Course on Design of Steel Structures
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Lecture 39
Module 8
Design of Double Lacing System

So far we have discussed about the single lacing system the design criteria of single lacing system is design procedure has been discussed in earlier lecture. Today we will be discussing about the double lacing system and we will see how to design the double lacing system the design procedure will be more or less similar except the certain configuration of the lacing like what will be the spacing of the lacing that will be decided from the that configuration it will be different from the single lacing system and double lacing system is used when the is used when we need less spacing between two lacing systems and it is required when the main compression members are weak in a certain direction means from radius of gyration point of view.

So if the slenderness ratio of a certain member is very weak in a direction then sometimes we need to provide very fine spacing between two lacing systems and in that case we go for double lacing system with lighter member. And in case of double lacing system also we can use flat bar, flat plate bar, we can use angle sections, we can use light channel section or also we can use the tubular section.

Now first I will go through one example today with the basis of this double lacing system also in this example we will see that if the angle sections are connected say four angle sections are connected then how to find out the sectional area of the angle, how to make the spacing of the angle and then the lacing systems, right. So let us go through the example.

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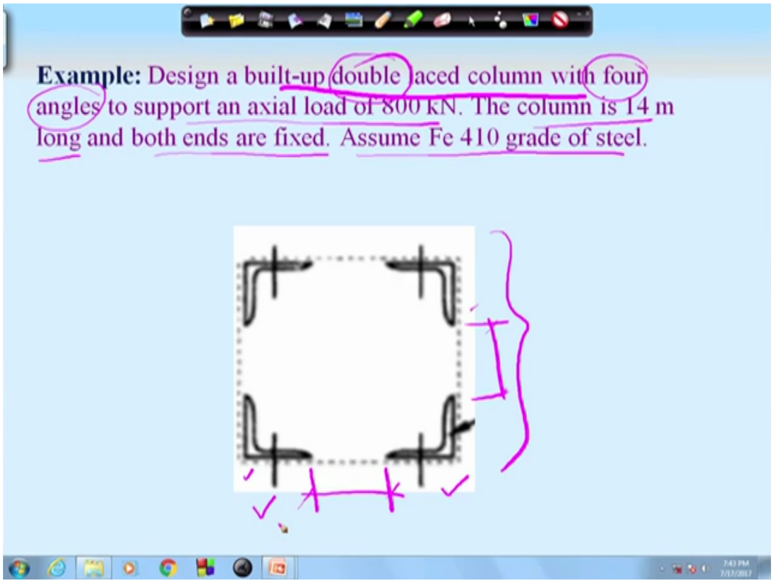

Here you can see that in the example you can see that design a built-up double laced column with four angles to support an axial load of 800 kilonewton. The column is 14 meter long and both ends are fixed. Assume Fe 410 grade steel. So what we need to do one thing is that we have to provide double lacing system which has been told and we have to provide four column four angle section to make the built-up section and this built-up sections has been shown here which will be making as a box section, so four angle sections say equal angle sections we have provided in this case four angle sections are provided.

Now for designing first we have to know what should be the angle size that means section size and what should be the spacing, spacing between the two angles and what should be the spacing in this direction so these things first we have to discuss and then we will go for the lacing system.

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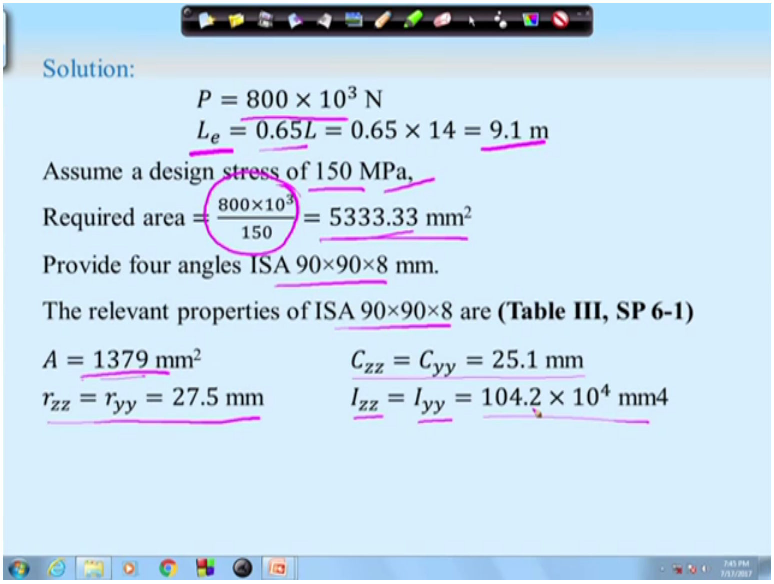

Now as we know the column sections are fixed in both end, so the effective length we can calculate as 0.65L as per the codal provision. So the effective length will be 0.65 into 14 which will be 9.1 meter and axial compressive load was given as 800 kilonewton. So from this we can find out the required area, required area we can find out by assuming certain permissible stress so we if we assume the permissible design stress as 150 MPa then required area we can find out from this that is 800 into 10 cube by 150 which will be 5333 millimetre square.

