Course on Design of Steel Structures
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Lecture No 19
Design of Eccentric Connection (Load Lying Perpendicular to Plane of Bolted Joint)

Welcome to this lecture, in this lecture will be the continuation of last lecture in last lecture we have discussed about the bolt group connection where the bolt groups are lying perpendicular the load or the load is lying perpendicular the bolt group that means load is out of plane of the bolt group.

So in that case how to find out the tensile force developing on the bolt and the shear force in each bolt how it is being calculated that we have shown and how the neutral axis will be decided and on the basis of that neutral axis how the tensile force is going to vary from bolt to bolt that we have seen and then we have found what will be the develop tensile force in each bolt and what will be the shear force in developing in each bolt and then through interaction formula we need to check the bolt group whether that is ok or not.

So today we will go through one example to understand the same process whatever we have discussed. So before going to the example just I will very briefly I will just give analysis overview of design procedure whatever I have discussed yesterday.

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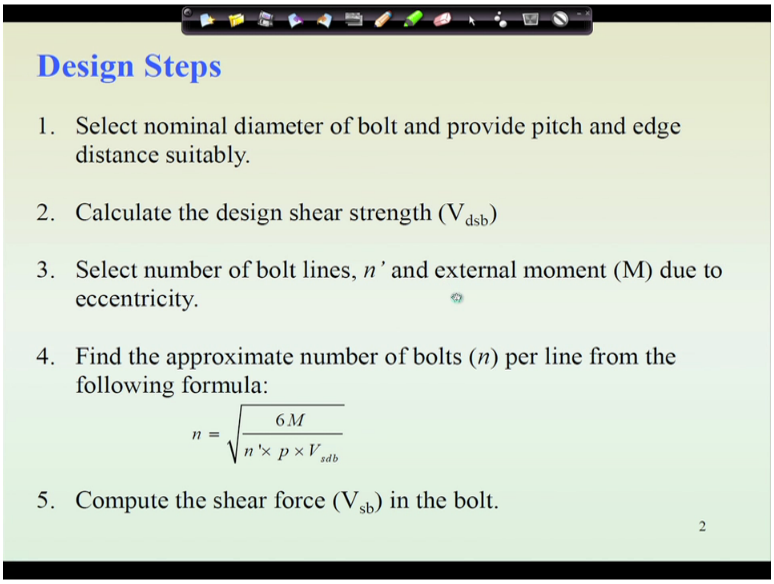

That is design steps means what we have to do we have to start the design with some basis basis means we have been given say one (())(1:53) one bracket bracket is connected to the (())(1:59) then it is loaded with certain amount of force at a certain distance away from the structure that means it is an eccentric connection if it is given then we have to see first whether it is out of plane load or in plane load, means depending on the type of connections, ok right. If it is out of plane load means whatever we have discussed in case of out of plane load then how to start.

So what we will do first we will start with certain assumptions assumptions means bolt diameter is not given, so we can start with certain bolt diameter then what we can do we can find out the what will be the pitch distance then edge distance due to this type of bolt diameter, then what will be the bolt strength due to shear and other things that we will try to find out, then again we do not know how many number of bolts are exactly required because it is not given.

So what we can do we can assume certain number of bolt groups, certain number of bolt lines, right two or three whatever it is, then per line what will be the number of bolt that approximately we can calculate this from the moment formula, right.

So that we are showing here, say suppose in first step we can see that we can find out the nominal diameter of bolt and we will provide the pitch and edge distance, then we will find out the design shear strength and number of bolt lines we can assume and we can find out the external moment due to eccentricity. Then we can find out the approximate number of bolt per line from this formula and also we can find out the shear force coming into the bolt in each bolt how much it is coming that also we can find out.

