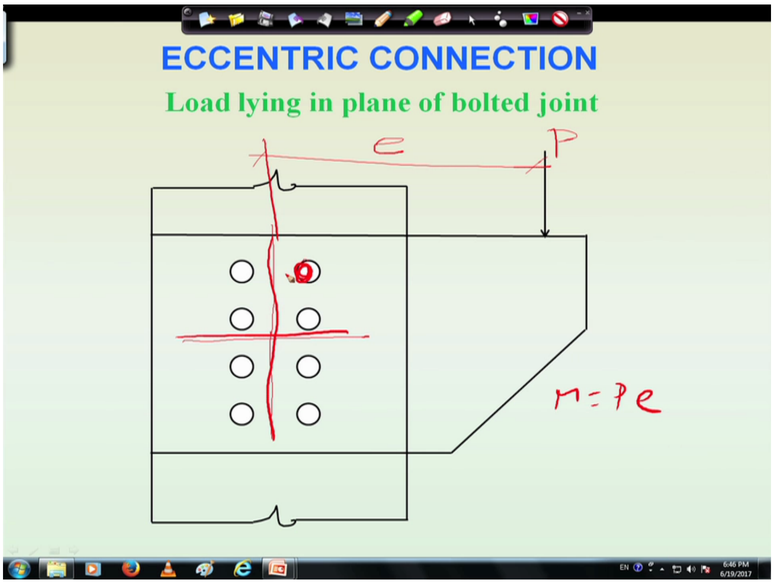
Course on Design of Steel Structures
Professor Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Lecture 13
Module 3
Eccentric Connection (Load Lying in Plane of Bolted Joint)

Hello today I am going to discuss about eccentric connections in last few lectures we have discussed the different types of connections but mainly those are concentric. Now in case of eccentric connections cg of the connection and cg of the load will be in different position so if it does not coincide then eccentricity will develop and because of eccentricity extra moment will come into picture and because of the moment extra stress will come.

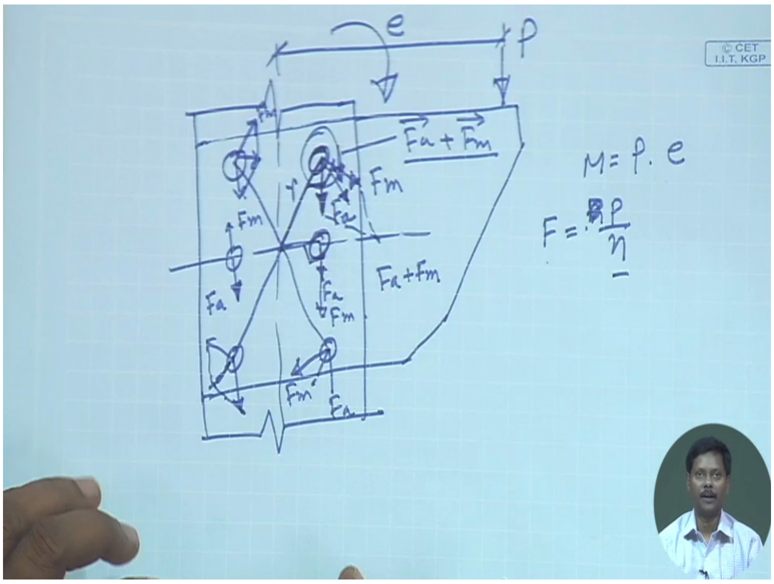
So therefore we have to design the joint taking consideration of the direct load as well as due to eccentricity say in case of eccentric joint we have different type of joint like when load is lying in the plane of joint it will be one type of eccentricity again that can be designed by weld connection as well as by bolt connection and similarly when load is lying in the perpendicular to the plane of joint then another type of eccentricity come into picture means another type of load reaction will come and that also can be designed using bolt joint and using weld joint. So basically four type of joints will be considered for design.

(Refer Slide Time: 1:45)



Now I will discuss today mainly on the bolted type connection where load is lying in the plane of joint. Say for example if we see this this is a typical example of load lying in the plane of bolted joint, so the cg of the bolted joint is this and the load is acting say here say we can load P and attend eccentricity e then the moment additional moment will come into picture that is P into e right so cg of the bolt joint is here so we have to calculate the load coming into the bolt at each bolt what are the load coming we have to calculate then we have to find out the bolt strength and we have to see whether this is safe or not.

(Refer Slide Time: 2:34)



If we draw this figure we will see say a column is carrying some eccentric load which is coming from beam or say gusset plate, so this is column say the eccentricity of bolt joint is this now so load is acting here. Now P is the load so the eccentricity will be e. So the additional moment due to eccentricity will be P into e now what will happen to the joint in each joint will see that in each joint there will be a load which will act in this direction means if n number of joints are there then load in each joint I can I can write say P by N assuming that the loads are distributed equally to each joint.