So to get this required area we can provide four angle sections because each angle sections are having cross-sectional area as this if we consider ISA 90 by 90 by 8, if we look through the SP: 6 we can find out the ISA 90 by 90 by 8 is having 1379 millimetre square cross-sectional area so required area can be satisfied from this. And the other properties will be required is the center of gravity distance Cg distance that is 25.1 millimetre which will be Czz is equal to Cyy because it is an equal angle section.

Similarly the radius of gyration about z-z axis and about y-y axis will be same that is 27.5 millimetre and moment of inertia Izz which will be equal to Iyy that is also given as 104.2 into 10 to the power 4 millimetre to the 4.

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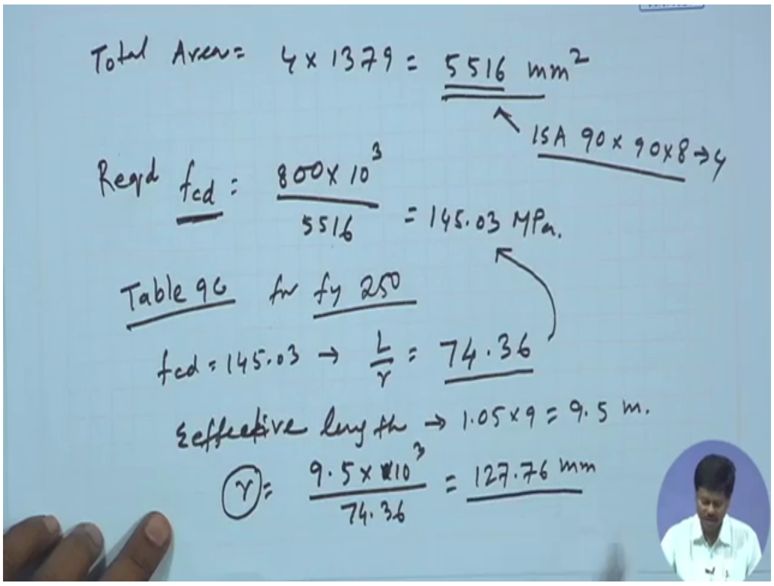

So the total area we can find out now that will be total area cross-sectional area will be 4 into 1379 millimetre square which will become 5516 millimetre square, right. So if we have this total area because actually we are providing ISA 90 by 90 by 8, so if we provide 4 numbers of this ISA section then actual area we are getting this, so if we have actual area this then what will be the fcd value required fcd value. So from this required fcd value we can find out.

So fcd value will be the 800 is the load by actual area which is coming 5516, so I can find out 145.03 MPa, right. Now if fcd is this that required fcd is this then what should be the slenderness ratio means corresponding to this fcd value we have to find out slenderness ratio and this can be found from table 9c because we are providing built-up section so for that buckling class will be c and in table 9c we can find out the value for say if you use fy 250 grade of steel then we can find out for fcd is equal to 145.03, I can find out the L by r ratio that will be 74.36. So required L by r ratio we can find out as 74.36 which will produce this fcd, right.

Now now we know the effective length for column was 9.1 effective length but if we use as a lacing member then its increase effective length will be increased by 5 percent so 1.05 into 9.1, so this will be around 9.5 meter, right. So effective length if it is required this then I can find out what will be the value of r because L by r ratio we know, effective length we know, so r value we can find out as 9.5 meter L into 10 cube to make it millimetre by L by r ratio is 74.36, so this is becoming 127.76 millimetre so required r the radius of gyration of the section should have this value, right.

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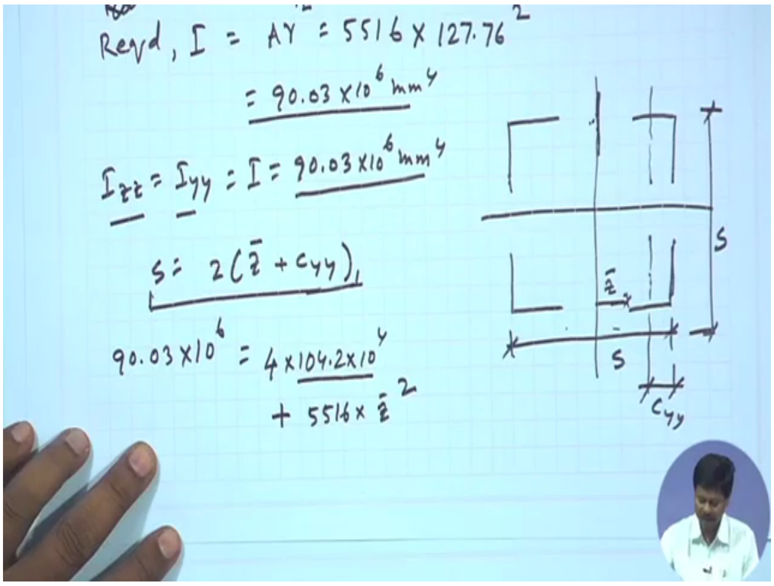

So if required r is this then we can say that required moment of inertia required moment of inertia I is equal to Ar square, now A is fixed, A already we have fixed as 5516 because the section size is fixed only the spacing between size is not fixed so into 127.76 square, okay. So 90.03 into 10 to the power 6 millimetre to the power 4 so this is the required moment of inertia about (I-I or z-z) y-y and z-z.

