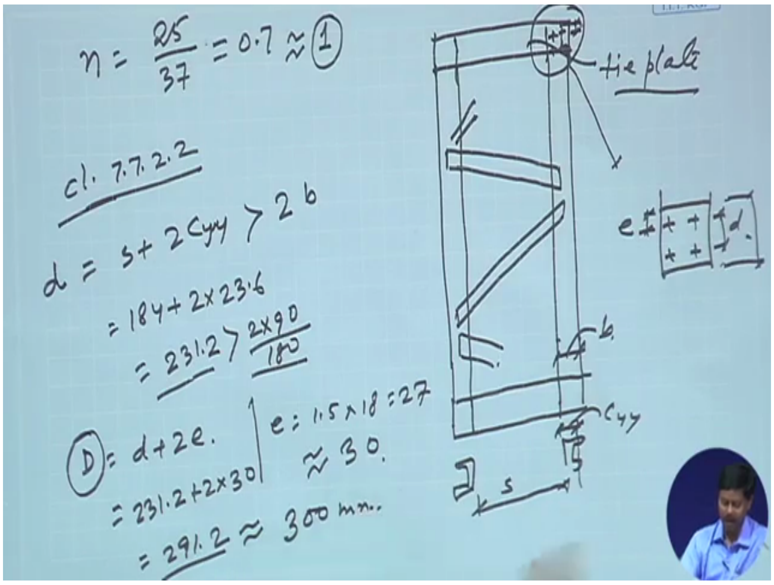

So number of bolt I can find out that will be resultant force as 25 and bolt value was 37, so that is becoming 0.7 that means here in this case also it is coming 1 that means if we provide one bolt at each end then that is sufficient, right. So this is what the bolt connections are made in this way.

Now after bolt connection another thing we need to remember that is important that when we are connecting the compression member the built up member by lacing system we have to provide tie plate at the end say for example this one. So this will go on like this right and finally we have to provide the tie plate at the end at top and bottom or at at the end of both means at both end we have to provide tie plate. So we need to this is called tie plate, right so we need to find out the dimensions of the tie plate and this is given the details are given in clause 7.7.2.2, right in clause 7.7.2.2 it is given.

So now the as per this codal provision the effective depth d can be found as S plus 2 Cyy where if we consider such type of channel section back to back for this case then this is Cyy somewhere here Cyy and this is S so the effective depth will be this one and it should be greater than 2 into b where b is the flange width means suitable width we are getting this flange width is called b, so here we are getting S as 184 plus 2 into Cyy we found earlier 23.6 which are becoming 231.2 and it should be greater than 2 into b, b was the flange width which was 90, so this is 180 that means the effective depth is greater than 180 so it is okay, right.

Now minimum edge distance also we need to provide minimum edge distance means when we are providing the bolt connections here say for example here now we have to provide certain edge distance, right means if I enlarge this here it will be something like this say suppose these are the bolt connections and this is d, right. So overall depth is basically d plus twice e because minimum edge distance means edge distance is if it is this then we have to include the edge distance.

So depth the total depth will be d plus 2 into e, okay. Now e we can find out e will be 1.5d0 d0 means 18, so 27 so we consider say 30, right. So the overall depth I can find out from this that is earlier we found effective depth as 231.2 plus 2 into e is 30, so this is becoming 291.2 that means minimum overall thickness of the plate overall depth of the tie plate will be 291.2 or we can provide little higher side that is say 300 millimetre, right. So we are providing 300 millimetre tie plate.

