Design of Steel Structures
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Module - 3
Eccentric Connections
Lecture - 5
Eccentric Connection

Hello. Today, our lecture will be focused on welding joint for the eccentric connections. In last few lectures, we have discussed details about the bolt joint and riveted joint for the eccentric connections. Eccentric connections means the connections is made in such a way the load is applied not directly in the connection but with an eccentricity. In fact, the load may lie on the plane of the joint or load may lie perpendicular to the plane of the joint.

So, depending on that situation we have to design the rivet joint or bolt joint or welding joint accordingly. We have seen in our earlier lectures that if load is lying in the plane of joint, how do design, and if load is lying perpendicular to the plane of the joint, how do design. Of course, again we have seen that the joint has made by the use of bracket connections or by the use of seat connections. So, all these details we have seen in our earlier lectures. Today, we will be focusing in a same way using the welding joint.

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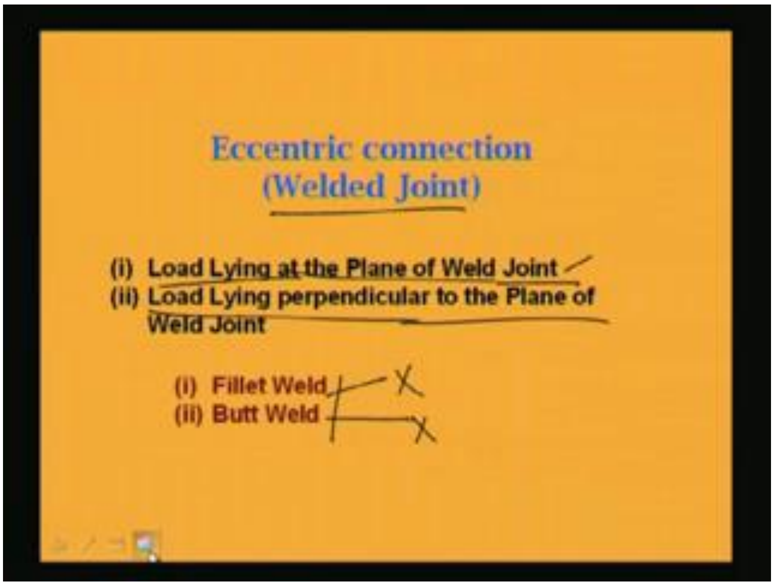

First thing is load may lie at the plane of the weld joint; this is one case. So, our calculation will be accordingly; means if it is at the plane of the weld joint, then torsional stress will come into picture as well as the direct stress. So, we have to take care accordingly, and if load lying at the perpendicular to the plane of joint, then the stress due to moment and stress due to the axial load will come into picture.

So, accordingly the calculations have to be done; accordingly, the design has to be made; accordingly, the size of the weld has to be made. Again weld means two type of welding we generally use for the building or bridge or other common type of structures. One is fillet weld, another is butt weld. So, here also calculation will be different for fillet weld and for butt weld. Basically, its permissible stress is different in the case of butt weld, and in case of fillet weld it is different. So, we will discuss all this in details in this lecture.

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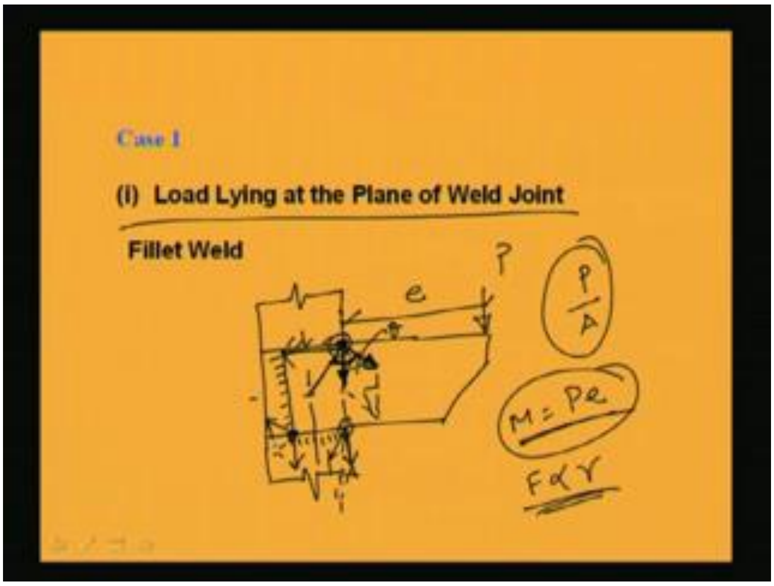

So, first to start with let us concentrate our lecture on load lying at the plane of weld joint using fillet weld. So, if load lying at the plane of welded joint, how it look like? Say one connections are there; means the bracket is connected to a column which will pass the load. So, load is here, say, P with an eccentricity of e. Now suppose we are making the welded connections in this way; say, this is the welding area.

