Design of Steel Structures
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Module - 3
Eccentric Connections
Lecture - 1
Eccentric Connections: Rivet Joints

Hello guys. Today, I will be starting another module that is eccentric connections. In last few lectures, we have discussed details about the fasteners, particularly the fasteners which are used for direct forces when it is coming. That means the forces when it is coming directly, the axial tension or compression vent is coming from beam to beam or column to column or beam to column then, how to join it; that we have discussed in details, for rivet connections, for bolt connection and for oil connection.

Today onwards we will discuss about the eccentric connection using those types of fasteners; that means the riveted connection, the bolt connections and the welded connections; only thing is here difference we will get that due to eccentricity of the load, the fasteners has to be met in such a way that it can carry not only the axial load but also the load due to eccentricity, load due to coming moment. Moment is developing due to its eccentricity, and that moment will develop some forces and some stresses in the rivet or in the weld or in the bolt. So, accordingly we have to design those things with those constants.

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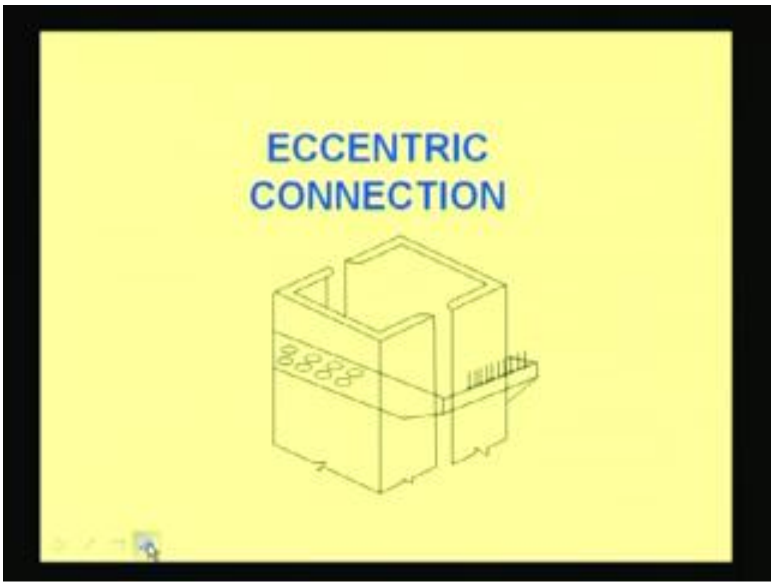

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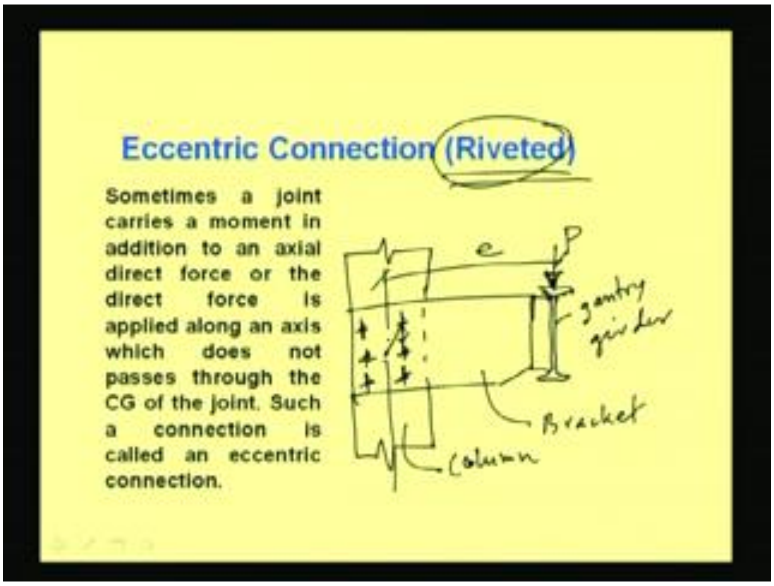

Today’s lecture, we will be focused on the eccentric connection using riveted joints. When the forces are not acting through the CG of the joint, then the eccentricity will appear. So, because of that eccentricity additional moment will come into picture, and because of that moment, the rivet will exert some forces and that additional force has to be taken care properly. Let us see how it develops; say one column it has to pass the load from the beam, say from the gantry girder.

Now the gantry girder is given here, and the load is acting in the gantry girder which has to pass to the column; this is column. So, this is the center line of the column. Now this is the bracket which has been joined. This is bracket; this has been joined by the rivet, and it has some eccentricity of, say e. Now this is gantry girder. So, what we have seeing here that a gantry girder is carrying a load of t with an eccentricity of e. So, the design has to be made in such a way that this load has to be carried by the joint, and it has to pass through the column.

So, this joint with riveted connection has to design in such a way that it can carry that much load without failure. So, these things we have to do. So, when we are having some eccentric load what we are seeing that we will be having some direct load, due to this some axial load and some load due to the eccentricity of the load. So, that we will how it is developing.

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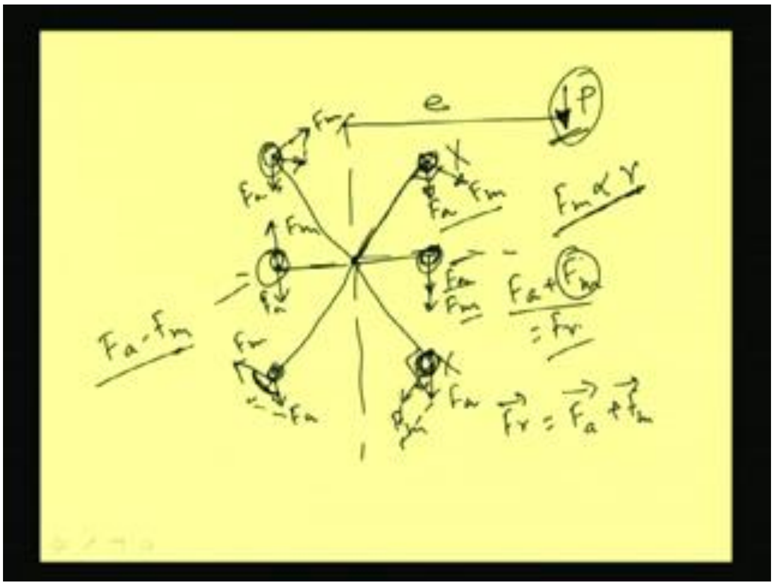

So, on a larger scale let us see how the forces are going to develop, say these are the some rivet group. So, six rivets are there let us assume, and let us assume that this is the center of the rivet group. Now the force p is acting here with an eccentricity e. So, this rivet will exert a force due to direct axial forces F a and due to eccentricity Fm due to moment, because of eccentricity of the load. So, this Fm will be basically acting 90 degree to this.

So, similarly for this rivet F a and F m will at downward, and in this rivet it will act like this F a. F a will always be downward, because p is always downward, and Fm will be 90 degree to this. So, accordingly it will develop. So, for this we will see F a and F m and for this, it will be F a F m. And for this it will be F a and F m. So, what we are saying that all the rivets are not coming same forces. The different rivets are exerting different magnitude of forces.

So, basically the magnitude of the force coming into each rivet will be depending on the geometry of the rivet group; that means how it has been placed and the direction of the force p. So, on that basis it will be decided like, say for this case we will see that force is coming F a and F m; means the total force will become F a and F m is equal to the resultant force F r. So, it is going to act, whereas in this rivet we will see it is become F a minus F m.

So, the force is going to reduce, whereas in this case force is going to increase. Again this F m depends on the distance of the rivet from the CG. F m generally varies with the distance between the CG and the rivet. So, naturally this rivet this corner rivets will exert more force due to moment because of more distance; r is more. So, in this case also, say for this rivet, the resultant force will be like this. So, F r will be becoming basically F a plus F m.

So, again this theta is depending upon the position of the rivet groups. So, theta is going to change. Here you see it is becoming less. This theta is going to become more. So, resultant will become less. And here also theta is becoming more. So, resultant will be this is the resultant; resultant will be less. So, we will see for these particular cases, this rivet and this rivet are going to exert more forces. So, we have to calculate accordingly and we have to see which one this how much load is coming into those type of rivets. So, how to calculate the resultant forces let us see.