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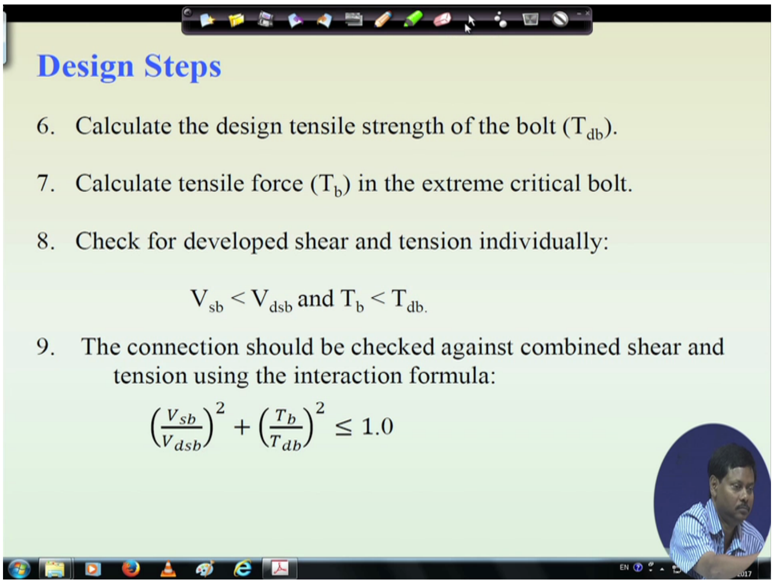

Then in next step what we can find out, we can find out, also the design tensile strength of the bolt group and also the tensile strength in the extreme bolt that also we can calculate and we have to individually check that the force develop on the means shear force develop on a particular bolt should be less than the design shear strength of the bolt and similarly the tensile force develop on the bolt should be less than the tensile strength of the bolt, right.

So individually it has to be less if it is not less than we have to increase the number of bolt either increase the number of bolt or we have to increase the diameter of bolt to make sure that these are these conditions are satisfied and once it is satisfied also we have to find out the checked against combined shear and tension using this interaction formula that is Vsb by Vdsb whole square plus Tb by Tdb whole square should be less than or equal to 1, so this also we need to check once it is ok then our assumptions in terms of number of bolts and in terms of diameter of bolts are ok, if it is not ok then we have to increase either number of bolt or diameter of bolt and we have to recheck once again, right.

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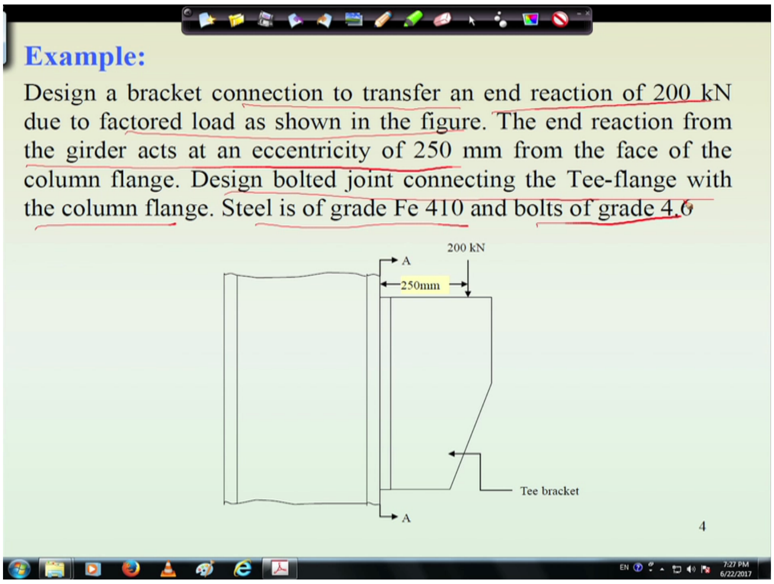

Now let us go through this example, so this example if you see this is given that design a bracket connection bracket connection to transfer analysis end reaction of 200 kilonewton due to factored load as shown in the figure. In the factor in figure it is shown the end reaction from the girder acts at an eccentricity of 250 mm from the face of the column flange. Now you have to design the bolted joint connecting the Tee-flange with the column flange. Steel is of grade 410 and bolts of grade 4.6 that means here only we have been given the force in terms of end reaction and the eccentricity.