So, what we are seeing here that one is P; this is the load. So, the stress will come P by area. Area is the total welding area, and another will be the moment which is coming P into e that is the torsional moment. And that has to be again calculated for the torsional stresses, and accordingly, we have to find out again the resultant stresses. So, what will happen here? We will see that the stress will develop in different way, and in case of rivet joint also, we have seen that one suppose if we consider this point.

So, P by A the vertically downward stresses will be developed here, one. Another is if the CG of the weld connection is somewhere here, then another will be due to torsional stress. So, one stress will be in this way; another stress will be in this way. This is 90 degrees along perpendicular to the radial axis. So, the resultant has to be made accordingly from this equation where this is called theta. Theta is the angle between the two stresses, okay.

Now where the stresses will be maximum? Maximum stresses will be either this point or this point, because in case of riveted joint also we have seen where the maximum stress will develop where there maximum forces will develop in case of riveted joint. Then why this is maximum? Because this is the maximum distance, and we know force varies with distance. Force will be more if the distance is more.

So, definitely this will be less. This is one thing. Another thing is that the force here if we see in this point force will be like this. So, it is adding, but if we see in this point, we will see what? This is like this, and this is like this. So, some of the component is going to be directed from the resultant. So, here the results will be less. So, in this way we have to find out.

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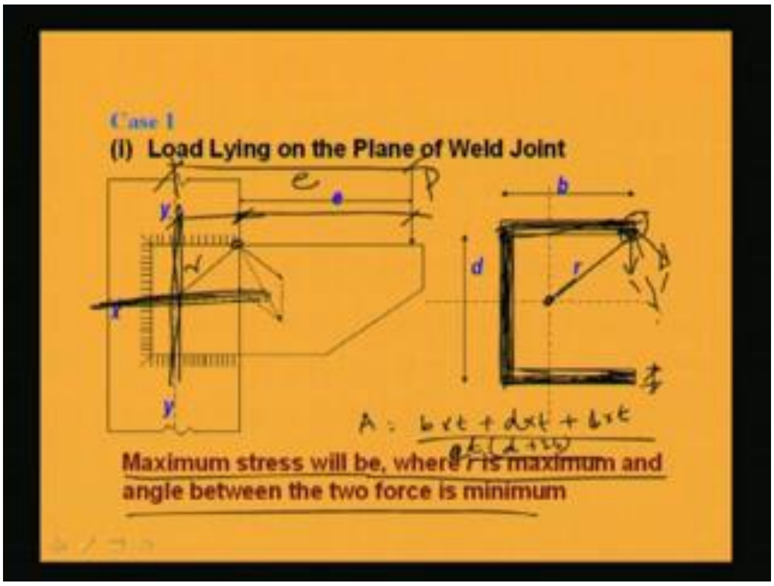

So, what I was discussing that maximum stress will be where r is maximum. R means the radial distance; this is r, and angle between the two force is minimum. So, angle between the two force but here we cannot make minimum here, because angle is fixed in this point. So, what is we have seen that maximum stress will be where r is maximum and angle between the two forces is minimum. The area will be totally this much. If you see the area of the weld joint; so, this will be total area.

So, we can calculate the area easily. The total area will be b into t plus d into t plus again b into t. So, we can write t into d plus 2 v; that means if this is v and if the depth of the bracket is this, then we can write that the area will be total this much. So, accordingly the force can be calculated in this direction and calculated in this direction and then we can find out the resultant.