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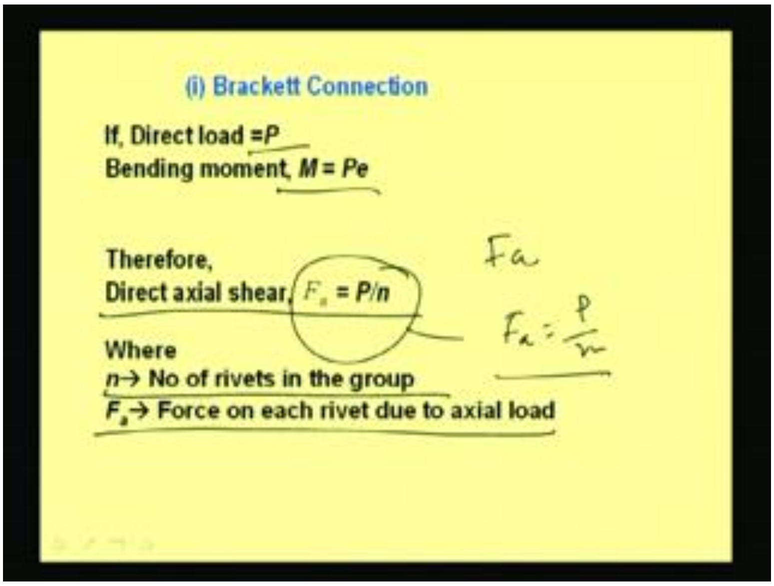

Say, if the direct load if P, then the bending moment we can calculate as M is equal to P into e. And direct axial shear on the rivet will become P by n, where n is the number of rivet group and F a is the force on each rivet due to axial load. So, F a whatever we have shown earlier is the force on each rivet due to axial load and n is the number of rivets in the group. So, in this way we can find out the direct axial force axial shear which is called F a that can be found out. So, this is one, and now we have to find out M a.

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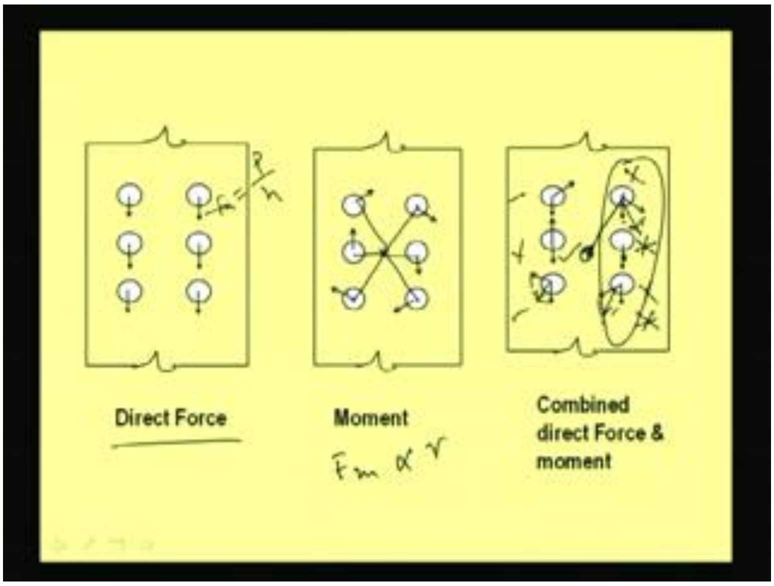

So, before going to M a let us see what I was telling the direct force always is coming F a. This is basically F a which is basically P by n; n is the number of rivets. In this case these numbers of rivets are six. And moment is developing like this if the center is here. So, it will be with 90 degree it will be like this; what I have shown earlier slides. And the combined force will be becoming like this.

Now you see that resultant force will be this one for this rivet. And for this rivet, this resultant force will be this one F r. So, similarly for this rivet, resultant force will be this side. So, from this it is clearly understood that the rivet is going to exert more forces in this and in this rivet, not in this. These two rivets will not be going to exert more forces, also this one. This is just F a minus F m. So, this is not also going to exert more forces.

So, these three rivets are critical. So, depending upon the magnitude of the Fm and depending upon the geometrical position of the rivet groups, we have to decide whether these rivets, say extending more forces or these rivets are exerting more forces. So, we have to calculate and we have to make it; as I was telling that F m basically varies with r, where r is the distance between the CG of the rivet group to the particular CG.

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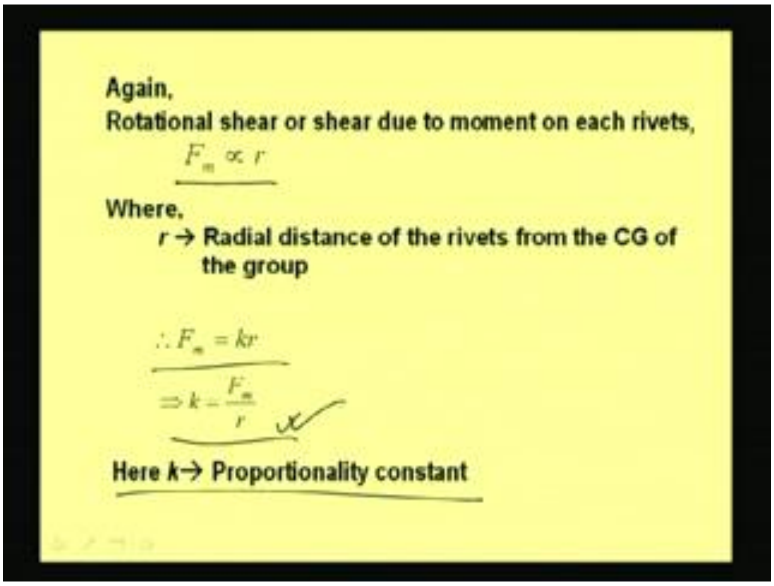

So, we can write Fm varies r, where r is the radial distance of the rivets from CG of the group. So, we can write F m is equal to k r. Thus k can be found out from this equation that is k is equal to F m by r, where k is the proportionality constant. So, from this we can find out k value and then again we can find out the F m. So, how we will find out?

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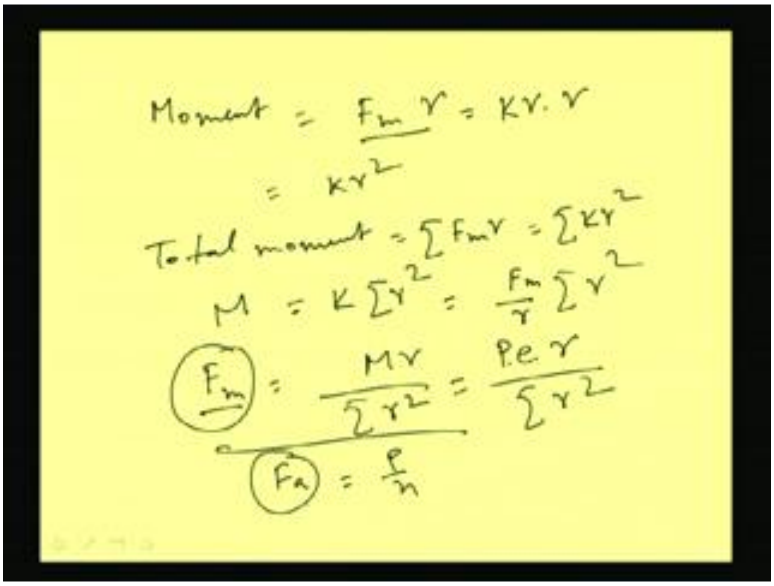

Moment we are getting will be F m into r. That moment exerted on the rivet will be Fm into r. So, F m is nothing but k into r the as we have seen earlier and into r. So, this will become k r square. So, total moment; total moment means total moment on the rivet which is exerting. So, total moment will be summation of F m into r, so summation of k r square. That means k is a constant; so k into summation r square.

So, moment M can be written as k into summation r square. That means k again can be written as F m by r. So, this can be written like this. So, from this we can write in other way that F m is nothing but M r by summation of r square. F m is the force due to the moment exerting on a particular rivet. So, that we have to we can calculate in this way. So, this also can be written as basically M is nothing but P into e. So, P into e into r by summation of r square, right.

So, in this way you can find out the values. So, F m we know and F a we obviously know that is P by n. So, from this F m and F a, we can find out the resultant force. Resultant force will depend on the angle between these two forces. So, that can be found out.

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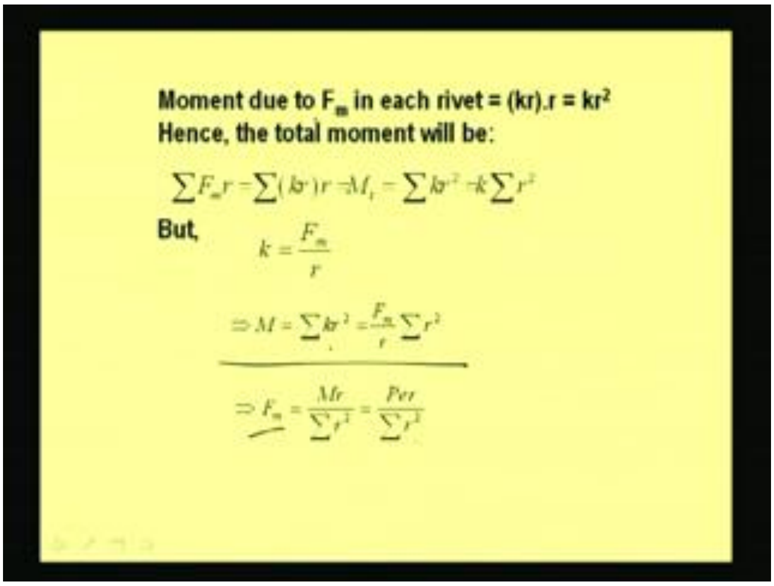

So, what we have done here that fast moment we have calculated; means moment we have calculated from this formula that is M is equal to summation k r square where F m by r is nothing but the k and summation r square. Thus we are finding out the F m value as this.

