Course on Design of Steel Structures
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Lecture 14
Module 3
Design of Eccentric Connection (Load Lying in Plane of Bolted Joint)

Today's lecture is a continuation of last lecture in last lecture we have discussed how to find out the strength of a bolt and what will be the critical bolt and what is the maximum load coming to a particular bolt when the load is lying in the plane of joint. So bolt arrangement first we have decided and we have found what are the total load is coming, total load means eccentric load then due to eccentricity what is the moment and what is the load in each bolt due to direct load and due to moment.

Then we found the resultant of the forces acting on different bolt we found the maximum load coming on a particular bolt then we see whether it is exceeding the design strength of that particular bolt or not. If it is exceeding we have to redesign means the bolt is not safe and if it is not exceeding then fine means it is safe but now today we will discuss that how to design a bolt group means you have been giving load then what should be the number of bolt. First we have to find out what should be a number of bolt then what will be the arrangement means how many lines of bolt we have given and how many bolt we have we will be giving in each line what will be the pitch distance, what will be the edge distance, what will be spacing means horizontal spacing. So all those things would be will have to be decided.

Now it is not easy to find out the number of bolt at the very beginning because number of bolt will be deciding on two factors one is due to direct load we can find out number of bolt is equal to direct load divided by means bolt strength but that bolt is going to be acted as also the moment so from moment of view also we have to calculate.

So that means the resultant we have to note unless we know the resultant force coming into particular bolt we will not be able to find out the design right so for doing that we have to go with certain trial and error basis means with certain trial with certain approximate calculation we have to find out what is the total number of bolt approximately required and then we will make an arrangement trial arrangement then we will see that whether with this particular number of bolt and with that arrangement whether the bolt will be safe or not that means the critical bolt strength is more than the critical bolt strength, critical bolt forces is more than the bolt strength or not.

If bolt forces are coming more than the strength then the design is unsafe so we have to rearrange the bolt group or we have to increase the number of bolt then we will find out right.

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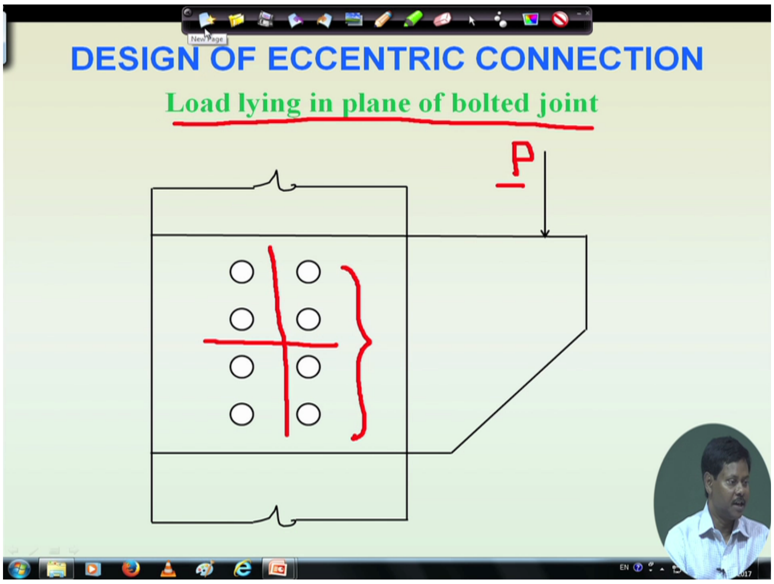

So if we see here that for this case we will decide load line in plane of bolted joint, so here say for example we have given say four bolt in each line and total number of bolt are 8 right. So with this if we have a value of P here then whether this is safe or not that we can find out from earlier lecture but we have the value of P then what will be the number of bolt that means whether 4 or 3 or 8 how do we decide that we will try to discuss.