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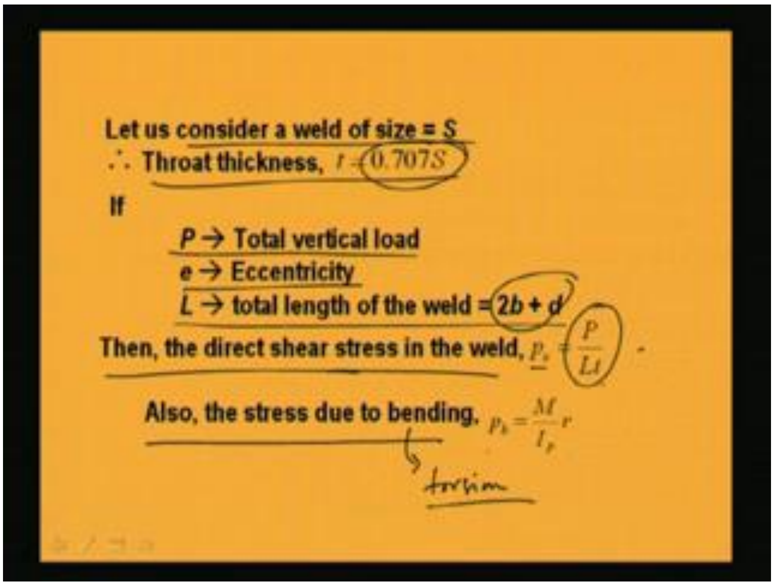

So, with this let us try to find out the resultant stress, how it is developing on that point. If the size of the weld is consider as we know the throat thickness can be written as 0.707S. So, throat thickness because we are calculating the strength of the welding joint on the basis of throat thickness, because this much thickness can be effective for the strength calculation of the weld.

Now if P is the total vertical load, and e is the eccentricity, then the total length of the weld also can be calculated as I have shown earlier which will be 2 b plus d. So, direct shear stress in the weld that will become P by L into t, where we see P is this. P by L into t, L is this total length, and t is the thickness. So, L into t is the area. So, it will be P by L into t. So, this is the direct stresses in the weld, and it will be equal to in each and every point of the weld, okay.

Now the stress due to bending will be P b that will be equal to M by I p into r. It is not exactly bending, we can tell as torsion also, right. So, stress due to torsion is M by I p into r, where M nothing but the P into e.

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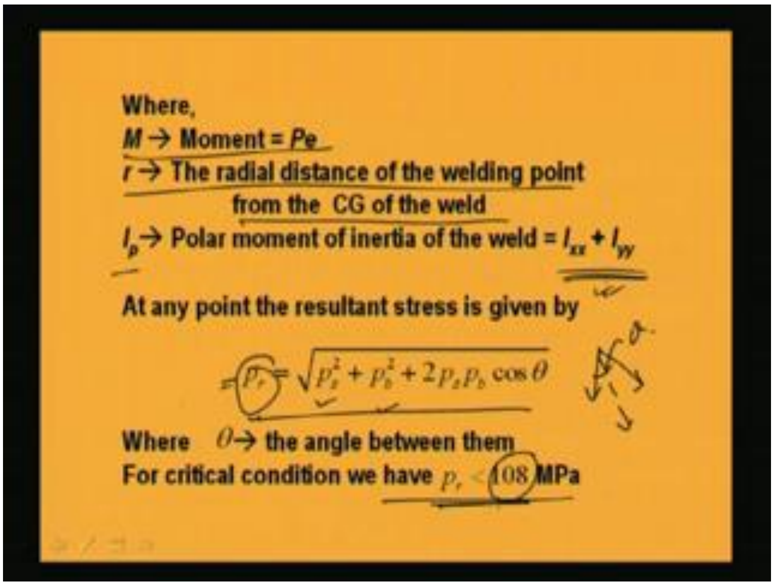

So, M is P into e force into eccentricity of the load. Then r, r will be the radial distance of the welding point from CG of the weld. R we have shown in the picture that this is the r value, radial distance from CG to the point where we are going to calculate. And here also you notice that e is not exactly this one. For calculating e, e will be the CG distance from CG to the load. So, this will be e.

So, the eccentricity from the column phase plus the CG distance will be the e. So, while calculating, e has to be calculated accordingly, and now I P; I P is the polar moment of inertia. And polar moment of inertia we know we can calculate as Ixx and Iyy. So, again we have to know Ixx and Iyy of the welding area. So, Ixx means from this and Iyy means from this one. So, in this way we have to make it. So, after calculating Ixx and Iyy, we can find out the resultant.

So, if we know this I p, then we can find out this value P b which is M by I p into r. So, we know P s, we know P b; we know P b and P s. So, resultant will be in this direction. If this is theta, then P r will be the resultant stress which will be equal to root over P s square plus P b square plus 2 P s P b into cost theta. So, in this way we can calculate the resultant stress. Similarly, this resultant stress has to be less than the allowable permissible stress which can be carried by the weld which is in general 108.

For the welding fillet weld, this is in generally we use it a 108 MPa. So, for critical condition we can consider that P r the resultant stress as 108 MPa. So, here we will check whether P r is exceeding the 108 or not that we will check. If it is exceeding, then we have to redesign, or if it is not exceeding, then we can again make it in that way.