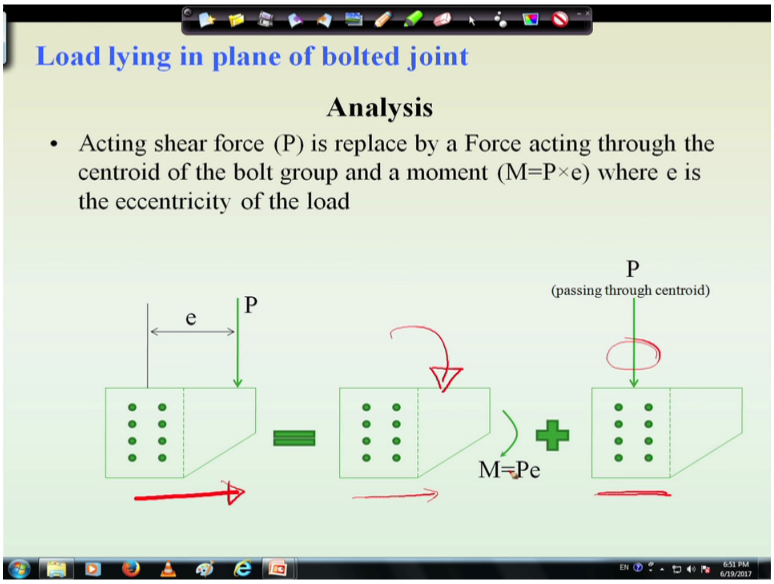
So if we consider that every bolt is taking equal load every bolt is sharing equal load then load at each bolt will be F is equal to P by n this is this is the load which is coming due to direct load now another load will come because of moment, moment developing so this moment because of this moment so this is direct load and another load will come or stress will come in this direction means perpendicular to this axis.

So this is the radial distance r we can say this is radial distance so for this bolt there are two types of forces will be acting one is called Fa due to direct load and another is called Fm due to moment moment and axial or direct load so we have to find out what is the resultant of this load and these resultant load will be the load acting on the bolt. Similarly for this case will see Fa will be this and also Fm will be also in this direction because it acts 90 degree to the radial distance so here it will be Fa plus Fm directly it will be addition but in this case it will be Fa vector plus Fm vector that means we have to find out the resultant of that.

Similarly for this case will see this will act Fm will act in this way and Fa will act in this way so we have to find out the resultant and we have to analyse for each bolt and we have to see which one is the most critical one here you see if we take the resultant we will see that it will be much less, it will be less resultant will be less. In this direction in this case Fa will be this and Fm will be this, so the resultant will be Fa minus Fm similarly for this case we can find out Fm in this direction and Fa in this direction therefore the resultant will be this Fr will be in this direction.

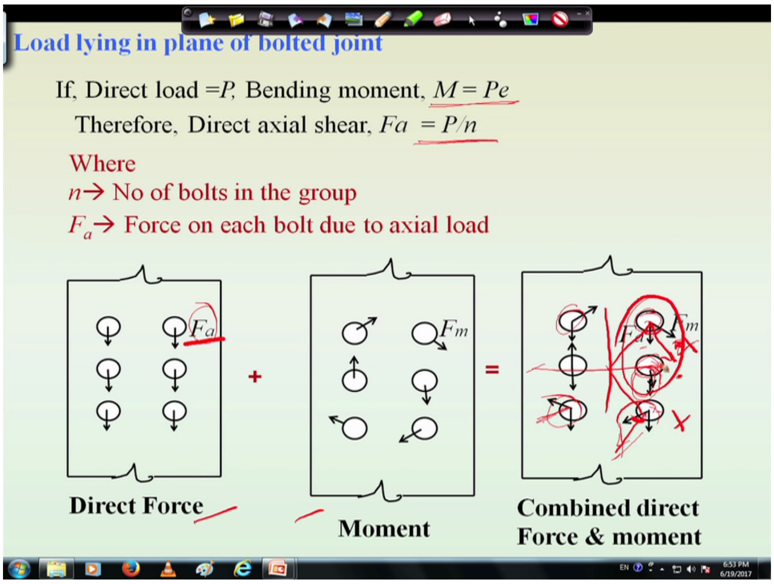
So for each bolt the exacted force will be different we have to calculate the force coming on each bolt and we have to see which one is the critical so case to case we have to consider and we have to find out the critical one.

(Refer Slide Time: 6:44)



So if we start with the load lying in the plane of bolted joint then we can see that so if we come to the case of load lying in the plane of bolted joint then we can see that this case can be made equivalent to this M is equal to Pe plus this one this direct load, so we are dividing into two part one is moment due to eccentricity another is direct centroid load.