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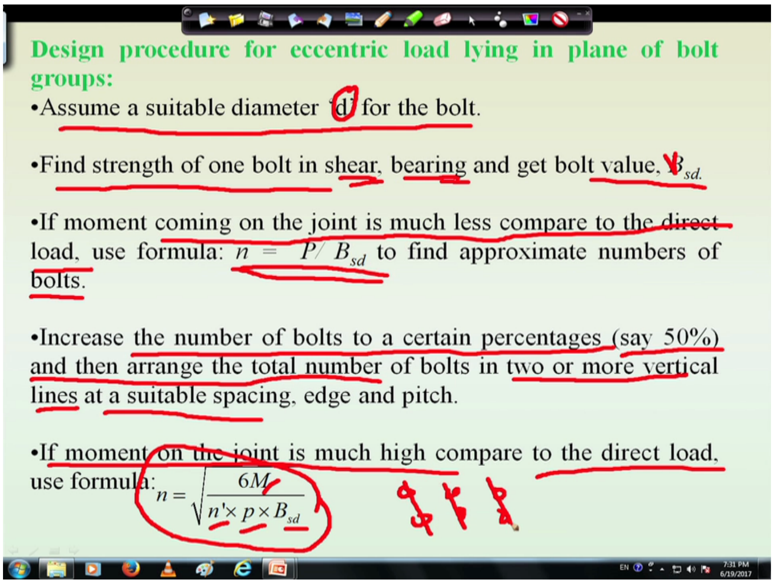

So first we will discuss about the design procedure then we will go through one example so that we will be able understand say design procedure if we see what will do first will assume a suitable diameter of bolt. We have to assume a suitable diameter of bolt depending on the availability or if if we want the lesser length of the joint then we have to make bigger diameter otherwise we can go for small diameter also it depends on the thickness of the member, so depending on that we will decide the diameter of bolt then next step is we find out the strength of one bolt in shear bearing and get bolt value Bsd or Vsd actually this will be Vsd right.

So we will find out the ok this is Vsd let us make Vsd is the bolt value correct so how do we find out this shear and bearing, this can be found whether it is double shear or single shear we have to know then in we have to find out whether it is HSFC bolt or whether it is bearing type bolt that we have to know then when we will be going for bearing stress we have to know what is the edge distance what is the pitch distance and accordingly we have to find out the kb, the constant value of kb then we have to find out the bearing strength right.

So for finding out the bearing strength we have to find out first the pitch and edge distance as well as the type of bolt whether it is bearing type or shearing type sorry friction type depending on that we will be able to calculate the strength of the bolt. Once it is calculated then we can use this formula, if P is the external load direct load then P by Vsd is equal to the number of bolt. So when will use this formula will use if moment coming on the joint is much less compare to the direct load that means if eccentricity is quite less and moment is coming therefore is less then we can use simply this n is equal to P by Bsd to find approximate number of bolts.

So approximate number of bolts we can find out from this equation that is P is n is equal to P by Bsd when the moment is comparatively much less than the direct load when moment will be less, if the eccentricity is less than moment will be less, then what will do will increase the number of bolts to a certain percentages that how much percentages say 50 percent or may be 100 percent may be 25 percent it depends on the designers experience.

From designer from that experience they can understand that how much percentage should be increased to make the total number of bolts and whether it is it will be in two or more vertical lines that will be also have to decided means in earlier lecture I have shown we had two vertical lines right so it may be two or more so with a suitable spacing we have to make. So we will increase the number of bolt with a certain percentage to find out the total number of bolt for checking the strength means strength of that bolt joint right.

And another case is if moment on the joint is much high compared to direct load that means if eccentricity is high then will not use the earlier formulae we will use this formula n is equal to 6M by n dash into P into Bsd right. So from moment equation we will try to find out that is n is equal to square root of 6M by n dash into P into Bsd where Bsd is the bolt strength and moment M is equal to P into V and this small P is the pitch distance and n dash is the number of vertical lines, n dash is the number of vertical lines means if we have bolt like this say like this if we have bolt. So in this case number of vertical lines are 1, 2, 3 so in this case it will be 3.