So if we see the section say for example this is the four angles placed to make the box section box type section built-up section, right. So we will provide the spacing between these angle section in such a way that the moment of inertia about both the sections will be same, right this will be the spacing. So spacing between these two should be same so that moment of inertia become same.

So Izz and Iyy has to be equal to same means that will be 90.03 into 10 to the power 6 millimetre to the. So Izz and Iyy we have to achieve this value, okay so this can be achieved if we make a particular spacing say if this is say if we make say z (dist) say z bar, right if z bar and if the Cg distance of angle if I write this is Cyy if I say then I can write spacing between two angles S will be S will be 2 into z bar plus Cyy, right. So the spacing between two angles in both the direction has to be z bar plus Cyy into 2.

Now to find out z bar we can find out the means we can equate the Izz and Iyy so if we equate the Izz and Iyy we can write 90.03 which is the moment of inertia that I can make. So if I calculate the moment of inertia about this and if I transfer to this distance means in in this axis then I can get that is a four angle sections are there so 4 into 104 into 2, this is the I section means I moment of inertia of individual section then plus Ar square A is 5516 into r means here z bar square, right. So there is 4 sections so we have total area is this so from this if I equate I can find out z bar as 124.76 millimetre, right.

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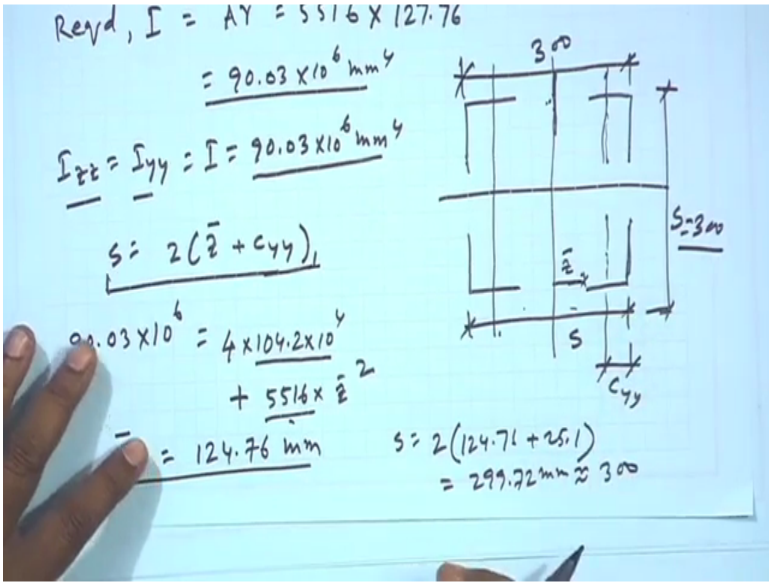

So if I get z bar then I can find out the spacing, so spacing will be 2 into 124.76 plus 25.1 is the Cyy so if I make this I can get the S value as 299.72 millimetre that means I can make 300 spacing, right. So spacing between the angles I can make 300 so that the required amount of moment of inertia I can achieve in both the direction because I am going to find out the spacing between two members as 300 mm and this spacing I am going to find out in such a way that the moment of inertia about Y axis and moment of inertia about Z axis will be equal and that will be the required area that is 90.03 into 10 to the power 6.

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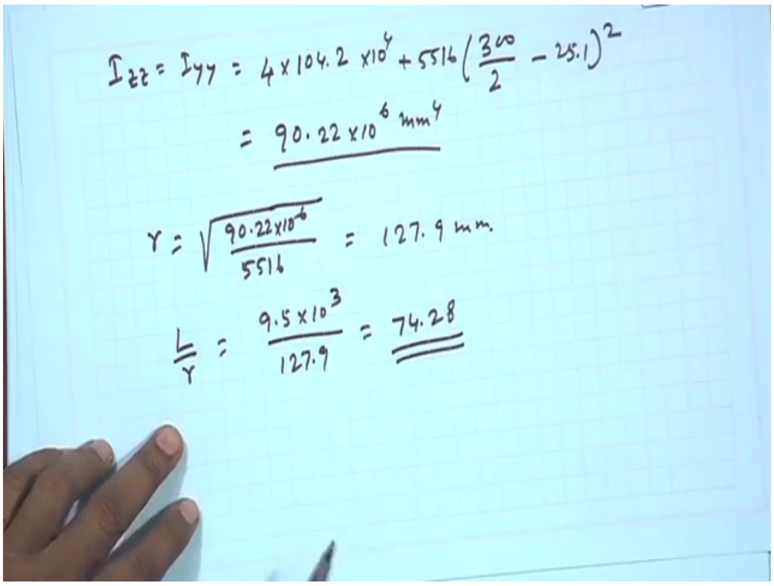

So once I make get this I can now find out the actual Izz or Iyy, right so that can be found from this equation this will be the actual one 10 to the power 4 plus 5516 because I am providing 300 spacing, right. So if I calculate it will be actual moment of inertia will be 90.22 into 10 to the power 6 millimetre to the power 4, this is slightly higher than the earlier one 90.03 because the spacing what we got actually 299.7 we are providing 300 that is why as we are providing little higher so Izz or Iyy is becoming little higher.