So P and e are given and it is told what type of grade of bolt has to be used and what type of grade of steel are used which will be required for strength calculation. So these are the things only are given, now I have to find out number of bolts, diameter of bolts and the arrangement means what will be the edge distance, what will be the pitch distance how it will be arranged, what will be the total depth edge those things we have to find out.

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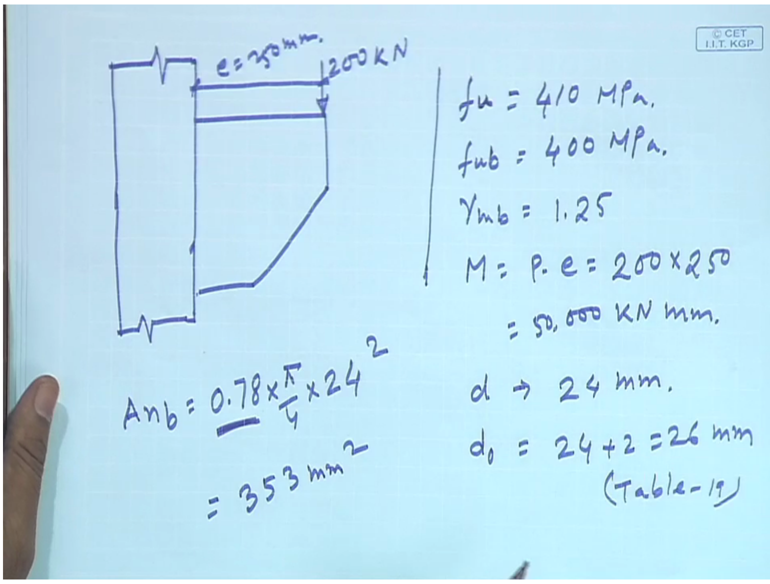

So if I see here that first of all this tension is connected to the bracket and a load of 200 kilonewton which is P at a distance of e is equal to 250 mm these are the two things are given, right. So we have to go for the solution, so here also it has been told that fu that means the grade of steel was fe410 that means the ultimate strength of the steel plate will be fu is equal to 410 MPa.

Similarly fub ultimate strength in bolt as 4.6 grade bolt is used so fub will be equal to 400 MPa, so these are given and also we know the partial safety factor in bolt gamma mb which will be required for calculation of strength that is 1.25, now moment also we can calculate that is P into e so 200 kilonewton into e was 250 millimeter so this is coming 50000 kilonewton millimeter.

Now we have to decide certain number of bolts sorry certain diameter of bolts. So diameter of bolt we can provide say for example say 24 mm diameter of bolt are provided in the connection, right. So if we provide 24 number of bolt then the hole diameter will become d0 as 24 plus 2 that will be 26 mm d0, this from table 19 we can find out, table 19 of IS: 800, right.

Now Anb the net area we can consider that 0.78 into pi by 4 into d square, so we are multiplying 0.78 thinking that shear plane is passing through the threads, otherwise it will be pi by 4 into 24 square. So to be in safe side we are assuming that the net area will be reduced to 0.78 so this if we calculate will get 353 millimeter square. So this is the net tensile area so tensile stress area will be calculated like this.