(Refer Slide Time: 7:29)

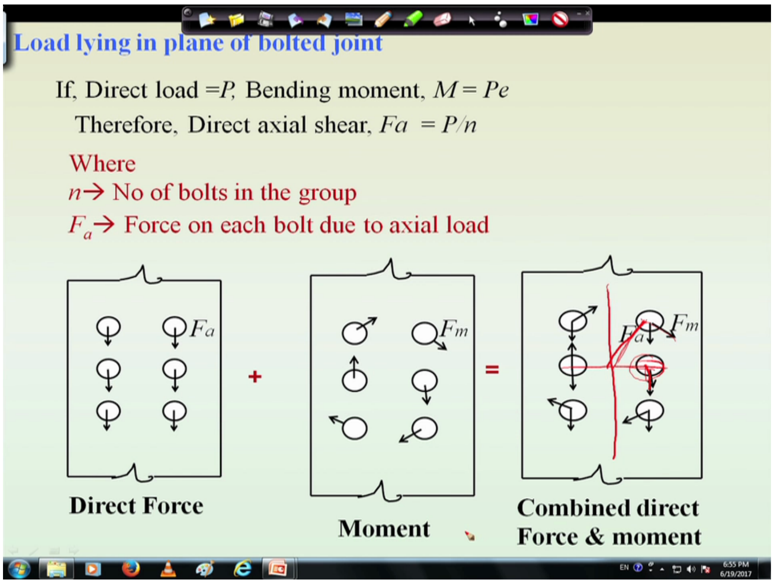


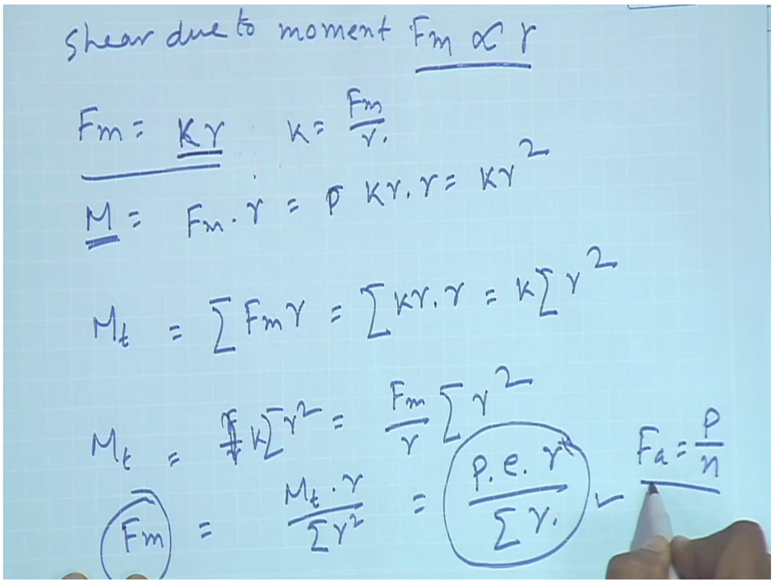
So this two will be added and we have to find out the equivalent load. So this is what I have discussed that if we can find out the direct force that will be Fa and this Fa will be simply P by n if P is the load then P by n will be the Fa and similarly moment we can find out moment will be P into e where P is the axial load and e is eccentricity so if we add this direct force and moment we can find out the combination of this. The things whatever I have drawn there that again I have shown here that if Fm is this and Fa is this its resultant will be in this direction we can find out.

Similarly here resultant will be the simply adding and here we can see that this will be again adding so out of this six bolts in this particular case will see the extreme case will come either this one or this one because this bolt and this bolt have similar magnitude because the theta will be same here so resultant force will be same because distance radial distance from here to this bolt and to this bolt is same.

That is why resultant force will become same for this case and this case however in this case it will be simply adding but in this case we will see it will be reduced, this Fr value will be less and here it will be Fa Fa minus Fm so it will be much more less than this and similarly this is will be equal to this one so it will be also less so what we can see that we have to check only two bolts means if we can check only these two bolts then we will be able to understand which one is means what is the critical bolt because this bolt and this bolt are same so we do not need to check one means if we check the extreme one that is sufficient and also we have to check this one then we have to find out the critical one.

(Refer Slide Time: 9:36)