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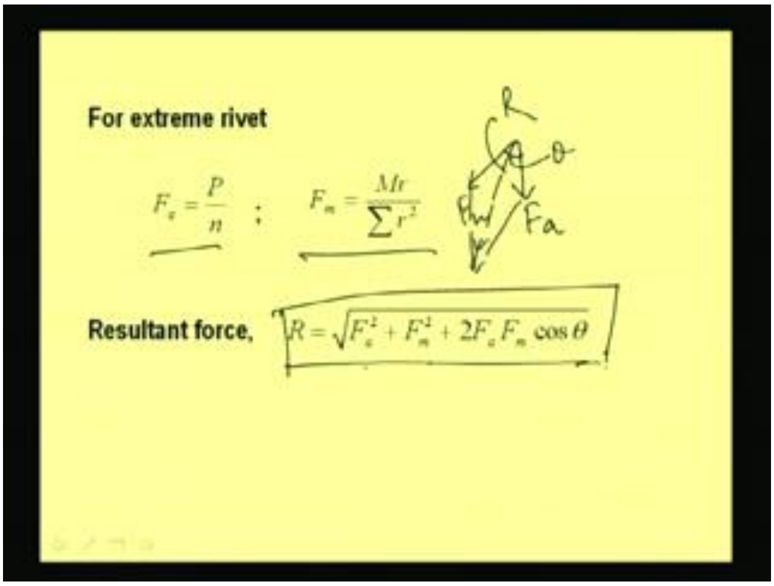

And we know this F a is this one and F m is this one. So, resultant force can be found out in this way because if this is F a and if this is F m and if this is theta, then the resultant force will be becoming in this way. So, this is called r. So, resultant force will become square root of F a square plus F m square plus 2 F a F m cos theta. So, in this way the resultant force on a rivet can be calculated.

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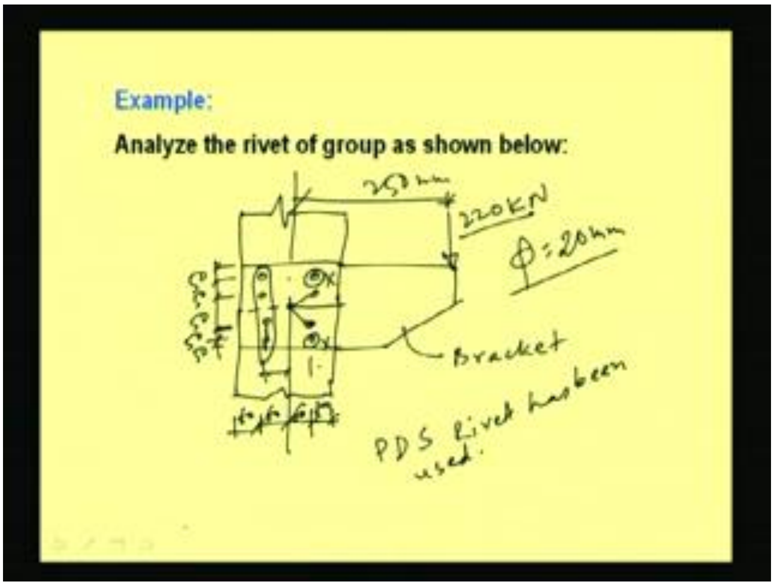

Now whatever I have discussed will be clear if I go through this example. Example is that to analyze a rivet group as shown below. So, let us draw the rivet group first, then we will see how we are going to find out the rivet value and how we will be checking whether the disjoint set is safe or not under this particular load. So, this is the, say column which has to carry the load through connections; say this is the bracket.

Now load is 220 kiloNewton with having some eccentricity of, say 250 millimeter. So, eccentricity is 250 millimeter, load is 220 kiloNewton, and rivets are given in this way. So, this is the center CG. So, the rivets are placed in this way. That is, say all pitch distance and edge distance are all 50, say let us assume. So, this edge distance is 50 and pitch distance also are 50. And this is the distance, this is 60 and 60. This is also 60, and, say this is also 60. So, in this way the rivets are placed, right.

Now, say assume that power driven shaft rivet has been used. And, say diameters of the rivet that is, say assume 20 mm. So, these are the problem we have to analyze. That means let me summarize once again; that a bracket connection is there with 8 rivet. Rivet diameter is 20 mm which is power driven shaft rivet, and the rivets are placed in such a way that pitch distance is 50 and edge distance also 50, and this distance is 60 and 60. And it is carrying a 220 kiloNewton load with an eccentricity of 250 millimeter.

Now we have to analyze this. Analyze this means we have to see whether the rivet is able to carry this much of load or not, whether the rivet is going to fail or not. So, what we will see here that because of its position, this rivet and this rivet will be exerting maximum force because this is less. Distance is less. So, F m will be becoming less. And in this direction rivet, the Fm will be to some extent opposite direction to the F a. So, the resultant forces on this rivet group will be less because it is going to make opposite.

So, only we will check whether this extreme rivets are going to take this much load or not. So, to work out this example, what we will do first? First, we will find out the bending moment what is coming due to this eccentric load.

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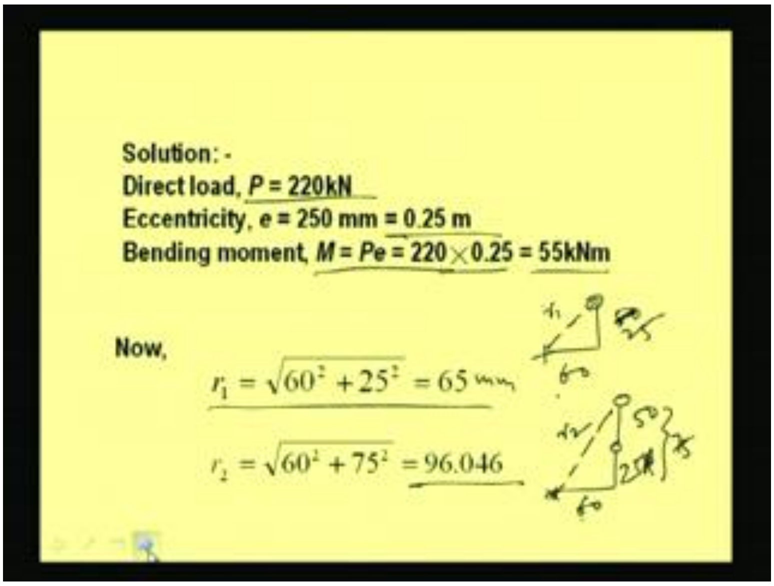

That is we know the direct load which has been given that is 220 kiloNewton, and eccentricity is given 250 millimeter or 0.25 meter. So, bending moment can be calculated as M is equal to P e is equal to 55 kiloNewton meter. Now summation r square we have to make. So, summation r square means first we have to find out the r. So, first r we will find out this one, this rivet.

So, for this we will see if the rivet is there and if the CG is here. So, we have seen that this is 50 and this is 60. So, the r 1 value can be calculated from this root over 60 square plus 25 square which is coming 65 mm. Similarly, the extreme fiber rivet; that means this rivet that can be calculated. So, extreme fiber rivet is somewhere here. So, this is the CG this is 25, and this is 50. This is also 25. So, this will come to r 2 as root over 60 square plus this is 75. So, 60 square plus 75 square which is coming as this. So, r 1 and r 2 we could find out. Now we can find out the summation r square.

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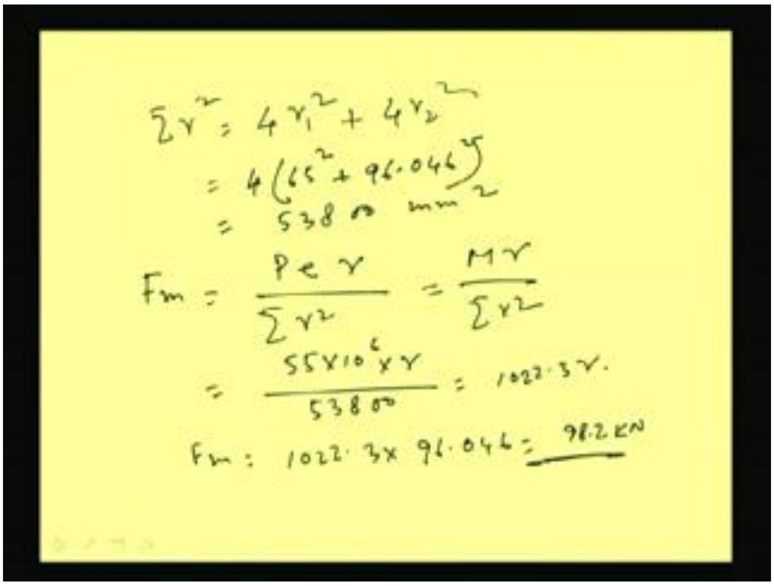

The summation r square will become 4 into r 1 square plus 4 into r 2 square, because 4 r 1 square means if this is r 1; this is also r 1; this is also r 1, and this will be also r 1. So, 4 into r 1 square; similarly, this is r 2; this is r 2; this is r 2, and this is r 2. So, 4 into r 1 square plus 4 into r 2 square. So, this will become 4 into r 1 square means 65 square plus r 2 square means it is given 96.046 square. So, this is coming 53800 millimeter square.