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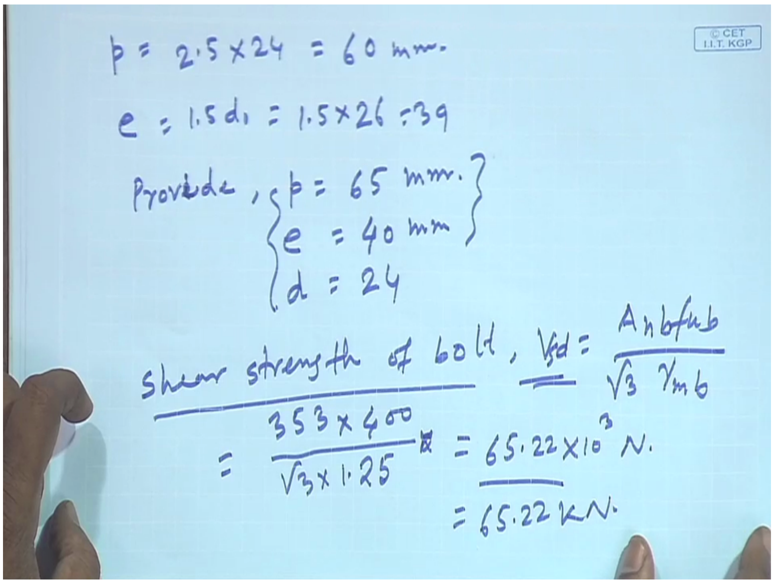

Now other details like pitch distance we can calculate 2.5 into 24, 2.5d so this will be 60 mm and minimum edge distance e will be 1.5 into d0 that means 1.5 into d0 means 26, so it is coming 39, right. So we can provide pitch means from this criteria this minimum pitch and edge distance criteria we can provide pitch distance as in place of 60 say let us make 65 mm and edge distance in place of minimum 39 so we can make 40 mm, right so these two we are providing. That means the assumptions is d we have provided 24 and because of this d, pitch and edge distance we are calculating and we are providing as 65 and 40, right.

Now strength of bolt in single shear it will be in single shear so shear strength will be strength of bolt (Vd) Vsd we can find out Anbfub by root 3 gamma mb, right. So if calculate means if we provide this value Anb we can we have calculated as 353 millimeter square into fub is 400 newton per millimeter square and root 3 into gamma mb we have we know as per codal provision it is 1.25 and ok this is coming as 65.22 into 10 to the 3 newton, right.

So shear strength of bolt Vsd we can find out that is 65.22 newton into 10 to the 3 newton or 65.22 kilonewton. So shear strength of bolt we can find out on the basis of bolt diameter 24 mm bolt diameter, we can find out shear strength.

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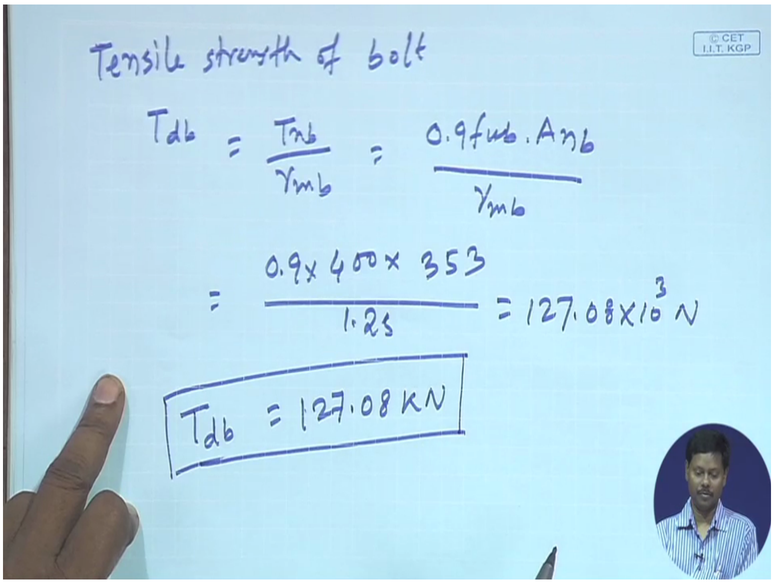