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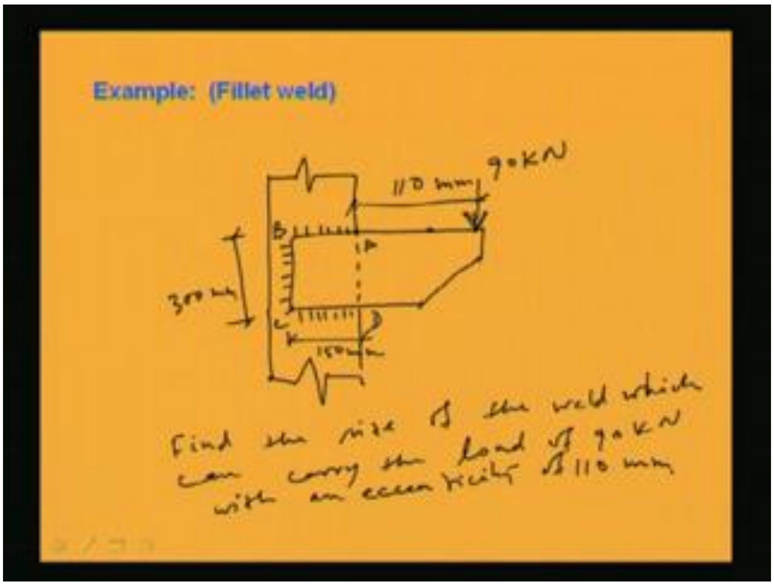

Now whatever I have discussed will be clear if I go through one example. Let us say one column section let us take, say, 90 KiloNewton load is applied 110 millimeter distance from the phase of the column. And now it has to be welded, and welding has been done throughout its periphery which is connected with the column. And this distance has been given as 150 mm, and this depth of the bracket has been given 300 mm. So, this is, say, point this is A B C D.

Now first what we have to do? 90 KiloNewton load is applied at this point which is 110 millimeter away from the phase of the column. Now we have to find out the stresses maximum stress while it is developing, and accordingly, we have to find out the size of the weld. So, question is that find out the size of the weld. Find the size of the weld which can carry the load of the 90 KiloNewton with an eccentricity of 110 mm. Remember eccentricity it is from column phase, but total eccentricity when you will be getting we have to find out through its CG.

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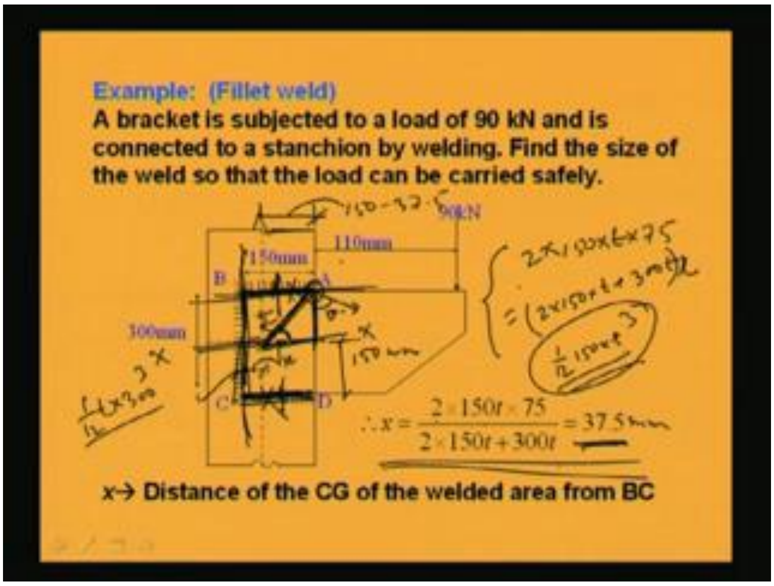

So, this is the question. This is the total area we will be getting; this plus this plus this into t will be the total area of the weld. Now before going to find out area and other things, first I have to know where the CG is lying. Now CG I can find out; we know this is symmetry about this. So, the CG will be exactly, say, 300 by 2 means 150 millimeter from bottom or from top. So, it will be at the middle, and if this we consider as x, then this x distance we have to find out.

So, that can be found out from this equation, how? If we take the area moment from about this axis along BC, what will happen? We can write 2 into 150 t into 75, because 150 is the length of this distance. So, 150 into t is the area, and CG will be 150 by 2 that is 75 and two side of this; so, two into this. This will be the moment area of this about this. And this should be equal to the total. Total if we take total area is basically 2 into 150 into t plus 300 t.