And so actual r we can find out I by A 90.22 into 10 to the power 6 by A is 5516, so this will become 127.9 millimetre. So L by r the slenderness ratio I can find out L we found earlier that is 9.5 meter by 127.9, so this will become 74.28. So slenderness ratio actual slenderness ratio we can find from this.

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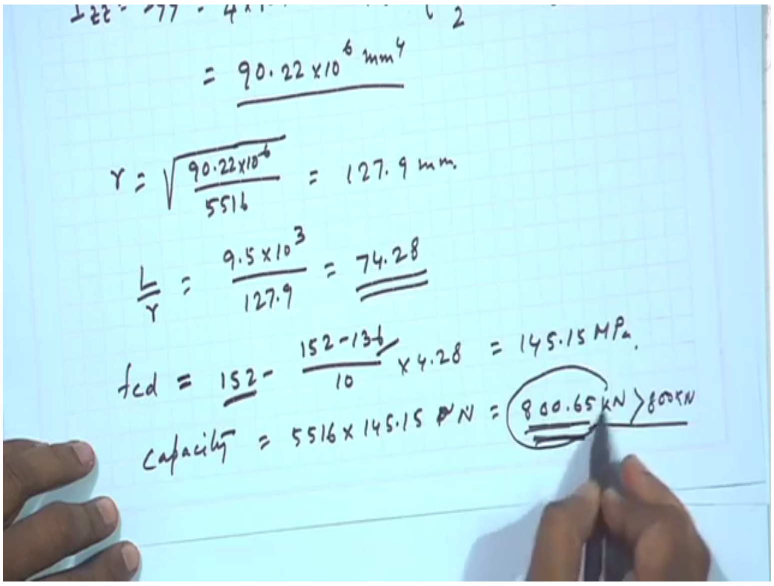

Now from table 9c I can find out the actual fcd earlier we got the required fcd now from the actual dimension actual spacing of the members we can find out the design compressive stress fcd as 152 minus 152 minus 136 this can be found from table 9c corresponding to L by r as 70 it is 152 and as 80 it is 136, so if we interpolate we can find out the fcd value as 145.15 MPa.

So capacity of the built-up section the actual capacity I can find out now the area was 5516 and the fcd value was 145.15, so it will be newton so it is coming 800.65 kilonewton, right 800.65 kilonewton which is slightly less than 800 kilonewton, right so it is okay. So what we have seen that the actual capacity of the built-up column has been found on the basis of the spacing whatever we have provided and from that we have seen that it is slightly higher than the external load 800 kilonewton. However this can be increased if we increase the spacing between the members in both the direction, if we increase the spacing then I can increase this, right.

Now I will go to the connecting system, so in first part what we have seen that we could find the section size of the angle and then the spacing between two members and two angles in z direction and y direction and spacing has been made in such a way that moment of inertia in both the direction becomes same so that the equal resistance of the column can be achieved and the spacing has been made in such a way that the strength of the member becomes more than the actual one.

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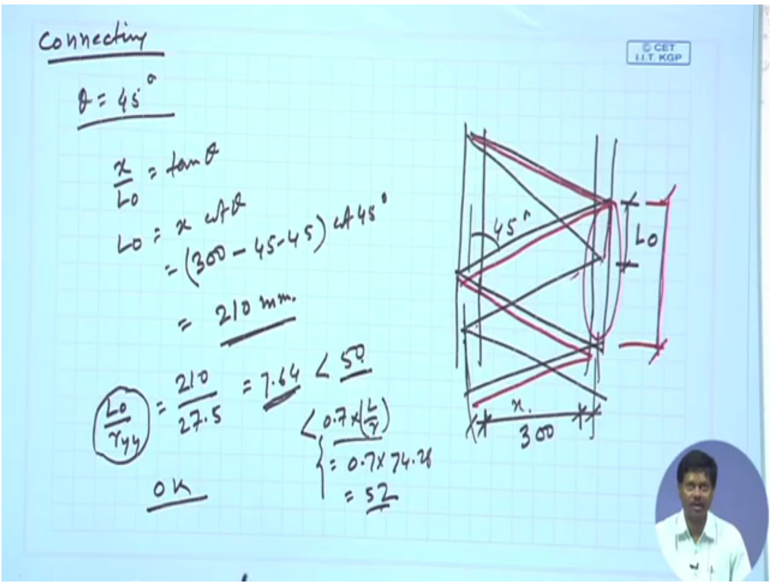

Now we will go to the connecting system that is double lacing system how to provide the double lacing system and its connections, right. So for connecting system if we use double lacing then we can see that if we have two columns and if we provide double lacing here say like this so the spacing between two lacing member will become L0. Now if u remember the for single lacing system the spacing was like this because if I provide single lacing system it is something like this, right. So the spacing between two system was this.

Now to resist the buckling about the column locally sometimes we provide double lacing to reduce the effective leg between this member. So in place of single lacing if the length is L then in place of double lacing length will become L by 2, so that is why to reduce the effective length we provide double lacing. Now let us provide double lacing with a angle of 45 degree so theta we are assuming as 45 degree.