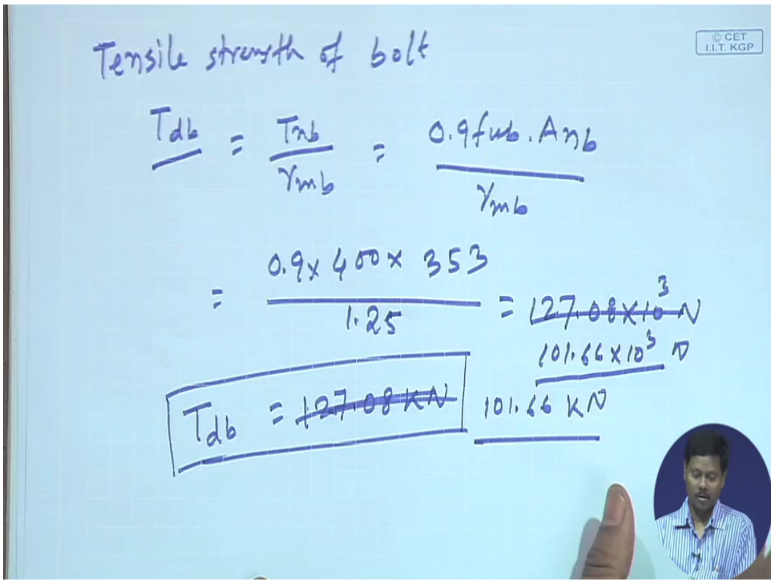

Now tensile strength of bolt that also we can find out Tdb tensile strength of bolt we can find out this will be Tdb is equal to Tnb by gamma mb, Tnb is basically 0.9fub into Anb and gamma mb and if I put this value 0.9 fub is fub value is 400 (An) Anb value is 353 by gamma mb is 1.25, so if we put this value we can find out as 127.08 into 10 to the power 3 newton or 127.08 kilonewton. So Tdb value the design tensile strength of bolt we can find out as 127.08 kilonewton sorry not 127 this calculation if we do 101.66 newton or that is 101.66 kilonewton, if we divide by 1.25 then it will be 101.66 into 10 to the 3 newton or 101.66 kilonewton. So Tdb and Vsd has been calculated that means design shear strength and design tensile strength has been calculated.

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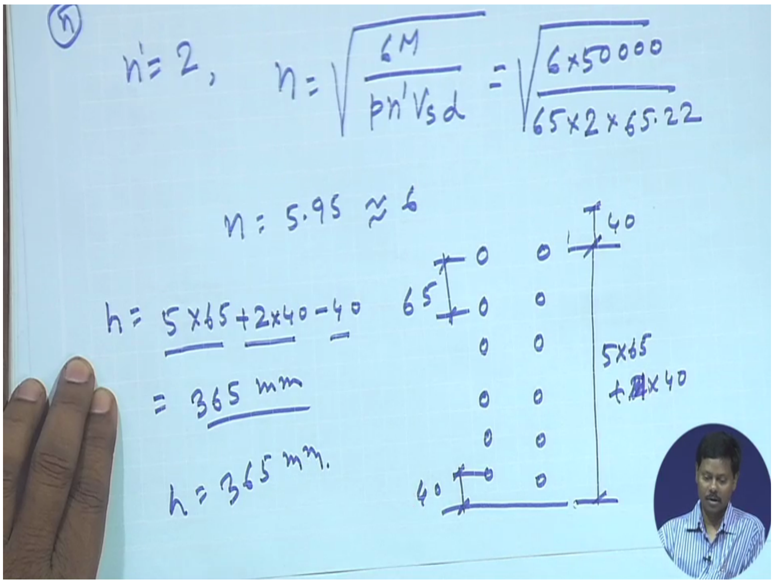

Now we have to find out the number number of bolts number of bolts we can find out but before that we have to assume the number of bolt line. In this case let us assume that number of bolt line as n dash is equal to 2. So if we decide number of bolt line then we can find out the number of bolts per line per bolt line we can find out from this formula that is p into n dash into Vsd, right. So if we put this value we can find out 6 into moment was 50000 kilonewton millimeter by p was 65 and n dash number of bolt lines have been taken as 2 and Vsd was 65.22, right. So n we can find out as 5.95 or 6. So we can provide 6 number of bolts in each bolt line that means 6 number of bolts we can provide in each line with 2 number of bolt line we can provide, right.