Now we have to find out F m, the forces exerting on the rivet due to moment. So, that is nothing but p into e into r by r square. So, that means p means M r by summation r square; that means M is calculated 55 kiloNewton meter. So, 55 into 10 to the 6 Newton millimeter into r by summation r square is 53800. So, this is coming 1022.3r.

Now as we have told that maximum force will develop at the extreme position of the rivet as you have shown; so F m will become 1022.3 into r means we will take 96.046. So, this will become 98.2 kiloNewton. So, this is the force which is developing in the extreme rivet due to the moment.

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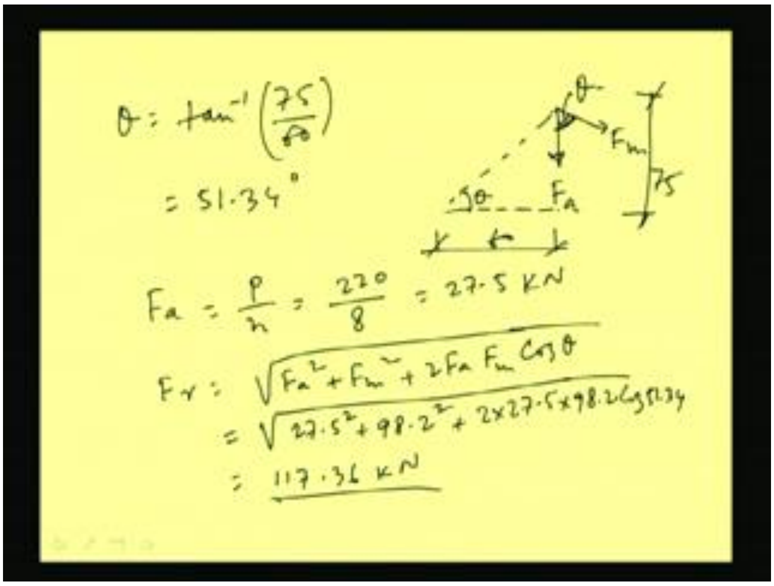

Now we have to see what is the angle between the F a and F m because F a is this one F m. So, we have see what is the angle this theta. So, that also we can find out because if I see this is the theta which will become this one. So, this theta can be found out; this is the distance which was given as 60, and this is the distance which was given as 75. So, theta can be found out from this which is coming 51.34 degree.

Now axial force we have to find out; F a is nothing but P by n. So, P is 220 kiloNewton by n is total number of rivets are given as 8. So, this is coming 27.5 kiloNewton. So, now we can find out Fr which is nothing but F a square plus F m square plus 2 F a F m cos theta. So, this will come 27.5 square plus F m is 98.2 square plus 2 into 27.5 into 98.2 into cos theta 51.34.

So, from this we can find out this value as 117.36 kiloNewton. So, this is the value we are going to find out in the extreme rivet. The resultant force in the rivet at the extreme position is 117.36 kiloNewton. Now we have to see what is the rivet value of a particular rivet? So, that also we can find out.

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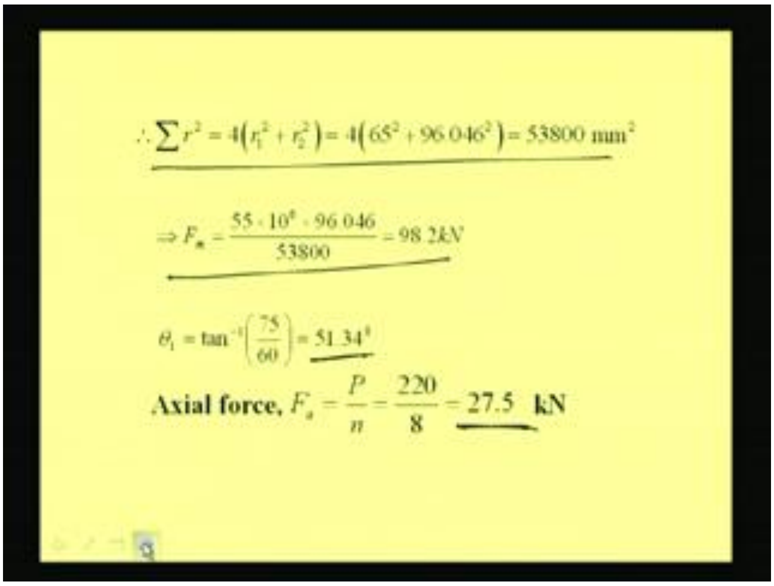

So, what we have done? That summation r square we have found first, then we have found F m. Then we have found again F a and the angle between F m and F a.

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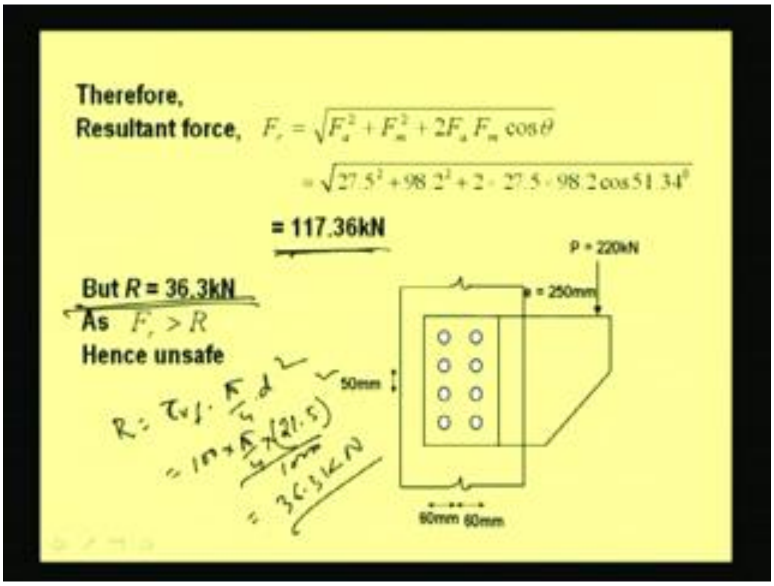

Then we found out the resultant force 117.36 kiloNewton. Now again the rivet value can be found out rivet value which will be basically tau v f into pi by 4 d square. So, for power driven shaft tau v f value will be 100 into pi by 4 into d square; that means 20 mm diameter rivet we have used. So, 21.5 mm will be the gross diameter. So, this will become this one by 1000 kiloNewton if you make. So, 36.3 kiloNewton. So, this is the rivet value. That means rivet value we are going to get 36.3 kiloNewton.

And the resultant force in rivet we are going to get 117.36 kiloNewton. That means this joint is unsafe under this load. So, in this way we can find out whether the joint is unsafe or not, whether the joint can carry this much load or not. Those things we can analyze and we can find out. So, in this way we can make it.

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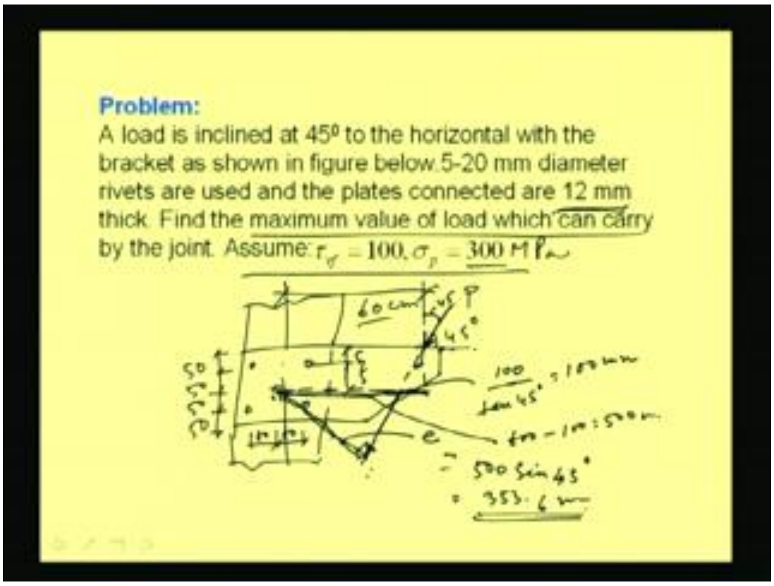

Another problem we will do through which we will be understanding how the load direction is going to change the calculation and how this direction of load is effecting on the rivet drop. Say the problem is given like this; say a load is inclined at 45 degree to the horizontal with the bracket as shown in figure below. Figure I am going to draw.