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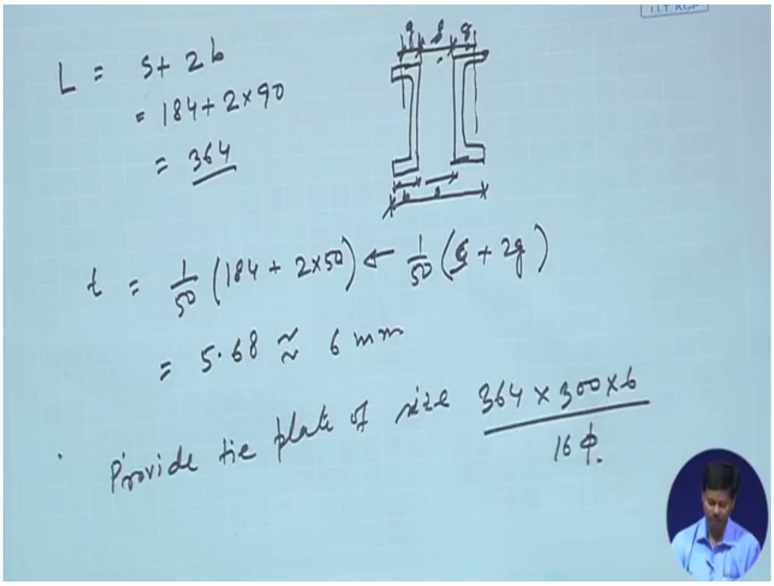

And the length I can find out length will be simply S plus 2b, right length will be S plus 2b so 184 plus 2 into 90, so length of tie plate will be 364. If we see in the picture if this is the cross-sectional orientation then the this will be the tie plate length, right this is b and this is S, right so 364 millimetre. Now thickness of the tie plate we have to find out thickness is as per codal provision this is 1 50th of the distance between inner bolts. So in this case it will be 184 plus 2 into 50, inner bolts means if this is the g then we can consider this is as g, right and this is this is S and this is g the gauge distance.

So basically we have considered 1 50th of (a plus 2g) S plus 2g, right. So from calculations I can find out thickness is 5.68 millimetre, so we can provide 6 mm thickness that means we can provide a tie plate provide tie plate of size 364 this is fixed because of the distance between two compression member. Then 300 is the depth and thickness is 6, so this size of tie plate has to be provided and we can provide certain diameter of bolt say 16 diameter of bolt we can provide.

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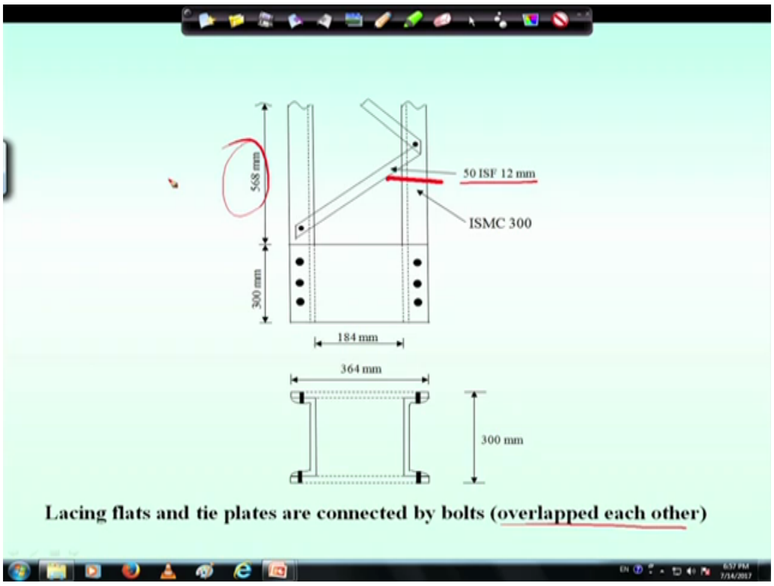

And a sample figure has been shown here I am going to show this is the figure, say for second case if we see we are providing a tie plate of 300 mm depth and 364 mm length, right and thickness as 6 mm and this is the size of the lacing plate and here it is overlapped we in this case we are considering the overlapped overlapping of both the lacing members at a certain point, so this is how we can make. And spacing between two lacing is 568 millimetre, so this is how we can do the bolt connection.