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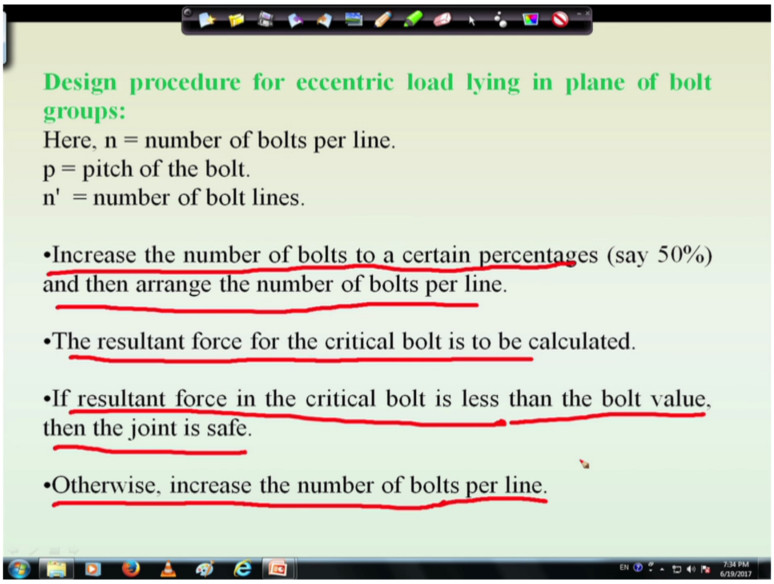

Then what will do we will increase the number of bolts to a certain percentages and then arrange the number of bolts per line. So in this case also similar thing will do that we will increase the number of bolts to a certain percentage again this depends means from the depends on the designers experience and also if if we see the eccentricity is much higher than the moment will be much more.

So in that case we have to take decision accordingly right so once we consider some approximate number of bolts will make the arrangements of bolts then will find out the resultant force for the critical bolt, we will have to calculate that means what we will do we will calculate the resultant force in different bolt. We will see in which bolt it may come more right if we cannot predict that then we have to calculate bolt to bolt means in each bolt we have to calculate or in few bolt we have to calculate because few bolts will be similar forces will be developed.

So we will calculate the resultant force in few bolts and will see what is the maximum force coming on that bolt then we will see the resultant force in the critical bolt is less than the bolt value or not if it is less than the bolt value then the joint is safe that means if the resultant force in the critical bolt is less than the bolt value then the joint is safe that means the arrangement whatever we have done is correct, the arrangement means in terms of number of bolts and in terms of arrangement means number of bolts, number of bolt line, pitch distance, edge distance and spacing between two bolt lines right.

So these arrangements are correct if it is not if the bolt value is coming sorry forces in bolt is coming more than the bolt value then we have to redesign that means we have to either increase the number of bolt or we have to rearrange the bolt in such a way that the reaction force on the bolt is coming less than the bolt strength. So if it is so what will do we will either increase the number of bolts per line or we will change the bolt orientation in different positions means either number of bolts per line will change or will change the spacing and edge distance and pitch and will check whether the critical bolt force is coming less than the bolt value in this way will design the entire process.

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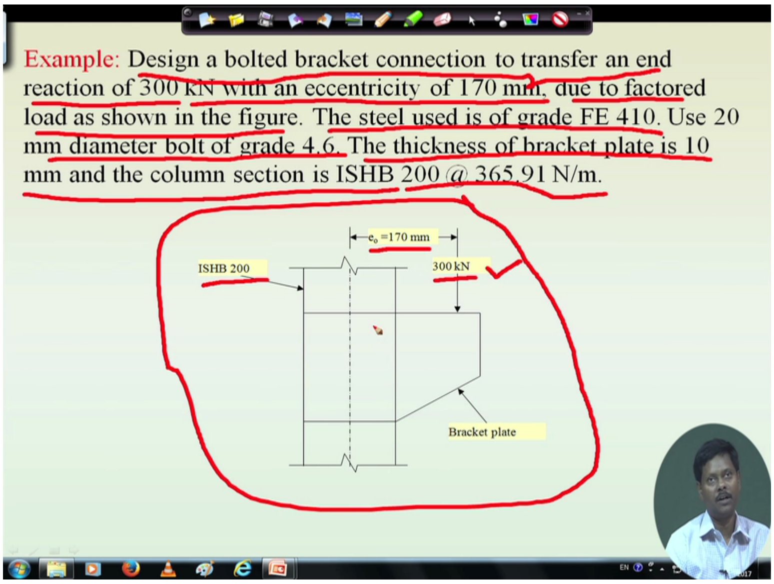

So this will be clear if we go through one example say let us go through this example right. So this example is that design a bolted bracket connection to transfer an end reaction of 300 kilonewton with an eccentricity of 170 millimetre due to factored load as shown in the figure right. Figure is shown here you can see the figure that is 300 load 300 kilonewton load is given and eccentricity is given 170 millimetre and the steel used is of grade of Fe410 and used 20 mm diameter of bolt of grade 4.6 that means bearing type of bolt and the thickness of bracket plate is 10 mm and the column section is ISHB 200 at 365.91 newton per meter.