Now 520 mm diameter means five number of rivets with having 20 mm diameter are used and the plates connected are 12 mm thick. So, plate thickness is 12 mm. Find the maximum value of load which can carry by the joint. Assume tau v f as 100 and sigma P as 300 Mpa. So, now let me draw the joint, then we will be able to understand what we have to do

Say, this is the bracket. Now the load is acting at a 45 degree angle its P. Again the rivets are given in this way and the distance is given pitch distance and edge distance is all equal which has given as 5 centimeter each. That is 50 mm, 50 mm, 50 mm, 50 mm, and similarly this also has been given as 60 mm. This is 60 and this is also 60. So, these are given, and the eccentricity of the load is given as 60 centimeter; that means 600 mm.

So, we have five rivets of 20 mm diameter each, and the pitch distance and edge distance has been given which is 50 in vertical direction and 60 in horizontal direction. The eccentricity of load is 60 in centimeter. And the load is acting at a 45 degree angle with the horizontal base. And the tau v f whereas the shear stress allowable shear stress is 100 Mpa and sigma P the bearing stress is 300 Mpa which has been given.

Now we have to find out the maximum value of load which can carry the maximum value of the load. So, what we have to do? We have to find out maximum load in which rivet is coming. The rivet which is carrying the maximum load that we have to find out, then we have to make it equalize, right, and rivet value we know. We can find out the rivet value. We can find out the maximum force in terms of P which is coming to a particular rivet and in which rivet it is coming; that also we can find out. Then we can make it equal, and then we can find out the values, right.

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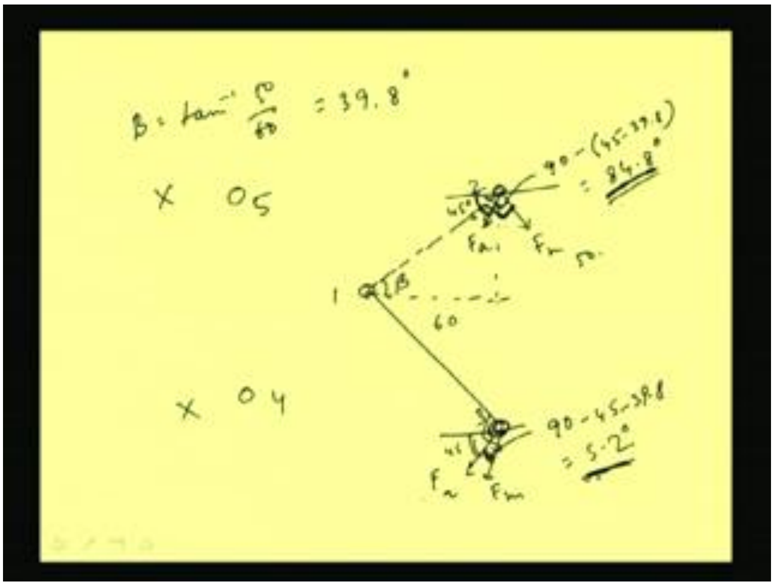

So, now to start with say let us make in a larger scale the rivet, so we will be able to understand. Say, this is one rivet, this is another rivet, rivet, rivet, and let us make it some numbering. Say, this is one, this is two, this is three, this is four, and this is five. Now, say first let us try to analyze this rivet. Now F a will be in this direction; that means with horizontal it is 45 degree angle, right.

This will be F a, and now I have to find out F m. Fm will be in this direction with a 90 degree angle to this F m. So, I have to find out this theta. This angle I have to find out. So, before going to find out this angle, okay, this angle let us find out, say this is 45 degree, and this is 90 degree. So, we can find out the angle. Now this angle is we can find out now, okay. This angle will be this is 6; that means 60 mm, and this is 50 mm.

So, beta will be, say this angle if I consider this is as beta, then beta will be tan inverse 50 by 60. So, this will come 39.8 degree, right. So, this angle is 39.8 degree, and this total is 45 degree. So, this angle will be this will be 45 minus 39 degrees. And similarly, this angle will become if I make this angle, this will be becoming 45 minus 39.8. Sorry, this will be 90 minus 45 minus 39.8 degree.

So, this is becoming 84.8 degree. So, this angle we have to find out; this is one. So, now what else I have to find out F a and F m, okay. To find out F a and F m; so F a and F m we can find out. Before that I have to find out what is the distance. Distance means see this inclined load. So, either we have to make the two component, one is vertical and another is horizontal. In this way, we can make and we can calculate; otherwise, let us find out the perpendicular distance between the CG and the load, load with a perpendicular distance

So, this we can make as e. So, this distance we have to find out. To find out this distance first, let us find out, say this distance; say this is 45 degree angle. So, this will become 45 degree. So, this length I can find out as 10 by 10 by 10 tan 45, right, because this is 10 mm. This is 5, and this is 5. So, this is 5, and this is 5, so 10 centimeter. That means 100 by tan 45. So, this is coming 100 mm. So, the rest distance this will become 600 minus 100. So, this will become 500 mm.

Now this is 90 degree. So, from this triangular, we can find out the value of this e. So, e will become basically 500 sin 45 degree. So, this is becoming 353.6 mm. So, in this way, the e value you could find out. E value means the perpendicular distance between CG and the load acting to this, so this distance. So, this can be found out the as 353.6 mm. So, this is one thing we need to know because you have to calculate the F m, okay.

Now another thing is for this rivet group because I know this rivet group is not dangerous, this rivet group is not dangerous compared to the two and three. And rivet one will not exert any moment. So, only F a will come. So, we will be focusing on two and three. So, in case of two, we are saying that the angle between these two forces F a and F m is coming 84.8 degree.

Now let us see for this group for rivet three. So, what will happen? Say, this is one thing. Say, this is F a, and this is F m. This is 90, and this is 45, right. Now I have to find out this angle, okay. So, this angle if we see this will become, finally, 90 minus 45 minus 39.8. So, this is coming 5.2, because total is 90, then minus 45 and 39.8. So, then I will get this value as 5.2 degree.

So, this is another aspect we have to know. So, from this we can easily tell that the angle between these two is less compared to rivet two. So, rivet three is the most affected rivet. So, if we take the value of rivet three, then we will be able to find the safe value of the joint, because in rivet two, the angle is 84.8 degree, and rivet three angle is 5.2. Lesser the angle between two load will become more resultant. Because f r is basically root over F a square plus F m square plus 2 F a F m cos theta. Now cos theta will be 1 if theta is 0;

so here if theta is less cos theta will be more. So, in this way was can find out. Now let us find out the value of F a and F m.

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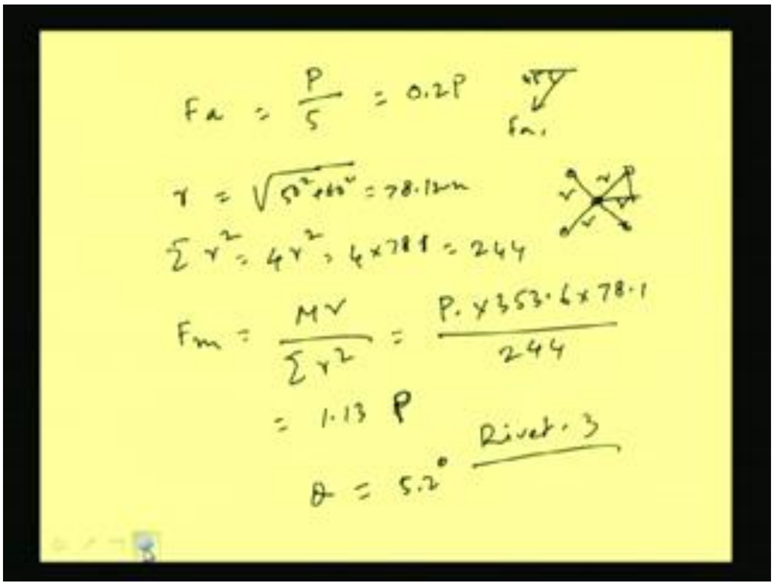

Say, F a we can find out as P by 5 because five numbers of rivets are there. So, this is basically 0.2 P. And this direction will be 45 degree to the angle. This is 45 degree, and this is F a, okay. And F m can be found out, okay. Before going to find out F m, let us find out r, r in the extreme rivet; means four corner rivets. That will become basically because this will be the r if rivets are there. So, this is r. This is the r. R will be basically this plus this square.

So, 50 square plus 60 square. So, this is coming 78.1 mm. So, now summation r square you can find out; that will become basically 4 r square. That means 4 into 78.1. So, this will become 244, right. So, this four, then now we can find out the stresses. So, F m is nothing but M r by summation r square. So, this can be found out. So, M means P into e.

E is nothing but 353.6 into r. R is 78.1 by 244. So, we can find out from this as 1.13 P and most affected rivet will be the rivet three. Rivet three will be most affected, where the theta between F m and F m is 5.2 degree.