This is 300. So, total area is 300 into t plus 150 into t plus 150 into t. So, this is the total area and into x. X if it is the distance. So, equaling this two, we will get the value of x. So, x is basically 2 into 150 t into 75 by 2 into 150 t plus 300 t. After calculating this, we are getting x as 37.5 milliliter. So, distance of the CG of the welded area from this line is 37.5 millimeter.

So, if this is 37.5 millimeter; so, I can find out this value which is 150 minus 37.5 millimeter. So, eccentricity will be basically this 110 plus 150 minus 37.5 millimeter; that will be the eccentricity which has to be made.

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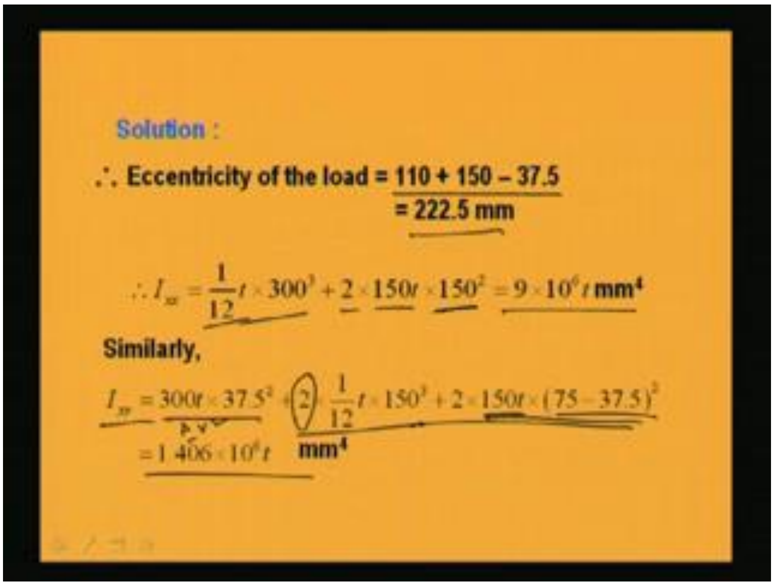

So, eccentricity we can calculate 110 plus 150 minus 37.5, because this is 110, and this is 150 minus 37.5. So, after calculating we are getting the eccentricity as 222.5millimeter. Now after getting the eccentricity, we have to find out Ixx and Iyy. Ixx how do I get? Ixx means the moment of inertia about this axis, say, xx. So, when I am going to calculate the moment of inertia about this xx axis, then what will happen? We have to calculate that first is this for this area BC that will be 1 by 12.

For BC, it will be 1 by 12 BD cube. That means t into D cube means 300 cube that will be the moment of inertia. So, 1 by 12 into t into 300 cube; this is this one, and then the upper and lower portion top and bottom portion. This will be first we have to calculate along this means at its own. Then we can take into there. So, when at its own we will do that will be 1 by 12; sorry, along this axis. So, that will be 1 by 12 b. B means 150 into t cube which is very less, because t is very less.

So, this term we are going to neglect it. So, the other term will be A r square; that means A r square means area. Area is 150 into t area 150 into t into r square. R square means 150 square. So, 2 into 150 t into 150 square; area is 150 into t and for two side it is top and bottom. So, that is why two and r is 150, okay. So, A r square; that means I am neglecting the moment of the inertia about its own axis because it is very less; that is why we are neglecting that t cube, okay.

So, after calculating this, we are going to get 9 into 10 to the power 6 t millimeter to the power 4. So, moment of inertia about x axis is 9 into 10 to the power 6 t, where t is the throat thickness of the weld. Similarly, I can find out Iyy. Iyy is the moment of inertia about yy axis. So, Iyy let us see how Iyy can we calculated. Iyy will be first I have to calculate in this direction means at the vertical at the middle 1 by 12 BD cube. Then we have to transfer to this distance.

This is for these two top and bottom, and for BC, it will be simply we can transfer to here because about its own axis, it will be very less. So, we can calculate. So, first is 300 t into this is the area 300 into t is the area into 37.5 square A r square. This is basically A r square; so, 300 t into 37.5 square. This is the moment of inertia of this portion. Then for this portion, we have to find out first at its own axis, then we have to transfer here with A r square.

So, 2 into 1 by 12 t into 150 cube; this is about one axis. Two is multiplied because of in two position. One is top; another is bottom and then A r square. A is this area. R is 75; 75 is the CG of individual. Then 37.5 has to be reduced; so, 75 minus 37.5 whole square. So, total will be this much, which has been calculated as 1.406 into 10 to the power 6 t millimeter to the power 4. So, we are getting Ixx and Iyy.