So this is the example we will try to solve that means you have been given 300 kilonewton of load acting at a eccentricity of 170 millimetre and this load is acting on a bracket of 10 mm thick bracket and this bracket is connected with a ISHB 200 I section column right. So now we have to design a bearing type of bolt to withstand this 300 kilonewton, so we do not know how many bolts will be provided here and we do not know how many lines will be provided, bolt lines will be provided here we do not have anything. So we have to fast find out the approximate number and then we have to arrange with increase of certain number of bolts and then we have to check whether it is ok or not. So through this example we will learn how to do it ok.

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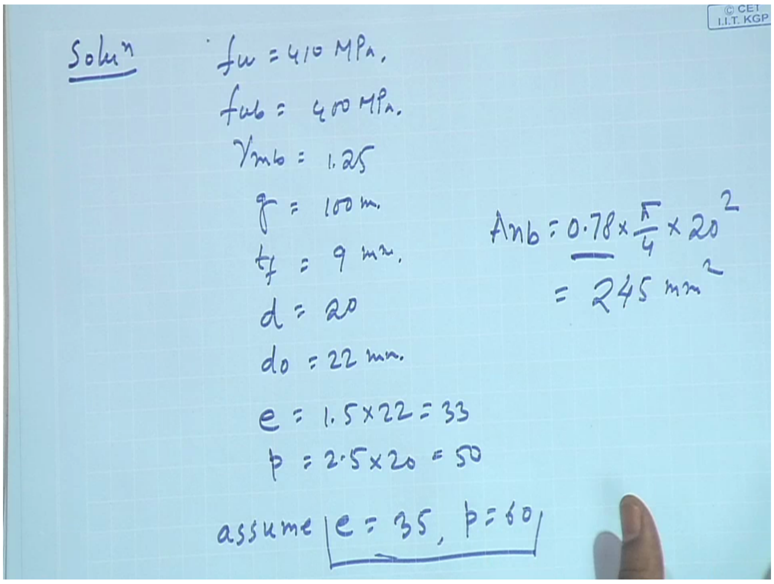

Now if we solve this problem let us see stage by stage what to do here we know that fu is given 410 MPa and fub is given 400 MPa, gamma mb we know 1.25 here gauge distance is 100 mm and thickness of flange of ISHB 200 thickness of flange is given as 9 mm right. Now diameter of bolt is given 20 mm so diameter of hole will be 22 mm as per table 19 and minimum edge distance will be 1.5 times d0 so it is coming 33 and maximum pitch distance sorry minimum pitch distance will be 2.5 into 20 so it is 50 mm.

So let us assume edge distance as 35 and pitch distance as 60, so we will assume that edge distance of 35 mm and pitch distance of 60 mm and assuming that shear plane is going through the threads so Anb we can find out that is 0.78 into pi by 4 into 20 square to be in safe side we will consider shear plane going through the threads unless it is mentioned we can consider this and this will be 245 millimeter square. So these are the some preliminary data we have to calculate for calculating a bolt value.

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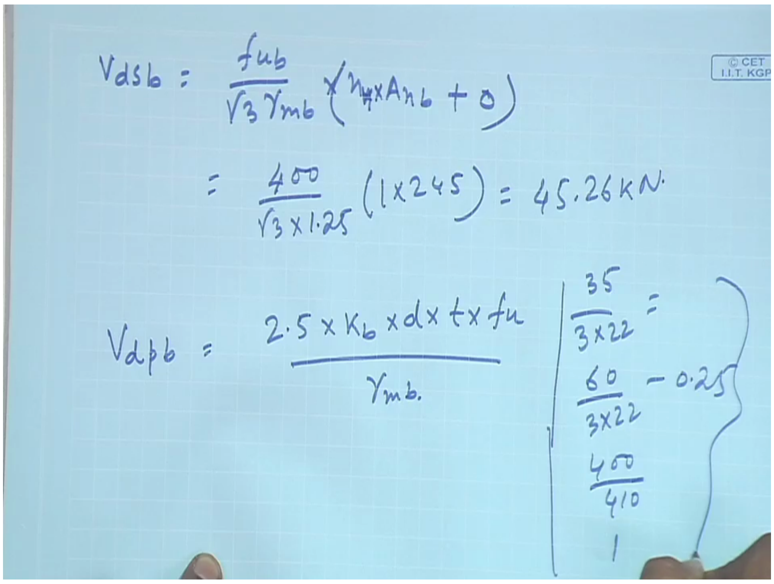