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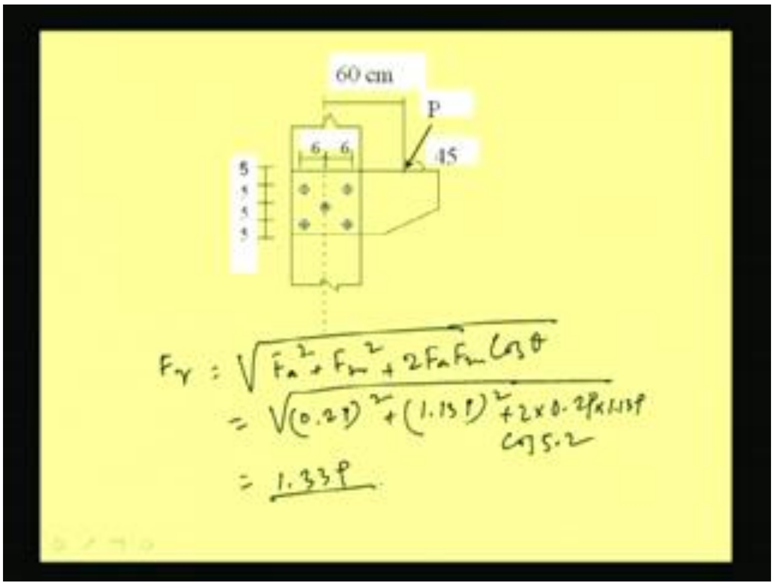

So, in this way we can find out the values say F r. F r will be F a square plus F m square plus 2 F a F m cos theta. So, this will become 0.2 P plus 1.13 P is the F m plus into cos theta 5.2. So, from this we are going to get 1.33 P. So, F r we are going to get as 1.33 P. Now what we will find out? Now we have to find out rivet value. So, rivet value can be found out, okay. Let us find out now rivet value.

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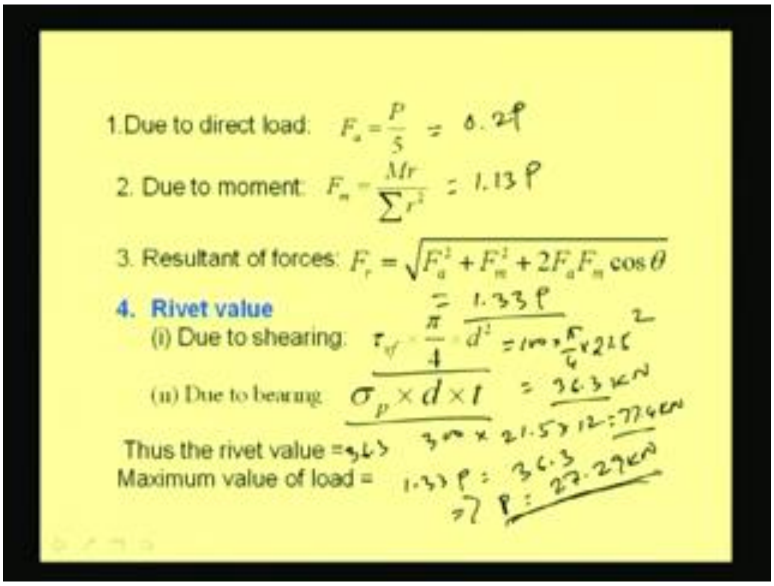

So, F a we are going to get 0.2 P, F m we are going to get 1.13 P and F r we are going to get the resultant force in terms of P as 1.33 P. Now due to shearing, the rivet value will become tau v f into pi by 4 into d square; that means 100 into pi by 4 into 21.5 square. So, this will become 36.3 kilometer. Similarly, due to bearing, this value will become 300 into 21.5 is the diameter, and thickness is 12 mm near to 77.4 kiloNewton.

So, we can find out rivet value as lesser value of these two. That means the rivet value will become 36.3 kiloNewton. So, to find out the maximum value of load, we have to find out that this rivet value will be becoming this r. That means 1.33 P will become 36.3.

So, from this the value of P can be found out which is coming 27.29 kiloNewton. So, the maximum value of the load which can carry by the joint is 27.29 kiloNewton. And the worst effected rivet is rivet number three as per our the dimension whatever it has been given; as per that the rivet three is becoming the worst effected rivet and that can carry 27.29 kiloNewton load on that joint, right.

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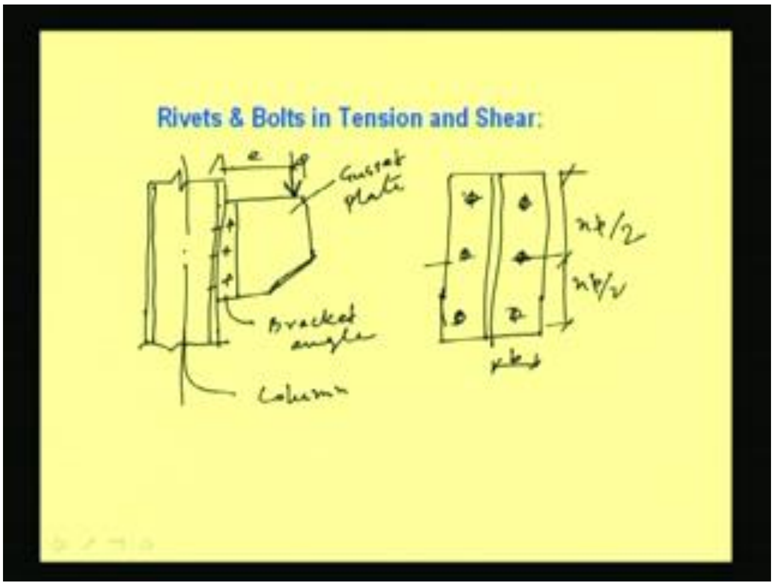

So, now we will be going to discuss about the rivets and bolts in tension and shear; that means tension as well as shear is going to be applied here. So, if the moment is not applied in the plane of rivet, in that case generally this happens. So, let us see how it looks like. So, if this is the column and this is the bracket and say this is the rivet which has been left, right.

Now this is the bracket angle. This is column. So, if force P is applied and e will be this one; that means if the moment is not applied in the plane of rivet, if the force is applied in such a way that it is not in the plane of rivet. So, in this case the moment will be P into e. So, if I see in this way, this is the gusset plate. The plan if I am going to see, this will look like this. So, these are the rivets or bolts whatever we can say and, this is the width. So, this is called n into P where n is the number of rivets in a line n P by 2, this is n P by 2.

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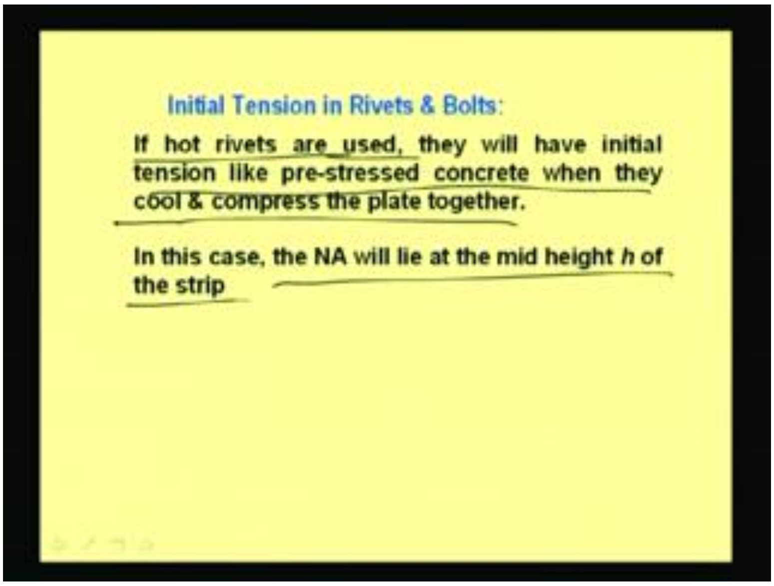

So, there are two type of case it can happen in case of rivet and bolts. One is the initial tension in rivets and bolts. Initial tension when it will come? When watt rivets are used. Power driven hot shaft rivets are used, then initial tension will come. Basically, they will have initial tensions like pre-stressed concrete when they cool and compress the plate together. So, in this case the neutral axis lie at the mid height of the strip.