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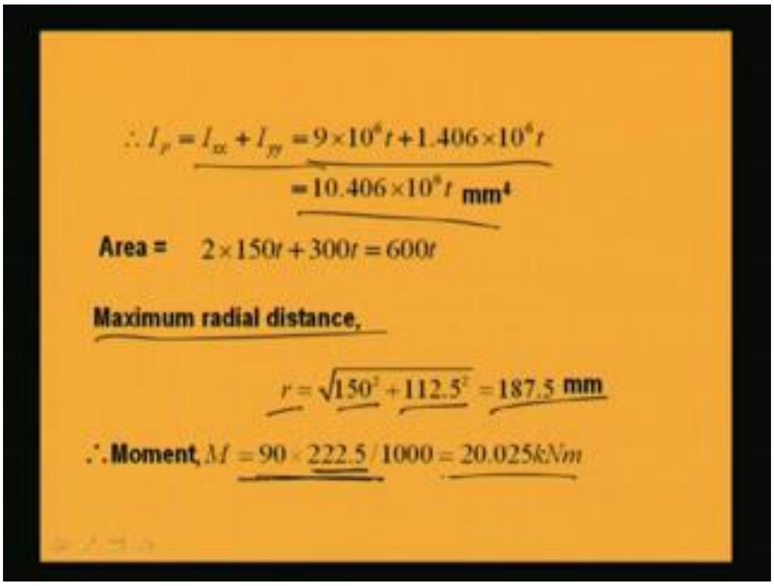

So, now we can find out I p that is the polar moment of inertia because we are going to calculate the torsional stress. For torsional stress, we have find out the polar moment of inertia because t by j or t by I p into r, okay. So, Ixx and Iyy if I add, this will be becoming 10.406 into 10 to the power 6 t millimeter to the power 4. So, the polar moment of inertia I p has been obtained as 10.406 into 10 to the power 6 t millimeter to the power 4.

Now radial distance; now I have to find out again maximum radial distance, because the stress will be developing maximum in this point at the point A. So, I have to find out the radial distance. So, radial distance means square root of this plus square root of this; that means square root of 150 that is the vertical distance and square of 112.5; that is 150 minus 37.5 which is coming 112.5. So, radial distance r will become square root of 150 square plus 112.5 square is equal to 187.5 millimeter.

Now moment, moment or torsion whatever you call will be force into eccentricity. Now eccentricity is not the distance between column phase and the load which is 110. Eccentricity is from load to the CG distance. Okay, perpendicular distance between CG to the load. So, this is coming 222.5. So, the moment we will be getting P into e as 20.025 KiloNewton meter; we have made it to meter, okay. So, moment we got now. Now what we will do? Now we will be finding out the stress due to bending or torsion whatever you call.

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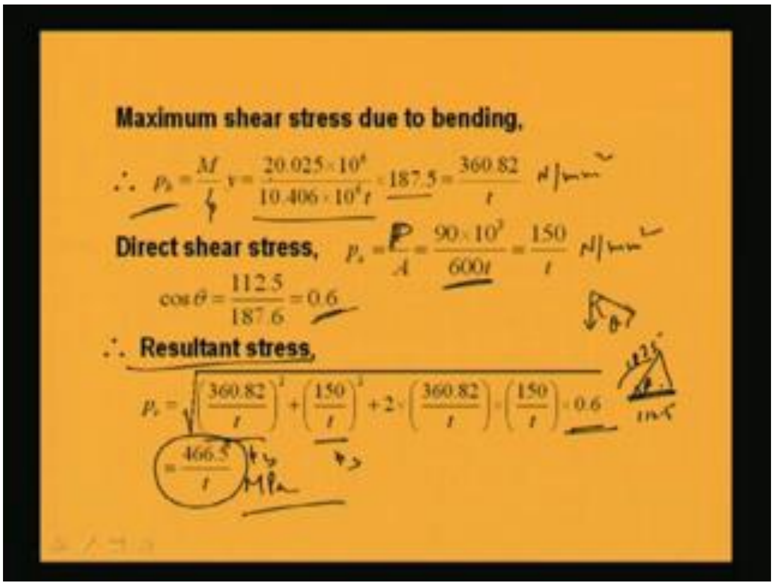

Stress we can find out which is M by I into y; I means I p, okay. So, moment is calculated as 20.025 into 10 to the power 6, and I p is calculated as 10.406 into 10 to the power 6 into t. And y is the maximum radial distance, where the maximum stresses are developing which is 187.5 where 187.5 we have calculated here. So, after calculation of this, we will get 360.82 by t. This will be Newton per millimeter square.