So if we two show and for both the cases we are assuming 45 degree then we can find out the value of L0. So if this is x if I consider then I can write x by L0 is equal to tan theta, so L0 will become x cot theta and x is basically 300 was the distance that is S this is 300, so 300 minus 45 minus 45 to get from the bolt distance, okay to get the value of of x from bolt to bolt, right so into cot 45 degree. So this is becoming 210 millimetre so spacing between lacing members is achieved as 210 millimetre.

Now L0 by ryy this is becoming so 210 by 27.5 so this is becoming 7.64 which should be less than 50 and should be less than 0.7 into L by r that is 0.7 into L by r was 74.28 we calculated, so this is 52. So what we see that L0 by ryy we got 7.64 which is less than 50 and 0.7 L by r that is 52, so this is okay so length of lacing member is okay means the assumptions of theta the inclination angle whatever we have considered is okay.

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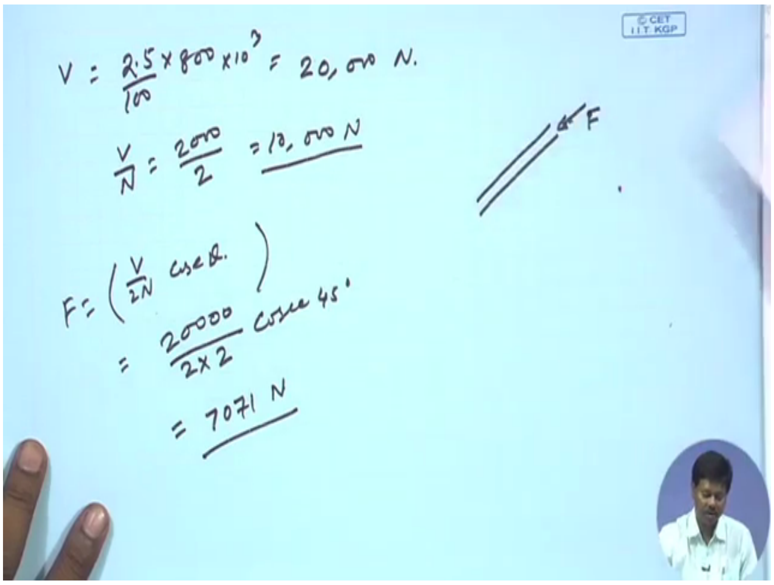

Now shear force so shear force we know that is 2.5 percent of the axial force will be the shear, so 2.5 percent of 800 so this will be the shear force 20000 newton. So transverse shear in each panel in each panel it will be V by N, so it will be 2000 by 2, so 10000 newton. So in each panel the transverse shear is coming this and as double lacing is provided so compressive force will be V by 2N cosec theta, right compressive force that the member taking the compressive force say if we if we call this as compressive force say F then F is equal to V by 2N cosec theta, right.

So if I put those value this is 20000 by 2N is 2 into cosec theta means cosec 45 degree, right. So this is coming 7071 newton, right. So compressive force in lacing member we can find.

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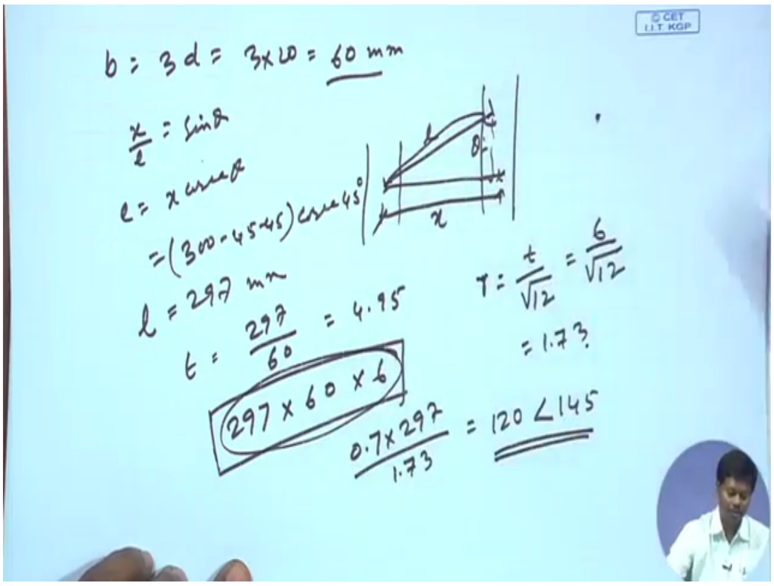

Now I have to find out the length of the lacing flat. So to find out length of lacing flat and the depth width of the lacing flat we have to use certain connection, so that can be found that whether we are going to use the weld connections or bolt connections. So there are two option in this case let us assume 20 mm diameter grade of 20 mm diameter of bolt of 4.6 grade we are using.

So if we use 20 mm diameter of bolt then the minimum flat width will be minimum width b will be 3d, so 3 into 20 that is 60 mm. This is given in clause 7.6.2 from where we can find out that minimum width is 60. And length will become length if I see this is the length so if I have to find out the length then I know this value is x so if this is x then and this is theta then x by l is equal to sin theta.

So l is equal to x cosec theta and x will be 300 minus 45 minus 45 into cosec 45, so from this I can find out 297 mm. So length of the lacing plate is 297 mm and the thickness I can find out as 297 means L by 60 so 297 by 60 so this is coming 4.95, so we can provide a flat size of means the lacing size of say 297 by 60 say 6, so this will be the size of the lacing plate.