So if we provide 6 number of bolts and we know the pitch distance was 65 and edge distance that was consider as 40 mm, right so 40 and 65. So the h will be the depth from bottom most bracket to the top most center of the top most bolt. So this I can find out as it will be 5 into 65 plus 2 into 40 minus 40, total distance will be 5 into 65 plus 2 into 40 and minus 40 because from here to here as I said it is 40. So h will be 5 into 65, 6 number of bolts plus 2 into 40 sorry 1 into 40. So that means this will be 365 millimeter. So h value we are getting 365 millimeter, right.

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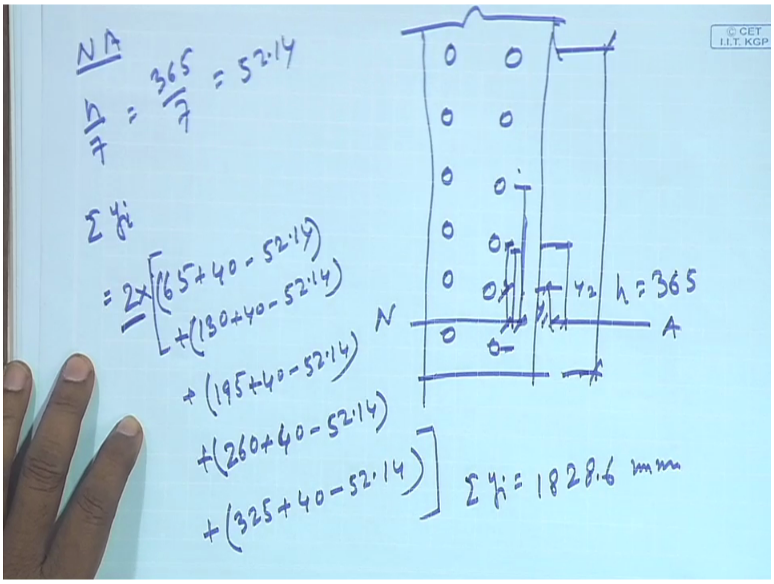

Now I have to find out the t value of tb the extreme bolt how much force is going to be (()) (17:24) by that extreme bolt, this tensile force that we will calculate. So for calculation of that we have to know yi and yi square summation of yi square. So if we put this one by one than I can find out yi and summation of yi square, that is this 3, 3, 6 so if I consider in this suppose this is the column flange, right so this value was h is equal to 365 and we can find out the neutral axis neutral axis distance will be at h by 7, that means 365 by 7 this will become 52.14, so 52.14 means upto this it is 40 so it will be sometimes like here, neutral axis depth will be here, right.

So now I can find out summation of yi, right the summation of yi I can find out as it will be one by one if I consider this will be actually 65 yi will be 2 into for 2 bolt line so we can calculate 65 plus 40 minus 52.14, this is y1, right. This is one, second one is 130 plus 40 minus 52.14, this is second one y2, this is y1, y3 will be similarly 195 plus 40 minus 52.14, then fourth one will be 260 plus 40 minus 52.14, then fifth one will be 325 plus 40 minus 52.14, right. So this is what the summation of yi will be. So if we calculate those value so summation of yi we will get as 1828.6 millimeter, right.

So summation of yi means y1 plus y2 y1 sorry y1 this is y2, this is y3 like this y4 and y5 and 2 number of bolt lines are there that is why we are multiplying with 2, right. So summation of yi, I can find out.