Similarly, the direct stress due to the load that will become this is P, P by a. So, P is 90 KiloNewton. So, 90 into 10 cube by area. Area we found 600 t. So, after calculating this, we are getting 150 by t Newton per millimeter square. And angle between two stress this theta can be found out from the diagram itself, theta will be becoming this one which is equal to this.

So, theta will become 112.5 by 187.5 which is coming 0.6. That means cos theta will be what? 187.5 is the redial distance, and this distance is 112.5. So, theta will be this one. Cos theta will be 112.5 by 187.6 is equal to 0.6. So, now the resultant stress can be found out from the equation that is P a square plus P b square plus 2 P s P b into cos theta. So, P s and P b values are given; this is P s, and this is P b. So, plus 2 P b into P s into cos theta; so, after calculating this, the resultant stress is coming 466.5 by t MPa Newton per millimeter square. So, this is the resultants stress which is coming at point A and which is the maximum.

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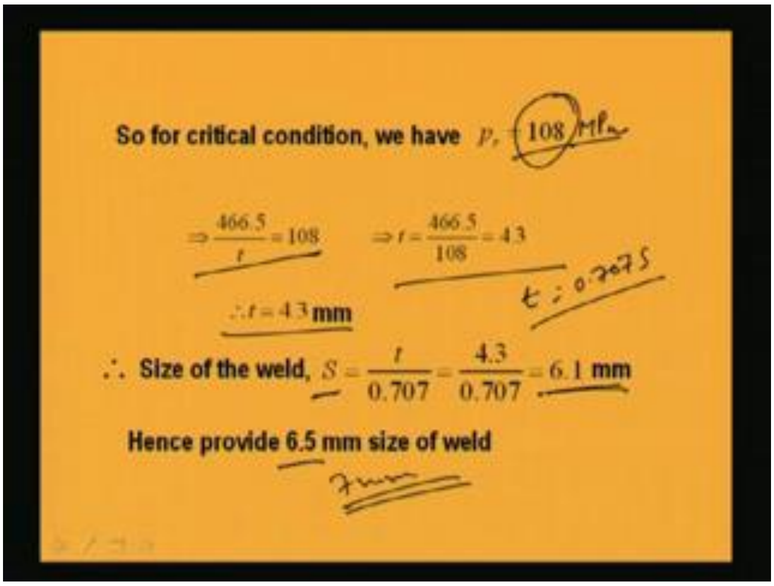

Now for critical condition, the maximum stress should be equal to 108 MPa; it should not exceed the limit of 108 MPa. So, to develop maximum stress at that point, we can make equal as this P r is equal to this, and from this I can find out t as 4.3 millimeter. So, the throat thickness of the weld is found as 4.3 millimeter. Now the size of weld is nothing but that t by 0.707 because t is equal to 0.707 into s generally we used to make.

So, size of weld is coming 6.1 millimeter; that is why we can provide as 6.5 millimeter size of weld or 7 millimeter size of weld whatever the designer will choose. So, in this way we can find out the size of weld; that means we are finding out the size of weld in such a way that it can be able to carry the load which has been given and thinking that the maximum stress is developing at point A which will be equal to 108, because we have to see the place where the maximum stress is going to develop.

And in that place, if it becomes to the permissible limit, what should be the size of the weld or thickness of the weld, and accordingly if we make equal, we can find out the size of the weld. So, in this way we can find out. So, this is a typical example we have gone through it, so that we can understand how to calculate the stresses, and what is the procedure; in what way we will calculate the resultant for a welded connection when the load is lying in the plane of the joint.