Now we have to check from radius of gyration point of view because this lacing plate may buckle so whether it is below the permissible radius of gyration or not or below the permissible slenderness ratio or not that we have to check so slenderness ratio we know to find out slenderness ratio first we have to find out the radius of gyration which r for rectangular section we know r is equal to t by root of r 12, so t we have consider 6 and this is root 12 so 1.73.

So I can find out the slenderness ratio that will be 0.7 into 297 0.7 L by r, r is 1.73 so this is becoming 120 which is less than 145, so okay so from slenderness ratio point of view the the size of the lacing member whatever we have consider is okay. So this is how we fix the size of the lacing bar however we have to find out whether the lacing bar is capable of taking tensile strength and compressive strength in the lacing bar tensile strength will develop so we have to check the developed tensile strength whether the lacing bar can take care or not.

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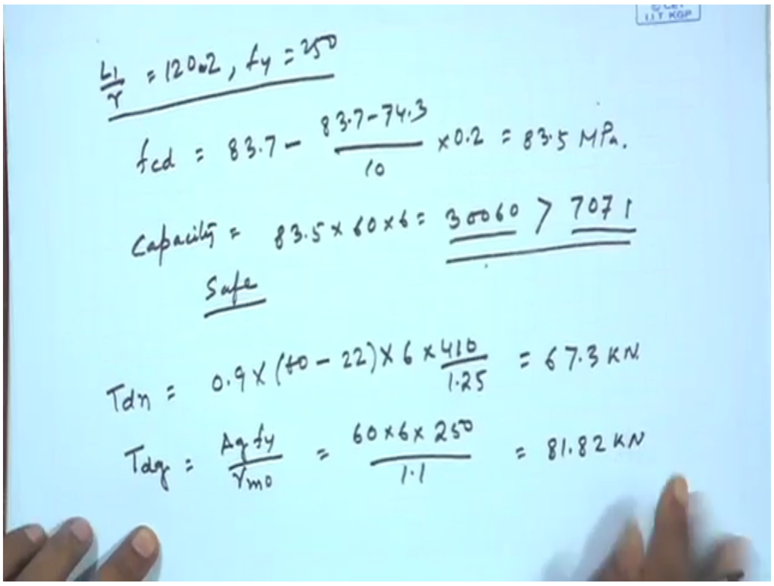

So for L1 by r means 120 and actually this is 120.2 L1 by r is 120.2, so and fy is equal to 250 from from table 9c I can find out fcd value, fcd value will become 83.7 minus 83.7 minus 74.3 by 10 into 0.2 so that is becoming 83.5 MPa. So capacity of lacing bar I can find out capacity will be 83.5 into fcd into 60 into 6 that is becoming 30060 which is greater than the actual force coming into the member, right.

So the compressive strength of the lacing bar is coming 30060 newton and the external force in the lacing bar is coming 7071 newton. So this is more than the developed one so it is okay, so this is safe. So from compressive point of view the members are safe.

Similarly for tensile strength of tensile strength point of view we can find out the Tdn value that will be 0.9 into b, b is 60 minus d 20 mm diameter bar we have consider 20 mm diameter bolt we have consider so bolt hole will be 22 into thickness is 6 into fu by 1.25 gamma m1. So if I put this value I will get 67.3 kilonewton. And strength due to gross yielding Tdg I can find out that will be Agfy by gamma m0 is equal to 60 into 6 into 250 by 1.1 so 81.82 kilonewton, right.

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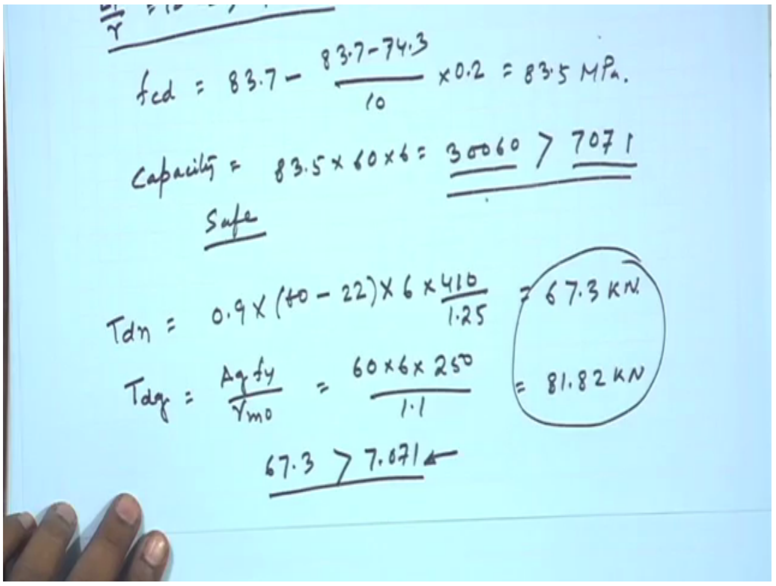

So tensile strength of lacing flat will become lesser of these two that means 67.3 kilonewton and this 67.3 kilonewton is higher than the 7.071 kilonewton which was the force coming on the lacing member. So from the force point of view the lacing member whatever we have chosen is okay.