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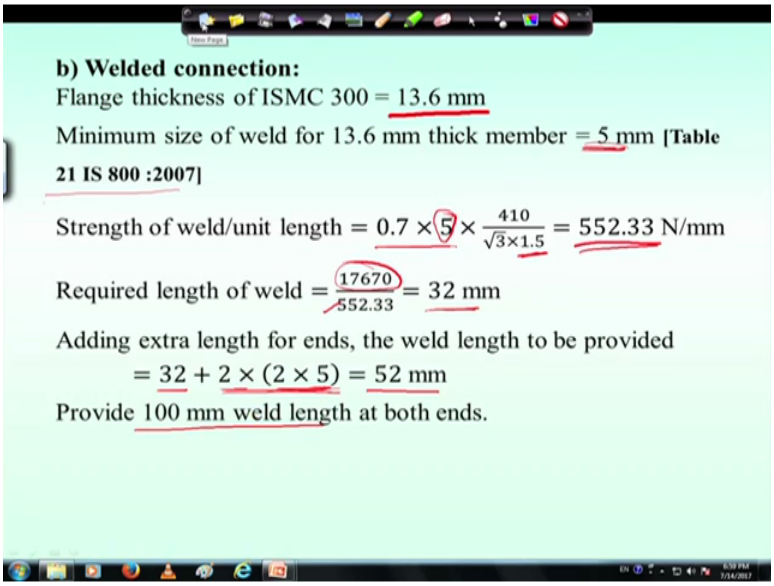

Now coming to the weld connection let us see how we can make details of the weld connection. So in case of weld connection if we see that here certain things are given which we need to know that is the flange thickness is 13.6 mm flange thickness of ISMC 300. Now is flange thickness is 13.6 then the minimum size of weld we can find out from table 21 of IS 800, so minimum size of the weld we can find out as 5 mm.

So strength of weld per unit length I can find out 0.7 into S, S is the size of weld so 0.7S into fu by root 3 gamma mw, for site weld gamma mw value is 1.5 as we know from table 5, right. So these values are coming as 552.33 newton per millimetre. So strength of weld per unit length we can calculate from this and required length also we can find out because the total force means axial force acting on the member is 17670 newton 17.67 kilonewton, so the required length I can find out from this force divided by strength per strength of weld per unit length, right so 32 millimetre length is required.

Now we need to add some extra length because of the at at the edge are the end ends end return, so 32 plus 2 into 2S size of the weld is S, so 2S at each end it will be required extra so 2 into 2S will be total so 52 millimetre weld length will be required, right and we can provide say little higher say may be 100 mm weld length at both ends so this is how we can calculate the weld length.

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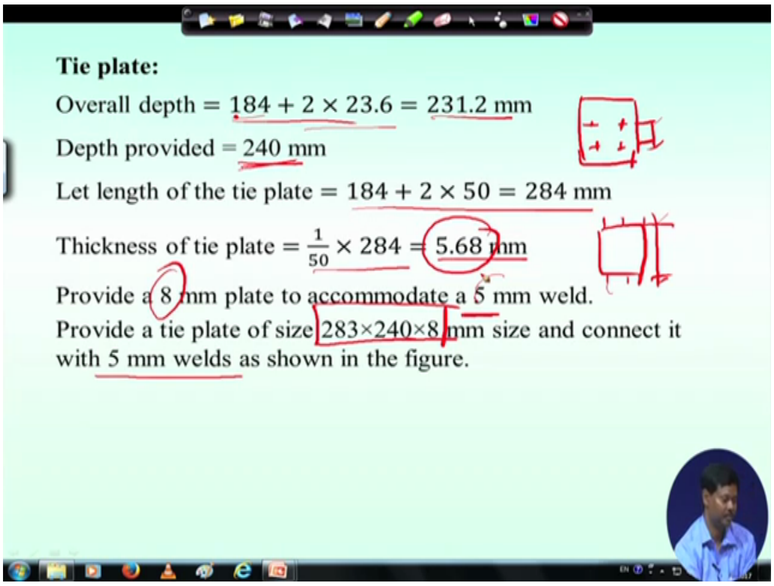

Now for this also we can calculate the tie plate dimension, so for this the tie plate dimensions will be like this 184 plus this 2 into Cyy, so we can provide depth as overall depth 231.2 millimetre which is can be increased to 240 millimetre. Here you remember here there is no effective depth, right so in case of bolt connections we have effective depth, right this is the overall depth and this is effective depth. But here in case of weld connections we are welding at the end so effective depth and overall depth will be same, right. So overall depth we have calculated this and we are getting means little higher side means higher value that is 240 millimetre, remember in case of bolt connection it was 300 we provided 300 millimetre.