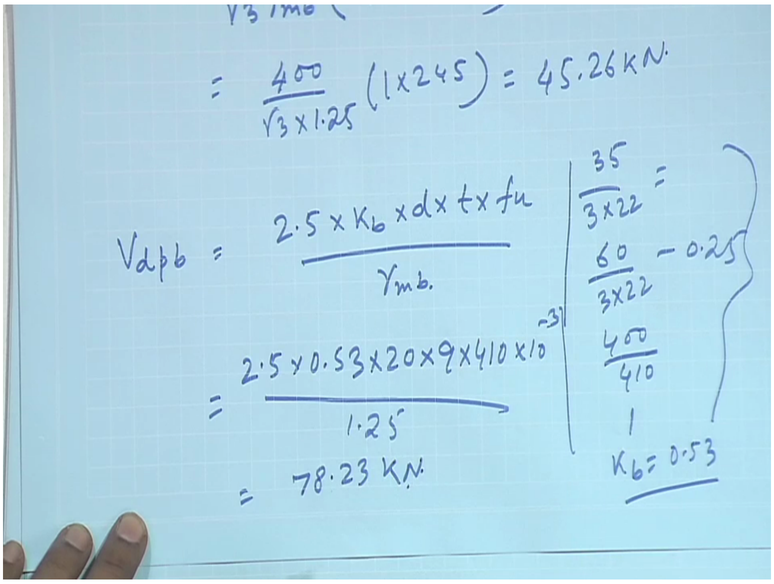

Now bolt value in single shear we can find out that is fub by root 3 gamma mb into nn into anb plus nx we can make zero right. So if we put those value we can find out the value of bolt means strength of bolt in single shear, so this is coming 45.26 kilonewton and strength of bolt in bearing Vdpb we can calculate 2.5 into kb into d into t into fu by gamma mb right.

So here kb will be basically e by 3d0 and then P by 3d0 minus 0.25 and fub by fu and 1, so least of this will become kb we will find out we can calculate that will be 0.53 right 0.53 kb value will come 0.53. So if we put those values then we can find out the value of bearing strength of the bolt so here d will be 20, t will be the thickness of the lesser one so that is 9 and fu is this. I can make into kilonewton so I can find out this value as 78.23 kilo newton right.

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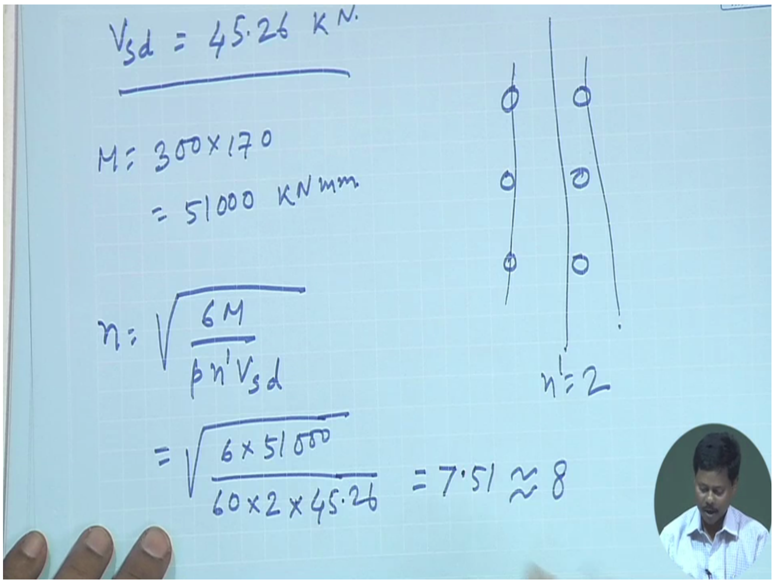

So Vsd value that means strength of bolt design strength of bolt Vsd will become lesser of these two Vdsb and Vdpb that is 45.26 and 78.23 so lesser of these will be be 45.26 kilonewton. So this is the value we got. Now we have now we have to design so we have to decide the number of bolt line so maybe we can start with two bolt line we can start, so if we do so then accordingly we can find out the value.