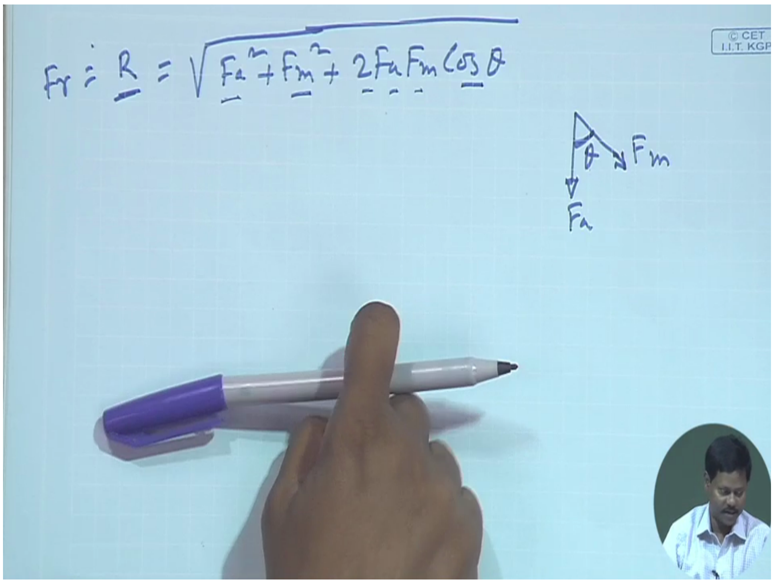


So from this we can find out the shear due to moment we can find out shear due to moment that will be Fm that will be varying with r because in this case if we see that the moment will be more if the distance is more. So it is varying with its distance so Fm will be more because its distance is more but Fm will be less in this direction in this bolt, so it varies with the distance so Fm we can write as Fm varies r where r is the radial distance of bolts from the cg bolt. So what we can do so Fm we can write k into r where k is the propositional constant k we can write as a proportionality constant. So Fm in each bolt is coming k into r where r is the radial distance from the bolt to the cg distance of the bolt group, so the moment on that particular bolt I can write moment will be Fm into r so Fm into r means kr into r that means kr square right.

So total moment it is individual moment so total moment say Mt I can write total moment will be Fm into r that means kr into r that means k into summation r square right again from here I can write k is equal to Fm by r so Mt I can write that Fm by r means summation kr square that means Fm by r, this is k into summation r square right. So from this I can write Fm that force due to moment will be Mt into r by summation r square that means P into e into r by summation r square.

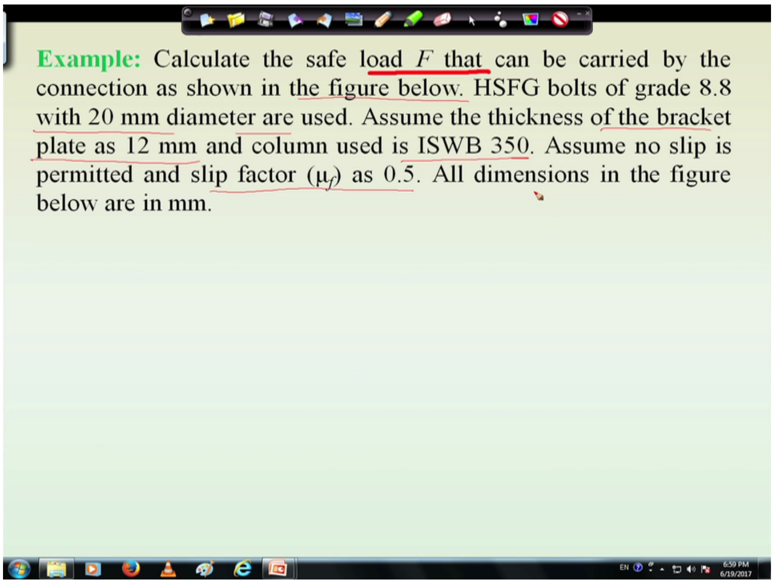
So this is how the force on a particular bolt can be calculated from this formula where e is the eccentricity and r is the radial distance of bolt to the cg group of the bolt, so Fm the force on the on a particular bolt due to moment can be calculated this and Fa we know that is basically P by n where n is the number of bolt, so if n is the number of bolt then Fa I can find out as a P by n so this is how we can find out the value of Fa and Fm.

(Refer Slide Time: 12:44)



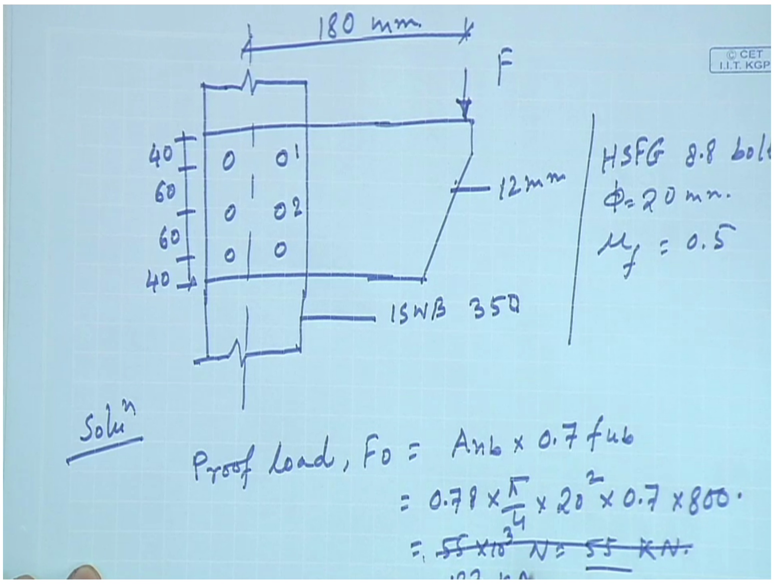
Now the resultant force, so we can find out resultant force that will be Fa square plus Fm square plus 2 Fa Fm into cos theta right, theta will be the if this is Fm and if this is Fa then theta is the angle between Fm and Fa. So I can find out R or I can write Fr resultant force at a particular bolt I can find out as a Fa square plus Fm square plus 2 into FaFm cos theta right, now this will be clear if we go through one example.