Now here length of the tie plate will be as usual means as we have consider in earlier case, so length of tie plate will be 284 then the thickness of tie plate we can find out thickness of tie plate will be 1 by 50 into this that is 5.68. So we can provide a say 6 mm tie plate or may be say little higher say 8 mm tie plate also we can provide and the size of weld we can provide 5 mm, right. So the final dimensions will be the provide a tie plate of size 283 by 240 by 8 millimetre size and connect it with 5 mm weld as shown in the figure, so final dimensions is this 283 by 240 by 8, right.

Now why we have provided 8 mm where 6 mm is sufficient, because if we provide 6 mm then the size of the weld has to be reduced again we have to recalculate everything. Therefore we have provided little higher side just to match the results.

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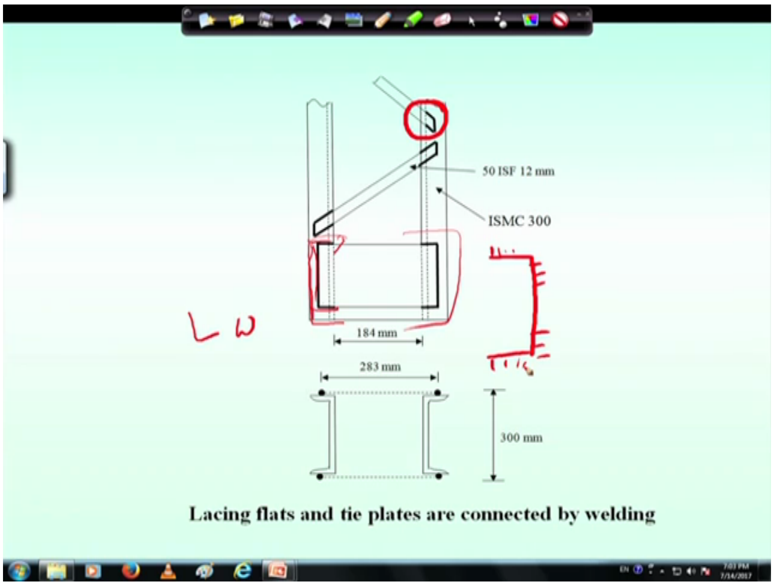

So the drawing will be like this that is this is how the connections have been made at each end and at the for the tie plate the connections have been made like this, right. So when we will be doing weld connections we have to do by this. Now it depends this it depends what is the total length and accordingly we have to distribute it is not that total length will means will be entire length, right we have to find out what is the total length Lw and we have to distribute in three sides properly, we may distribute like this also. Suppose this is the tie plate we may distribute here, certain distribution here we can do, certain distribution here also we can do as per the requirement.

So in todays lecture we have demonstrated a connection between lacing member and the compression member, connections two type one is weld connection, another is bolt connection again for bolt connections we have shown that if the lacings are overlapped and if lacings are not overlapped. How to calculated the forces for overlapping lacing and for not overlapping lacing and then how to provide the number of bolt because the strength of the bolt will be different for two cases.

And also we have found the dimension of the tie plate, how to find the dimensions of tie plate that also has been demonstrated through the example in this lecture and then again we have calculated the same for weld connections calculated means the length of weld what will be the length of weld required we have calculated and how to distribute also we have shown and how to calculate the length of weld based on the size of the weld that also has been demonstrated, right. So I hope this will be means this example will make you clear about the connections between compression member and lacing member, thank you.