Now M value the moment due to eccentricity we can find out, this is P into e, e is 170 mm so 51000 kilonewton millimeter right so now number of bolts required so number of bolts we can find out from this moment formula 6M by P into n dash into Vsd. So here we have considered n is equal to 2 n dash that number of bolt lines we are considering 2 this is our assumptions right so if we put this value 6 into M 51000 kilonewton millimeter by P 60 into 2 into, so pitch we have considered 60 into 45.26 so if will calculate will get 7.51.

So we can assume that 8 number of bolts can be used but this is not sufficient because 8 number of bolts can withstand the moment only we have to withstand the direct load also so number of bolts we have to increase because the bolts will be exerted the force due to moment and due to direct force.

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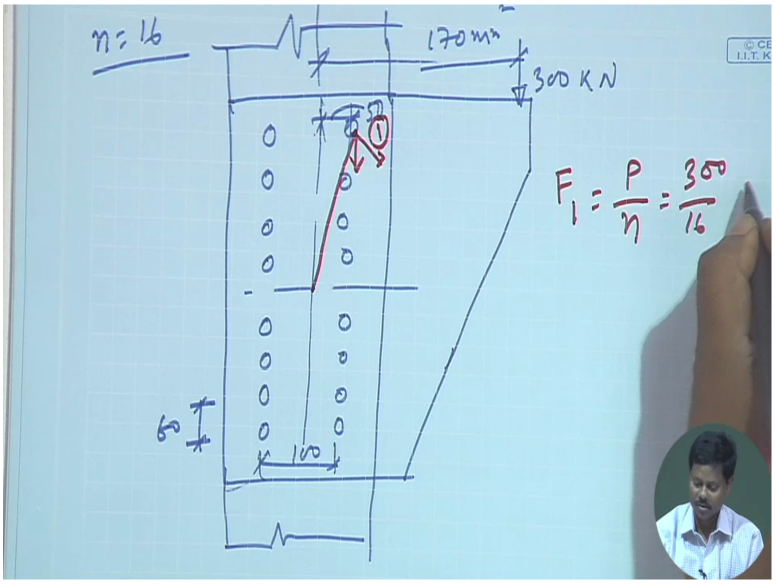

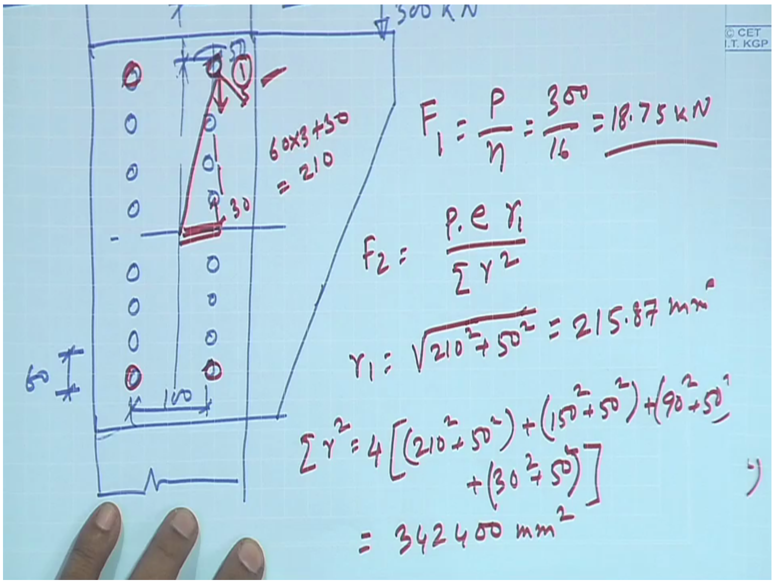

So we have to increase the number of bolts say for example this case we are increasing number of bolts up to say 16 that means in each row we can provide 8 bolts . If we make two bolt line then say total number of 16 bolts we can provide and we can see whether this bolt group this proposed bolt group is sufficient to take care the load or not right so this is 300 kilonewton and this is 170 millimetre right and this value will be gauge was 100 so this will be 50 mm, this is 100 mm right and we have considered this as 60 ok. So now we will find out the bolt value of the extreme one right of the extreme one we will find out because that will be the critical one.