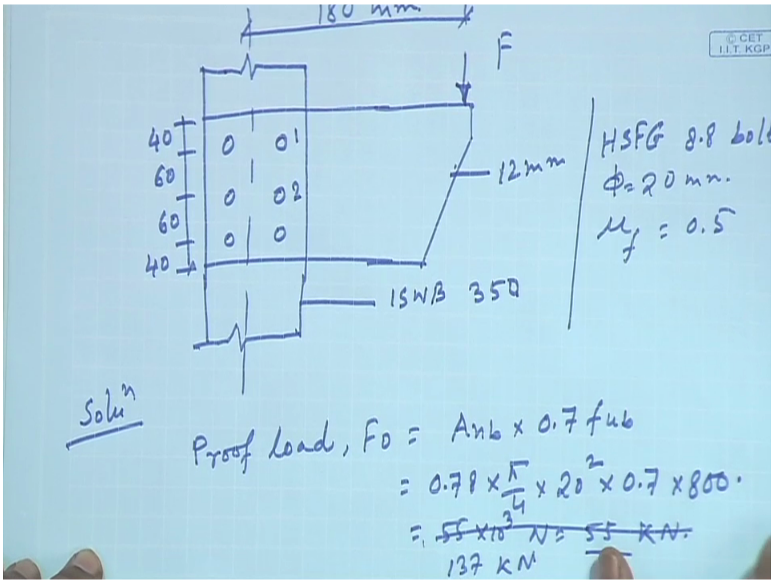
(Refer Slide Time: 13:43)



Now let us go through one example right, so this example let us go through. Say calculate the safe load F that can be carried by the connection as shown in the figure below I will show the figure. HSFG bolts of 8.8 grade with a 20 mm diameter are used. Assume the thickness of bracket as 12 mm and column used is ISWB 350. Assume no slip is permitted and slip factor Mu has been given that is Mu f as 0.5. So all dimensions in figure are given in millimetre.

(Refer Slide Time: 14:36)



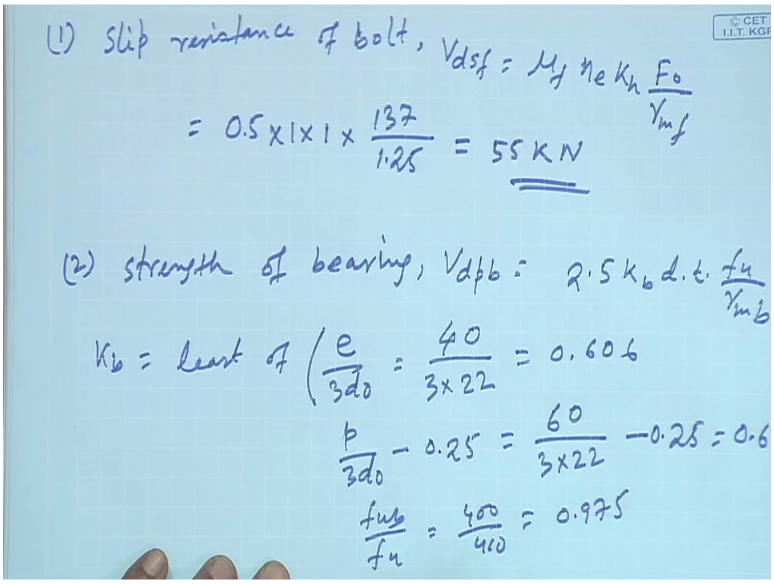


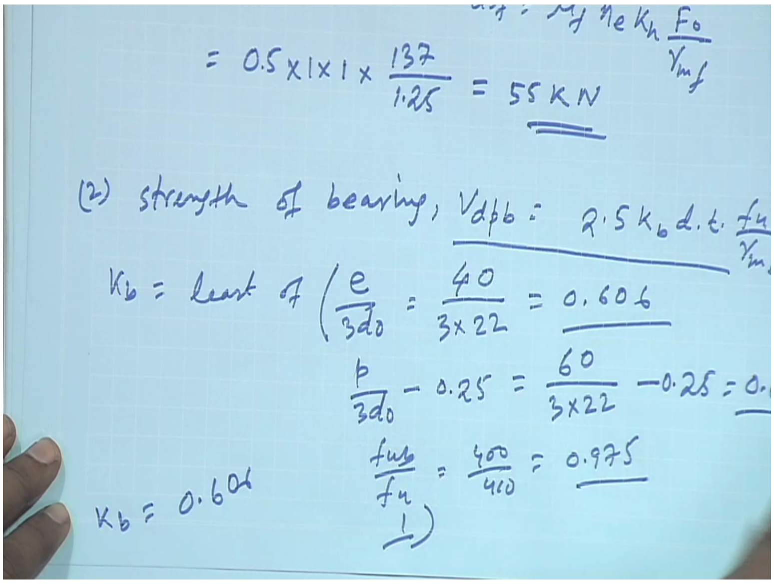
So if we try to solve this problem then it will be clear to us say in this problem the figure is given like this say it is a ISWB 350, is connected with a bracket and it has a force F this is F and it is situated at a distance of 180 millimetre. Now bolts are placed in this way six bolts are placed with a pitch distance of 60 mm and edge distance of 40 mm right. Say this is bolt number 1, this is bolt number 2 and this bracket thickness is 12 mm and this is ISWB 350 section.