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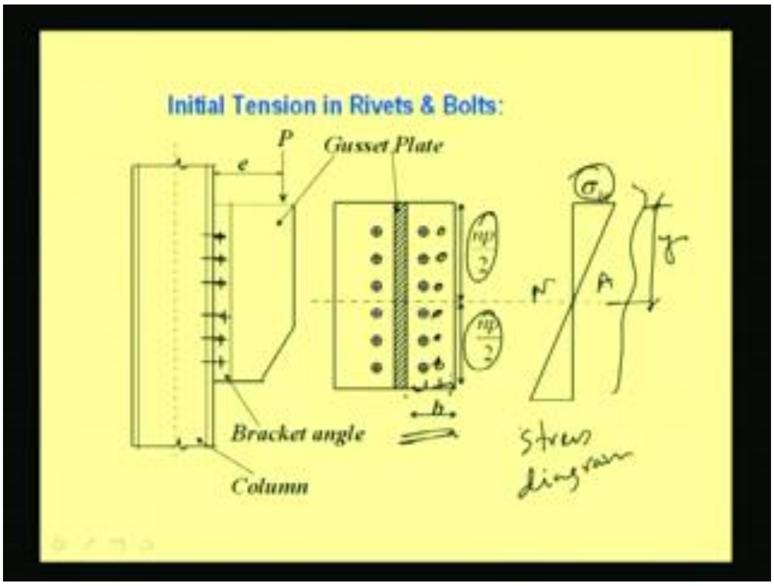

So, the stress diagram will become like this. This will be the stress diagram. This extreme fibers stress. So, this is sigma b t. So, stress will develop like this where this is the neutral axis at the middle and this is n p by 2; this is n p by 2. This can be called as b. So, due to the eccentricity, the stresses will be developing like this. This is the way which has been developed.

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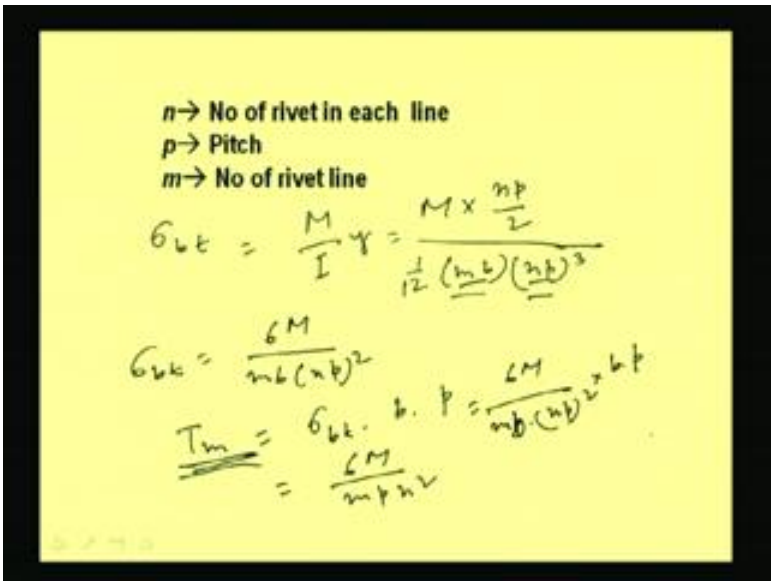

So, now if I consider the n as number of rivet and p as pitch and M as number of rivet line, then we can find out the value of sigma b t. So, sigma b t can be found out from this formula that M by I into y. So, M by I into y; that means M into y means basically from here to the extreme fiber distance this is y. So, this is basically n p by 2 and I is nothing but 1 by 12 m b into n p 1 by 12 b d cube. B means how many rows are there.

Suppose, we have another line of rivets, then this is b, this is b, this is b. So, here M will become 2. So, m b number of line we have to consider. Another is d cube d means n p. Here n is the total number of rivets. So, n p is the total depth. So, from this formula we can find out as 6 M by m b into n p square. So, this will become sigma b t. Thus the effective tensile load on extreme fastener which may be denoted as T m; that can be find out as sigma b t into b into p. So, sigma b t is nothing but this. So, I can write 6 M by m b m b into m p whole square into b into p. So, now simplifying this, we will get 6 M by m p n square. So, the effective tensile load on the extreme fastener will become 6 M by m p n square.

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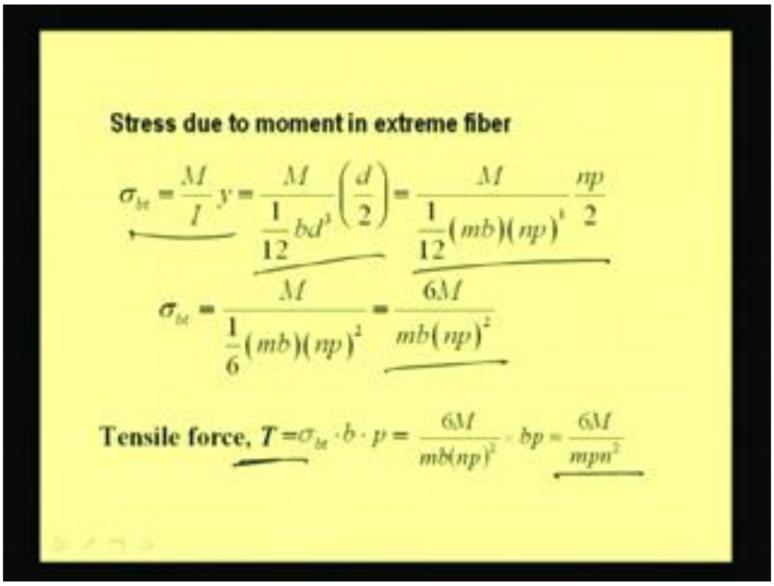

So, this is how we have calculated sigma b t is equal to M by I into y. Sigma b t is the basically stress due to moment in extreme fiber, and this is becoming this which after calculation we will get this one. And the tensile force t will become, finally 6 M by m p n square.

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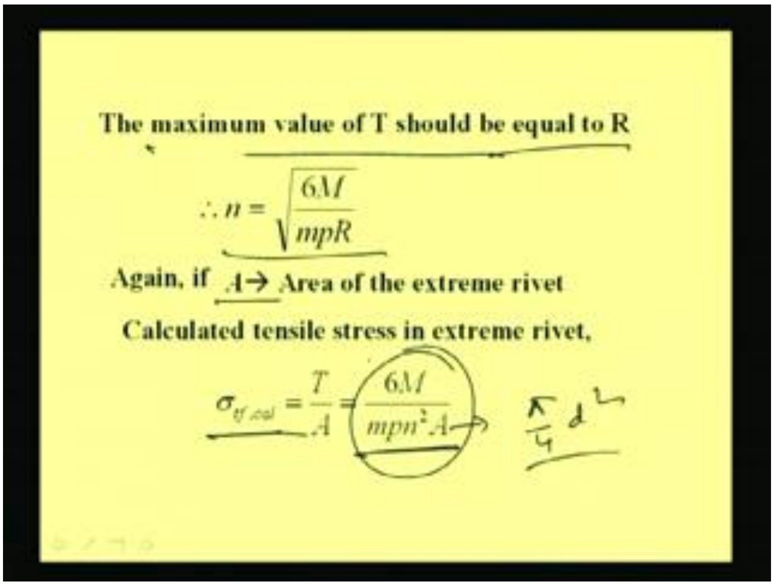

Now from this we can find out n. N is the number of rivet in one line. So, that can be find out as root over 6 M by n p R, right. So, using the maximum value as equal to the rivet value, we can find out n is equal to 6 M by m p R. Now again if we consider A as the area of the extreme rivet, then the tensile stress in extreme rivet will become T by A which will be 6 M by m p n square into A, right, where A is equal to pi by 4 into d square, right. So, sigma t f calculated means tensile stress calculated can be found out from this formula, right.

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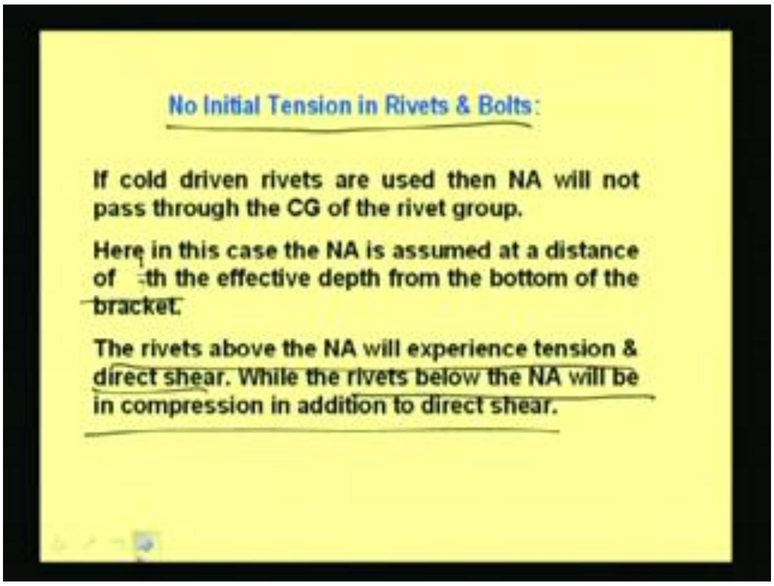

Now another case may happen which is called no initial tension in rivets and bolts. This happens when the cold rivets are used. In case of cold rivets, the neutral axis does not pass through the CG of the rivet group. The neutral axis is assumed in generally one-seventh of the effective depth from the bottom of the bracket. So, these are the assumptions we use to make, and then with that assumptions we use to find out what is the actual neutral axis depth.