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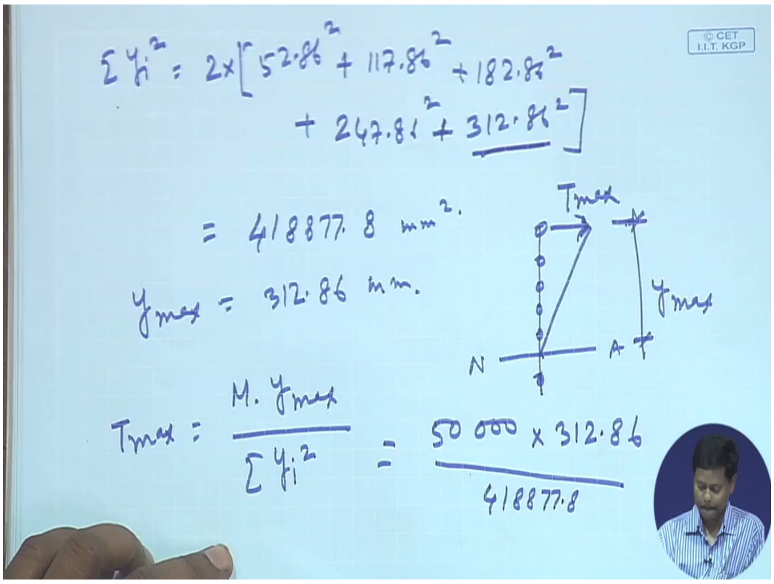

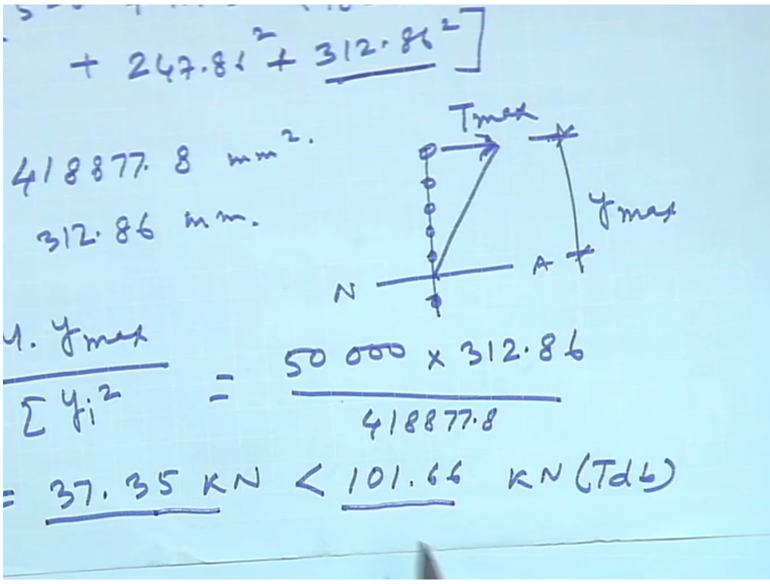

Similarly I can find out summation of yi square, this will be 2 into if I calculate first one y1 that will be 52.86, then second one will be 117.86, third one will be 182.86 the way I have calculated yi in the similar way I can calculate yi square 247.86 square plus 312.86 square, right.

So summation of yi square will become 418877.8 millimeter square and ymax we can find out ymax will be this one 312.86, right ymax I can find out. So once we find out ymax that means if the neutral axis is following in this way then ymax I can find out this is the bolts are there 1, 2, 3, 4, 5 and 6, so this is how so this is the ymax and maximum bolt force due to tension will be develop in the extreme one in extreme bolt the extreme top most bolt will be developing the maximum tensile force tmax, so we can calculate the tmax value.

So tmax will become M into ymax by summation of yi square, so if I put this value M was 50000 kilonewton meter and ymax was we have calculated 312.86, right then summation of yi square is equal to 418877.8, right. So if we put this value we can find out the value as 37.35 kilonewton this is the tensile force developed on the critical bolt and it is less than the Tdb Tdb value was coming 101.66 kilonewton Tdb value, right.

So what we could see that maximum tensile force develop on the extreme bolt is less than the tensile carrying capacity of the bolt. So this is ok, that means the number of bolts chosen in this case are ok.