Now here we are using HSFC bolt 8.8 grade bolt right and diameter of the bolt we are considering as 20 mm and Mu f was given as 0.5 mm. So if we want to solve this problem what will do will first try to find out proof load because this is a high strength friction bolt so due to friction we have to find out the load carrying capacity. So proof load we can find out F0 as Anb into 0.7 fub right.

So Anb we can find out as 0.78 into pi by 4 into d square, d is 20 mm into 0.7 into fub is 800 in this case right. So this will be 55 into 10 cube newton or 55 kilonewton, this is one. So proof load we can find out as 55 sorry this is coming 137 kilonewton, this is coming 137 kilo newton.

(Refer Slide Time: 17:33)



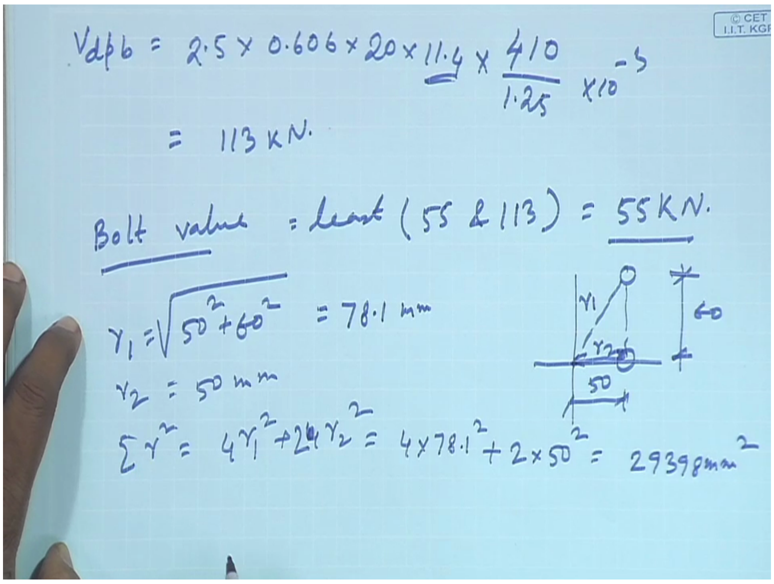


Now we have to find out the slip resistance so slip resistance of bolt can be find as Vdsf is equal to Mu f ne kn into F0 by gamma mf so this if we put the value Mu f is considered as 0.5 and if we assume this as 1 and F0 we have calculated as 137 kilonewton and gamma f is 1.25 considering shop bolt, so sorry gamma mf is 1.25 so if we consider then it will be 55 kilonewton.

So Vdsf value is becoming 55 kilo newton and strength of bolt in bearing because it it may fail due to bearing also so we have to find out the strength of bearing Vdpb that we can find out as 2.5 kb dt fu by gamma mb right. Now we have to find out the constant kb which will be least of e by 3d0 that means e in this case we have consider 40 mm and 3d0 d0 will be 22 so this is coming 0.606 and P by 3d0 minus 0.25 so that is coming P is considered 60 into by

3 into 22 minus 0.25 this is 0.66 and fub by fu is 400 by 410 that is 0.975 and 1. So list of these four 0.606, 0.66, 0.975 and 1 so kb value we can consider kb value we can consider as 0.606 so now we can find out the value of Vdpb.

(Refer Slide Time: 20:14)