So, the rivets above the neutral axis will experience tension and direct shear, whereas the rivets below the neutral axis will be in compression in addition to direct shear. So, rivet above the neutral axis and below the neutral axis will have different type of axial load; means whether it is compression or tension and also shear will be there.

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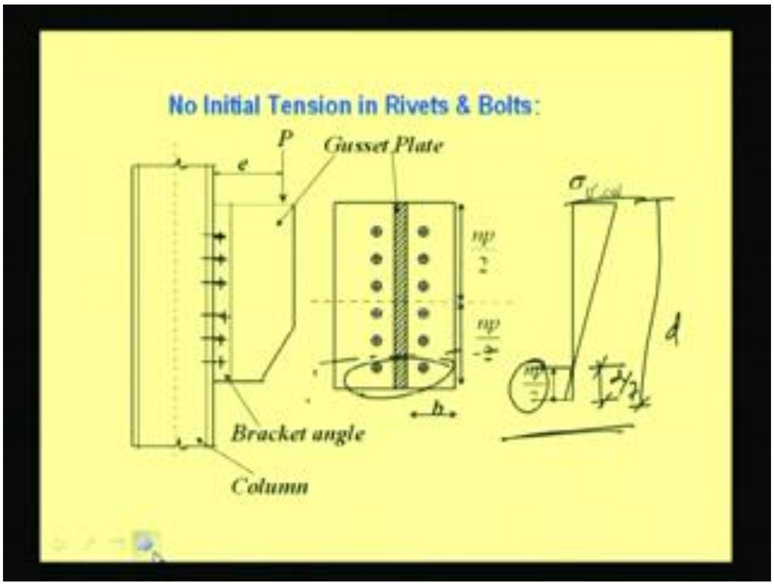

So, from this we can draw the stress diagram like this. That means our main assumption is that the neutral axis is around one-seventh of the total depth. If this is d then d by 7; so total depth is n p. So, n p by 7 is the neutral axis depth. So, with these assumptions, we will first find out where is the possible neutral axis depth. Then with that assumptions we will find out where is the actual neutral depth is happening. Then we can find out what is the sigma t f cal. That means tensile stress what is coming in the extreme fiber of the rivet. So, those things you can calculate. Then we can see whether it is safe or not, right.

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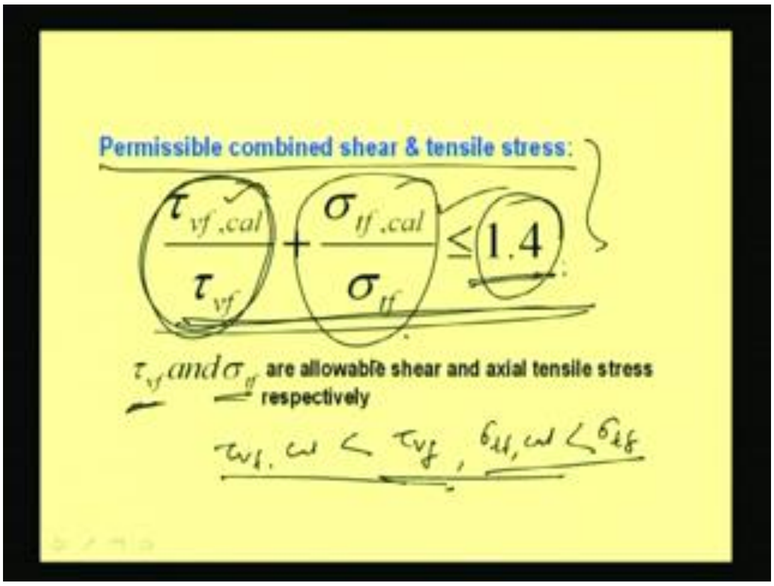

Now another thing is that permissible combined shear and tensile stress. So, if shear stress and tensile stress develop in the rivet, then we have to check that whether it is exceeding shear stress and whether it is exceeding tensile stress and jointly with this formula. That is tau v f cal by tau v f plus sigma t f cal by sigma t f should be less than or equal to 1.4. This check as per the codal provisions you have to make.

Now what is tau v f? Tau v f is the allowable shear stress. And sigma t f is the allowable tensile stress. Similarly, tau v f cal is the calculated shear stress; that means the developed shear stress in the rivet and sigma t f calculated means that the developed axial tensile stress on the rivet. So, on the basis of this means first we have to see this should be less than 1. That means tau v f cal should not exceed tau v f. Tau v f cal the calculated shear stress in the rivet should not exceed tau v f. It has to be less than tau v f.

And similarly, sigma t f cal has to be less than sigma t f. These two has to be individual check we have to do for these two. And then again for combined one, this has to check that this should be less than 1, this should be less than one and jointly should be less than 1.4. If it is more than that, then we have to change the number of rivet or we have to change the dimension of the rivet joint, then we have to make it; otherwise, you have to reduce the joint load, right. So, in this way we have to calculate.

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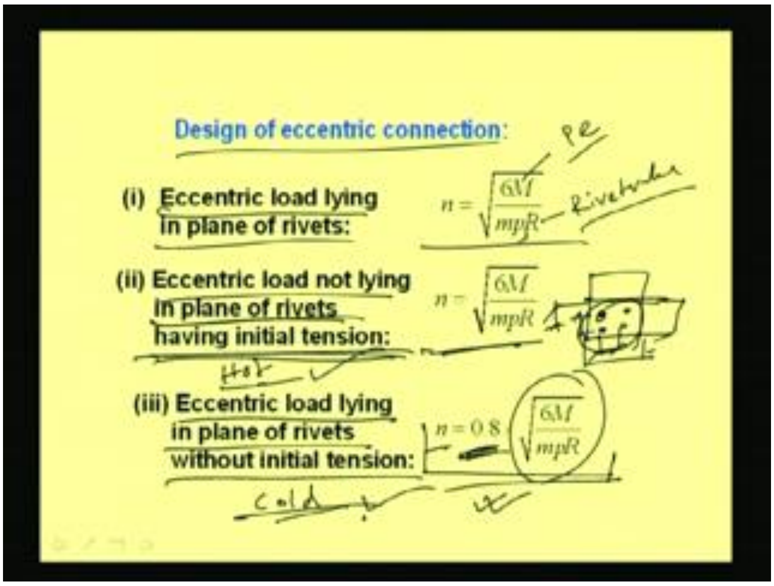

Now design that is design of eccentric connections how to design different type of connections? So, there are three type of things we have experienced. One is that eccentric load lying in plane of rivets. In that case, the number of rivets can be calculated as this n is equal to 6 M by m p R, where m is the moment due to eccentric load which is nothing but P into e, and R is the rivet value; that means one rivet which can carry.

How do we find out rivet value? Rivet value can be found out from means the calculation due to shear and due to bearing. That means the rivet value can be this which depends on the diameter on the rivet. So, tau v f into pi by 4 into b square, right. So, from that we can find out the rivet value r. Now p is the pitch; that p also we can decide means if nothing is given then we can assume some pitch.

Suppose, we have a connections, say some connections has given. So, we do not know what will be the number of rivet. So, to start with we can assume some pitch and edge distance. Then on that basis we can find out the value n. So, the moment we are finding out the value n, what we will do? Then we will go for this edge and pitch and its details. Then after detailing of this, we will see we will check that tau v f cal how much it is coming shear stress and how much the tensile stress is coming. Then whether it is under permissible limit or not that we have to check.

If it is okay, then fine; otherwise, you have to increase the either number of rivets or some dimensions, okay. Another case is that eccentric load not lying in plane having some initial tension; this is another case. So, in this case the formula is same n is equal to 6 M by m p R. Eccentric load not lying in plane of rivets having initial tension, and another case come eccentric load lying in plane of rivets without initial tensions. Without initial tension when we are going to consider we will be considering that n is equal to 0.8 into 6 n m p R, okay.

So, n is equal to 0.8 into 6. That means the number of rivets are going to be reduced by 0.8 times. Here number of rivets will be little bit less; requirement will be little bit less. So, the code has suggested that 0.8 times the square root of 6 M by m p R can be made to find out the number of rivets. In all the cases as I have told that after finding the number of rivets we have to detail the joint, then again we have to check whether it is exceeding or not, because this formula is used to find out some approximate number of rivets with some approximate dimension.

Approximate means M is approximate if p is approximate. Whether p has to increase or decrease, what is the total length depth will be; all those things has to be decided finally. So, after deciding we have to check once again to see whether it is okay or not, right. And what I told that when this happens that having initial tension, when the rivet is hot and when the rivet is cold, initial tension can be neglected.

So, on this basis we can find out whether it is power driven shaft rivet or means power driven shaft hot rivet or power driven shaft cold rivet. If it is hot rivet, then we can assume that initial tension is there. And if it is cold rivet, then we can neglect the initial tension and accordingly we can make it. So, in case of cold rivet means the number of rivets will be little bit less. So, with all these we can make the design accordingly.

So, in next class we will see how to design a rivet, how to find out the number of rivets and its details in the case of hot rivet and in the case of cold rivet; that we will see and then again we will see for the welding joint.

Thank you.