So here we can see that F1 if this is number 1 bolt then F1 will be P by n right so here it is 300 by 16 so this is coming 18.75 kilonewton, this is F1 F1 is the load, force on the bolt due to direct load. And F2 we can find out that will be P into e that is moment into r by summation r square, r means r1 for this bolt number 1 bolt right like this bolt, this bolt, this bolt and this extreme four bolts will have same forces ok.

So now we have to find out r value, r1 will be here 210 square plus 50 square because this is 30, this 60, 60 and 60 so 60 into 3 plus 30. This is coming 210 and this is 50 right so after calculating we can get this value r1 as 215.87 millimeter. Similarly summation r square we can find out this will be four numbers each bolt will be so this will be 210 square plus 50 square for extreme four bolt then 150 square plus 50 square then 90 square plus 50 square then 30 square plus 50 square right 50 square.

So this is what summation r square will be so after calculating we can find out this summation r square was 342400 millimeter square ok.

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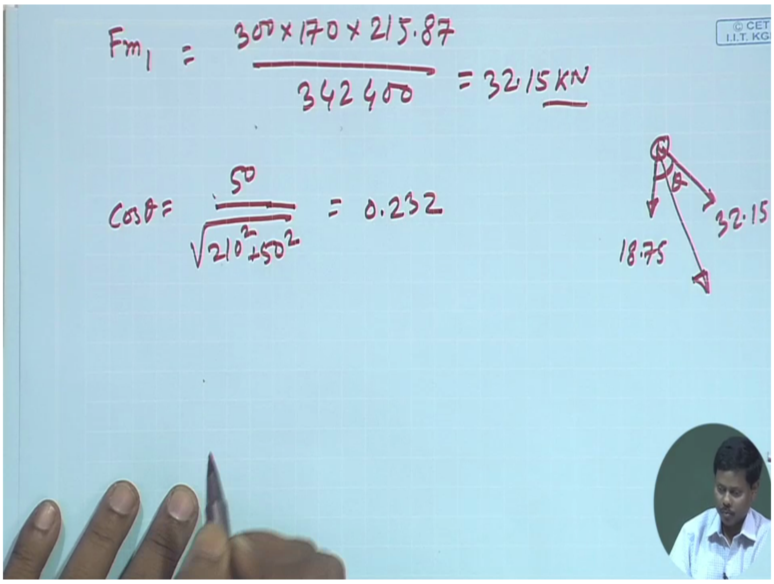

So once we find out now we can find out the value of F2 means Fm right so Fm at number 1 bolt will become 300 into 170 that is M, M into r r is 215.87 Mr by summation r square, summation r square will be 342400. So this is becoming 32.15 kilonewton so in number 1 bolt one load is coming of 18.75 kilonewton and another load due to moment is coming 32.15 kilonewton.

Now we have to make resultant resultant will be of these two forces acting at a angle of theta now this angle of theta we have to find out. Now here if we see cos theta will be will be horizontal distance 50 by vertical distance sorry radial distance radial distance will be 210 square plus 50 square so this will be 0.232.

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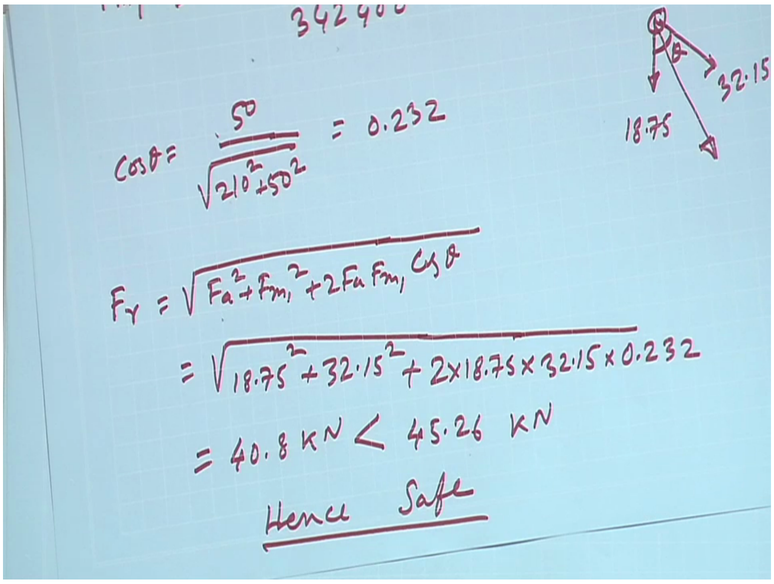