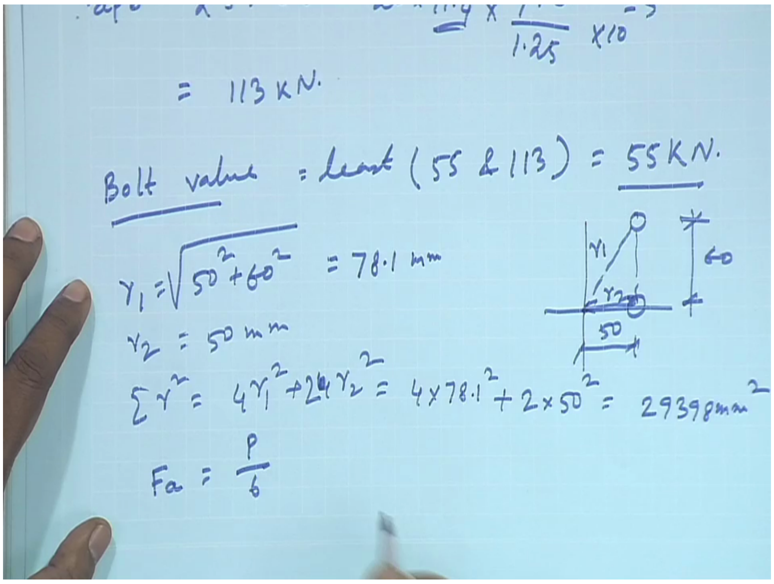


So Vdpb value if we calculate will get Vdpb as 2.5, kb is 0.606, d is 20, t is 11.4. This is 11.4 because the thickness of flange of ISWB 350 is 11.4 which is less than 12 so lesser of the two thickness that is lesser of the bracket plate and the column flange, column flange thickness is 11.4 and bracket thickness is 12 so list of these two we have taken as 11.4.

Now if we put this value we can get as 113 kilonewton. So bolt value we can find out as least of bearing and shearing, shearing is 55 and bearing is 113 so it will be 55 kilonewton right. So bolt value we could get now we have to find out what are the bolt reaction is coming due to external moment, external force and its moment. So here r1, r1 we can find out r1 will be r1 means if we see here this is one bolt, this is another bolt so if we consider this r1 r1 will be this distance square plus distance square and its square root.

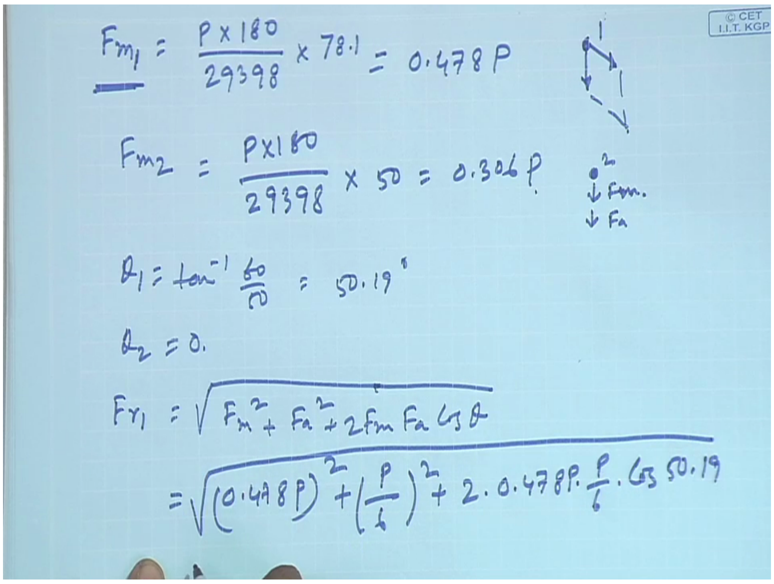
So this is 50 square plus 60 square of square root of this so this is 78.1 millimetre right 78.1 millimetre because this is 50 and this we have consider 60 right and r2 r2 will be this one r2 r2 will be simply 50 mm, so summation of square means summation of all r square will be 4r1 square plus 4r2 square so we can find out the value of this summation of r square sorry 4r1 square plus 2r2 square. So 2 into 50 square so this is becoming 29398 millimetre square right.

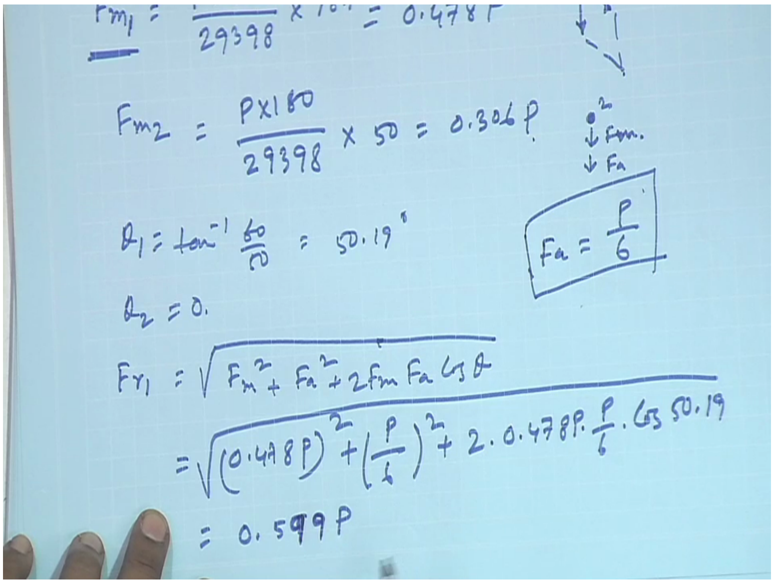
(Refer Slide Time: 23:01)



So now the force due to direct load in each bolt will be Fa is equal to P by 6 right.