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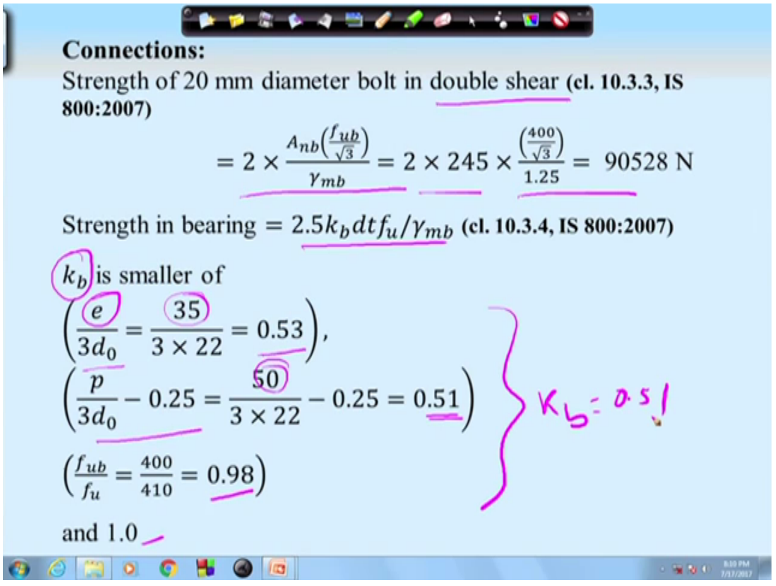

Now very quickly I will discuss about the connections because connections already we have discussed earlier. So in case of connections I will just give an overview because we know how to do connections only difference will be in case of double lacing if we overlap the lacing system then it will be double shear, okay. So in case of double shear the strength of the 20 mm diameter bolt can be found and that will be 2 into 245 into this so 90.528 kilonewton.

And strength in bearing also can be found to find the strength in bearing we have to find first the value of Kb and Kb we know the smaller of these three four. So one is e by 3d0 which is coming 0.53 and p by 3d0 minus 0.25, here e we are assuming as 1.5d0 so greater than that so we are assuming simply 35 and p we are assuming 2.5d as 50, so this is what we are getting and fub by fu we we get 0.98 and 1, so smaller of these will be Kb value will be finally Kb is equal to 0.51, right.

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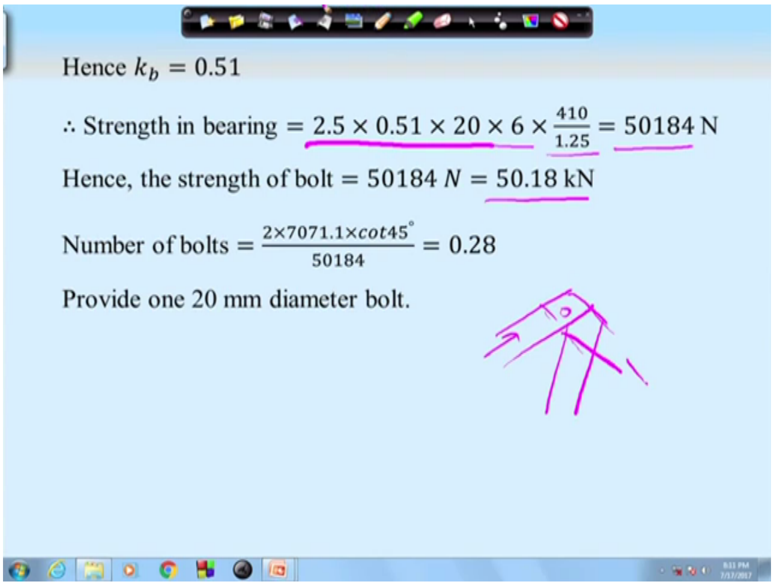

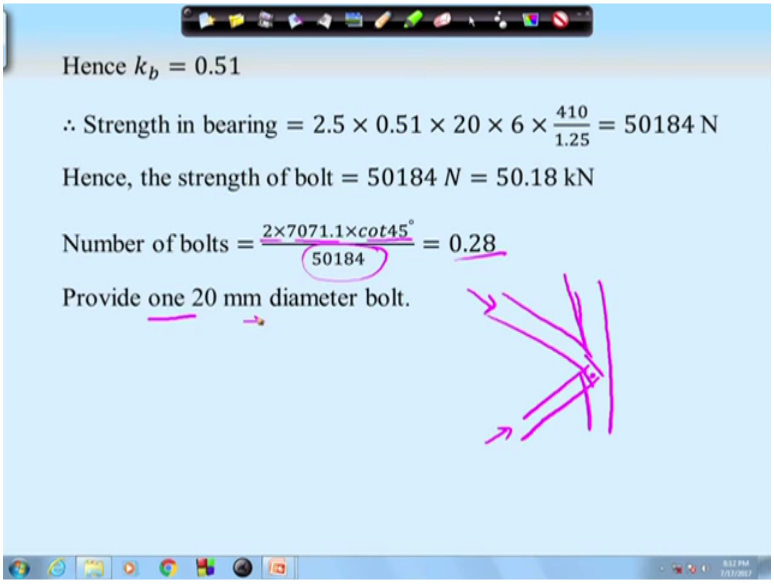

So after getting this Kb value we can find out the value of bearing strength. So strength in bearing I can find from this if we put the value 2.5 Kb, d is 20, t is 6, then fu by gamma mb so 50.184 kilonewton. So the strength of bolt will be lesser of these two bearing and due to shearing double shear so that is coming 50.18 kilonewton. So number of bolts I can find out number of bolts will be actually if we consider as overlapping the lacing then forces will come from this and from this sorry sorry if I consider this like this and if we overlap this then force in compression are coming so if we add this then we will get 2 into that F cot 45 degree that is the force coming and this is the bolt value so 0.28 that means one number of 20 mm diameter bolt is sufficient to carry this load, so this is what we can find out.