So resultant force say Fr will become Fa square plus Fm1 square plus 2FaFm1 cos theta is equal to you can put this value as Fa square is 18.75, Fm is 32.15 plus 2 into 18.75 into 32.15 into cos theta, cos theta value is 0.232.

So these value if we calculate we will get 40.8 kilonewton which is less than the strength of the bolt that is 45.26 kilonewton that means the connection is safe right, so this is how we can design a bolt group and we can find out the connection whether it is safe or not right so here you may see that we have checked with the extreme bolt, extreme one so that is because the extreme one in extreme one the maximum force due to moment will develop so that we have to make calculation and then we have to check.

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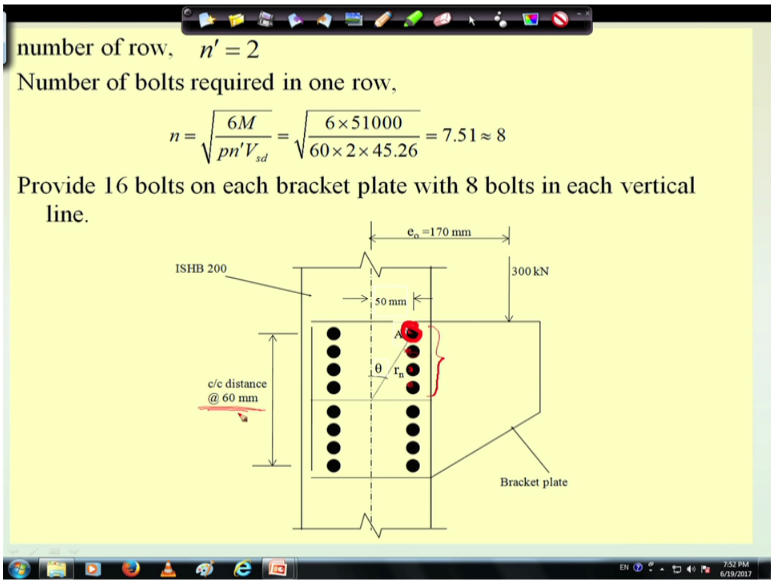

However we can check the another one also that means if we see I am showing you with the screen yeah the arrangement is something like this say this is the number 1 bolt so for this we are checking also we have to check for this and we have to check for this and we have to check for this right others will be same.

So if we check for this four and if we find out the critical one then we can see whether the proposed arrangement of bolt and proposed number whether it is ok or not right, this arrangement also can be changed little means to make use of Fm value as different means Fm value is coming here little more that can be reduced slightly if we change the this P P value suitably then also Fm value slightly will be reduced but always it is suggested that you cannot change much more so if the design strength of bolt is quite less than the force coming on the bolt then it is better to increase to increase the number of bolts in place of changing the pitch distance or edge distance or the spacing because it will not change much.

If it is slightly more means if the forces coming on the bolt is slightly more than the bolt strength then we may not increase the number of bolt in that case if you rearrange the bolt then you can get the value means you can make the design safe that is possible. So this is what we have discussed today to summarize once again let me conclude that design of a means bolt group due to eccentric load lying in the plane of joint can be done by trial and error method.

We can find out the approximate number of bolt either from force or from moment then we can increase a certain number of bolt on the basis on that approximate number and then we can arrange the bolt group means bolts in a particular way, once it is arranged then we have to check whether that bolts are means bolts are safe or not that means the forces on critical bolt is coming less than the less than the bolt strength or not. If it is not then we have to redesign we have to increase the number of bolt or we have to change the orientation means position of the bolts in terms of spacing and pitch and edge or if it is safe then we can stick to that connections right, thank you.