(Refer Slide Time: 23:13)



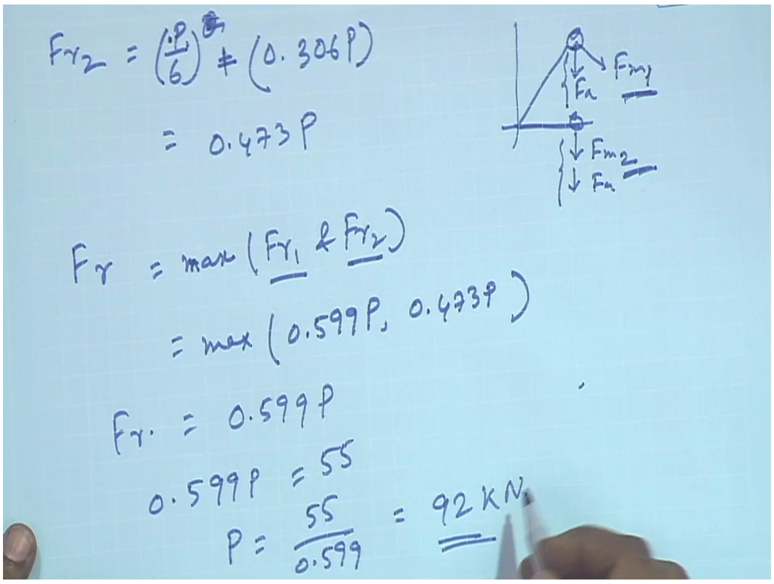


And force due to moment Fm1 will be P into e, e is 180 this is moment by summation r square that is 29398 into r r means 78.1. This is Fm1 means bolt number 1 which we had marked at the extreme end so that is coming 0.478P. Similarly Fm2 we can find out as P into 180 by that means m by summation r square into r 29398 into in this case r will be 50 so this will be 0.306P.

So here the bolt is this so we are providing in this direction one and in this direction another one so we have to find out the this is bolt number 1 and in this case for bolt 2 this will be Fm and this is Fa so we have to add it right, so here theta 1 will be 10 inverse 60 by 50 right so it is 50.19 degree and theta 2 will be 0. So Fr1 means resultant force on bolt 1 I can find out as Fm square plus Fa square plus 2FmFa cos theta right so if we put these values will get 0.478P square plus P by 6 square plus 2 into Fm is 0.478P into P by 6 into cos theta, cos 50.19 right.

So after calculation we can get this as 0.599P right 0.599P right here let me tell you that Fa we got assuming that all bolts are sharing equal loads Fa will got P by 6 because number of bolt bolt are 6 so load will be shared by shared as P by 6.

(Refer Slide Time: 26:24)



So now again Fr2 because we do not know whether in bolt 1 and bolt 2 will be maximum we do not know because here it is adding Fm and Fr is adding but Fm say 2 and here it is adding here (())(26:44) for means in the resultant it will be Fm1 and Fm.

This Fm1 and Fm2 is not same, this is more and this is less again here directly we can add but here we have to get resultant so without calculation we will not able to see means we will not be able to predict which one will be more so we have to find out Fr2 also. So Fr2 we can find out in this way that Fr2 we can find out that 1 by 6 1 by 6 P, P by 6 whole square plus P by 6 plus 0.306 we got P right.

So if we add these two will get 0.473P, so Fr value will be the maximum of means maximum force will be maximum of these two Fr1 and Fr2 so this will be if we calculate we have seen that after calculation these values are basically Fr1 was 0.599P and that is 0.473P, so this will be 0.599P Fr right. So now we can find out we can equate with the bolt value bolt value we have obtained as 55 kilonewton.

So 0.599P is equal to 55 we can equate and then we can find out P as 55 by 0.599 and this will become 92 kilonewton that means to withstand the load on this arrangement of bolt we need means we can apply maximum value of P as 92 kilonewton, 92 kilonewton at a distance of 170 mm, I think 170 no 180 mm at a distance of 180 mm we can provide this. So this is how if we know the distribution of bolt and the loading distribution then either we can find out the load considering the maximum capacity of bolt due to shearing and bearing or we can apply certain load and we can check whether the existing bolt in what way it is distributed are safe or not means if we provide certain load then we can check what is the load coming on these bolt or in the critical bolt what is the load coming and that load if it is more than the bolt strength then it is unsafe otherwise the bolt is safe.

So this is how in other way we can do either of the way we can do, either we can find out the critical load or we can find out whether the section is mentioned the connection group bolt connection group is safe or not. So in this way the calculation can be made when the eccentric connection in a sense that load is lying in the plane of connection if it is then I can find out the section whether it is adequate or not section means bolt group whatever it is being distributed is adequate or not, thank you very much.