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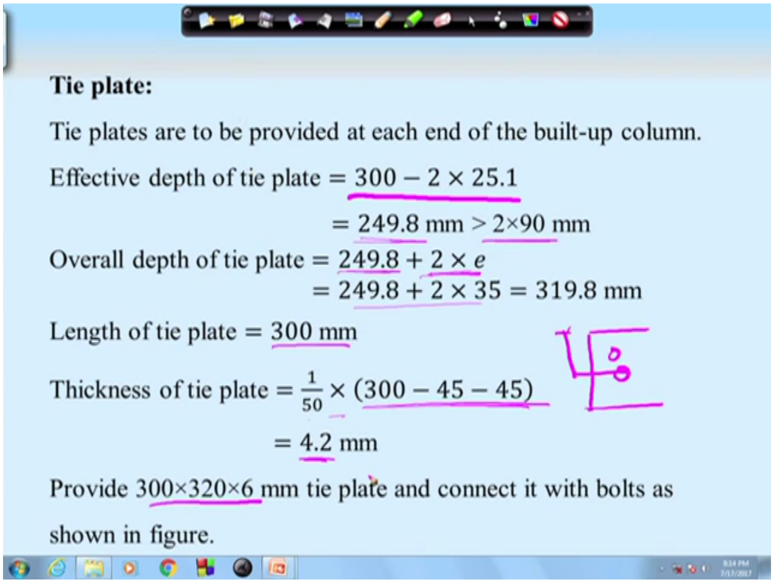

Now we will go to tie plate design so tie plate also will be designed similar way what we did earlier effective depth we can find out effective depth will be 300 minus that is 300 minus 2 into Cyy, so 249.8 and that is more than 2b so it is okay. Overall depth of the tie plate we can find out now depth plus 2 into e edge distance because overall depth will be this in case of tie plate if we have bolt actually one bolt is there so if we have bolt then the e distance from here we have to find out, so overall depth of tie plate will be 249 plus 2 into e, right.

Then length of tie plate so this is what length of tie plate we can find out that is 300 millimetre, then thickness of tie plate thickness of tie plate also we can find out that is 1 50th of the inner distance of the bolt, so that we can find out 4.2, we can consider in place of 4.2 say 6 mm. So we can provide a tie plate of 300 by 320 by 6 mm at both the end, right with bolt. So so tie plate design is over.

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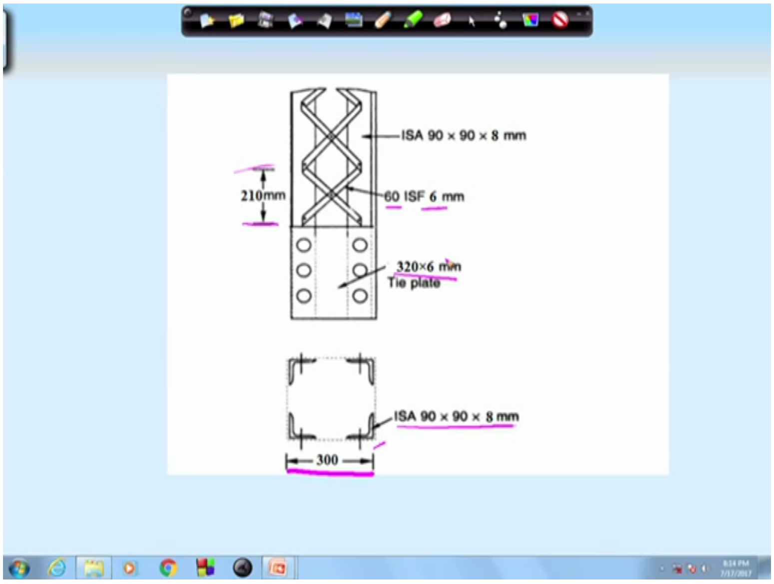

Now we can show in the drawing, so whatever we have consider in the design and whatever outcome was obtained that has been written here, like the spacing between two members are given outer to outer 300 and it is a box section and section size is 90 by 90 by 8 and similarly tie plate size we have consider 320 by 6 mm and the lacing plate we have consider 60 mm (())(34:45) and 6 mm thickness and the distance between two lacing we have consider this, right. So this is all about the design of a compression member using double lacing system.

So in this lecture in short if we tell that we have understood how to find out the appropriate section of the angle to withstand that given load then how to find out the distance between two angle that is spacing in both the direction to withstand that much load and then how to design a lacing system using double lacing, right. So this is all about the lacing system in next class we will discuss about the batten system, thank you.