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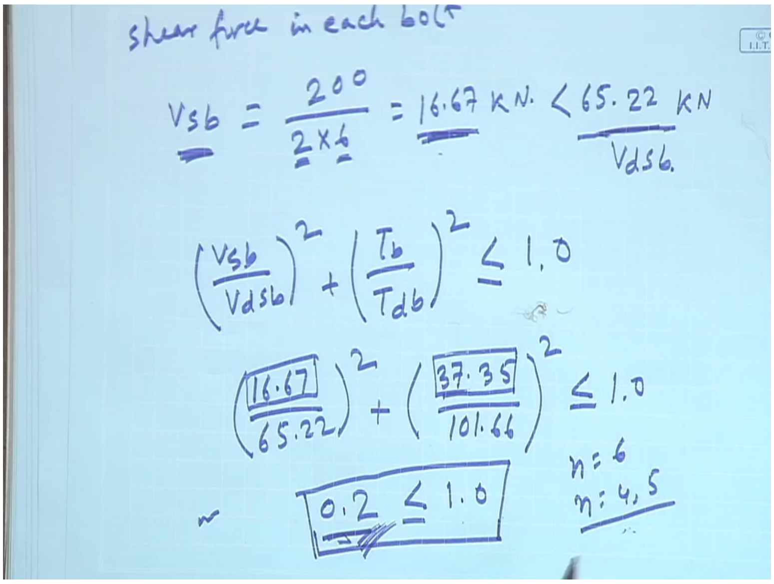

Now again we will find out shear force shear force in each bolt will be how much shear force in each bolt we are considering that total force divided by n, total number because we are assuming at the beginning of assumption we have consider that the all bolt will carry equal amount of force means the direct force, ok.

So Vsb the shear force in the critical bolt means in total means in each bolt will be p p was 200 by number of bolt, number of bolt will be 2 into 6, because in each line 6 number of bolts are there and there is 2 bolt lines so 2 into 6. So this is coming 16.67 kilonewton, right and this is less than the shear force carrying capacity means shear strength capacity of the bolt which is 65.22 kilonewton, this is Vdsb basically, right. So Vsb the shear force in the bolt can be found as 16.67 kilonewton which is less than this.

So individually these are ok, that means from shear force point of view and from tensile force point of view the bolts are ok, that means the extreme bolt is ok from tensile point of view and shear force point of view.

Now we have to check from the interaction formula that means (())(25:46) combinly then the combination of this formula we have to (())(25:51) Vsb by Vdsb Tb by Tdb it has to be less than 1. So if it has to be less than 1 that means we can calculate the values that 16.67 by Vdsb was 65.22, right plus the tensile force (())(26:25) was 37.35 and tensile capacity of the bolt was 101.66 and this if we calculate will get it has to be less than 1, that means these value are coming 0.2, which is much much less than 1.0, right that means if we do the combination means combine checked that also we are seeing that the bolt groups are safe from both tension and shear, right. So this is how we have to check.

Now what we can see here we can see few aspects that interaction formula shows that the combined coefficient is coming 0.2 only in place of 1, right so it is much much safer than the means much much safer with this combination of bolt number one, number two the Vsb was much less right and Tb Tb was also much less compare to 101, Vsb was also much less compare to 65, that means may be it is over designed.

So in place of number of bolt 6, we can come to number of bolt 4 or 5 and we can check, right to make economy in the design what we can do we can change the number of means we can decrease the number of bolt and then we can check once again or the diameter of bolts also can be decreased if we decrease the diameter of bolt than strength capacity also would be reduced then also we can check, right.

So if it is much much higher means if it is if design is much safe means over designed than to make it economy we can redesign redesign means either we have to decrease the number of bolt or we have to decrease the nominal diameter of bolt. So if we decrease that then we can find out means we have to try to bring in a economic one. So if we reduce the number of bolt automatically that interaction formula it was much less than 1, it will be near to 1, right.

So this way we can think, right again at the same time if we see that interaction formula from interaction formula if it is more than 1, then we have to increase the number of bolt or diameter of bolt to make it safe, this is how we can do, thank you.