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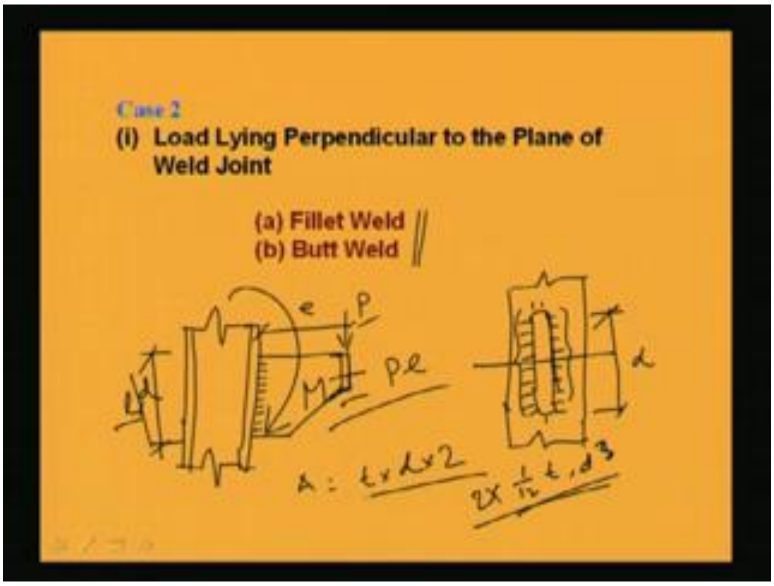

Now another case we will discuss that is called load lying perpendicular to the plane of weld joint. That means in this case, we can use either fillet weld or butt weld. How it look like? We know in case of riveted joint, we have seen riveted and bolted joint. We have seen if load lies perpendicular to the plane of joint, how it looks like. Say, this is the load which is P, and this is the eccentricity e, right. Now the welding has been done here. So, because of P, this will act as moment also M P into e where M is equal to P into e.

So, we have to calculate the size of the weld or the depth of the weld means this depth or length whatever you say length or depth whatever you can call that has to find out for a particular value of P and e, or P and e is given, we have to find out the size of the weld if other details are given. Now if we see in the plan we will see this is coming something like this. In the plan if we see the welding, we will see this

So, what will be the shear stress; how do you calculate? What will be the area of the weld? Area of the weld will be if this is d if I say and if the throat thickness of the weld is t, then I can say t into d into 2 because in this side also and in this side also, welding is done. So, 2 into d will be made. So, area will be 2 into d into t, and accordingly, we can find out the stress due to direct force.

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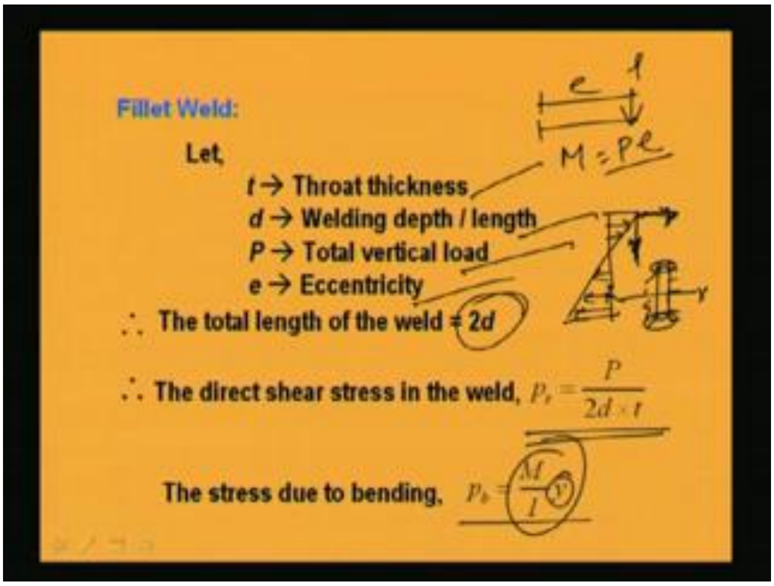

So, stress due to direct force can be we can calculate; that is P by 2 d into t if P is the vertical load acting at the distance of e from the phase of the column. Here t is basically throat thickness; d can be called as welding depth or welding length whatever we will say, and P is the total vertical load, and e is the eccentricity. So, total length of the weld is becoming here 2 d because two times it is coming, and accordingly, we have to find out the values.

So, the stress due to bending here what will happen. Because of P is here. So, moment will be developing P into e. So, stress will be developing in this way along the depth of the cross section if we see, it will develop like this. So, P will be become M by I into y. Stresses due to bending of the system the P b will become M by I into y, where M is the moment which is P into e, and I is the moment of inertia about x axis; means if the weld is like this, then I e will be in this direction if weld is given like this, and y is the distance from the CG to that particular point.

Where it will be maximum? Maximum will be at the extreme edge where the distance is maximum. So, either here or here it will be maximum. So, maximum stress can be calculated from this. Again we will see due to the force P, the direct stress is coming in this way, and bending stress is coming in horizontal way. Stresses due to bending is coming like this because the stresses will be developing like this, right. So, one force is coming in this way, another force is coming in this way, and these are perpendicular, because load is perpendicular.

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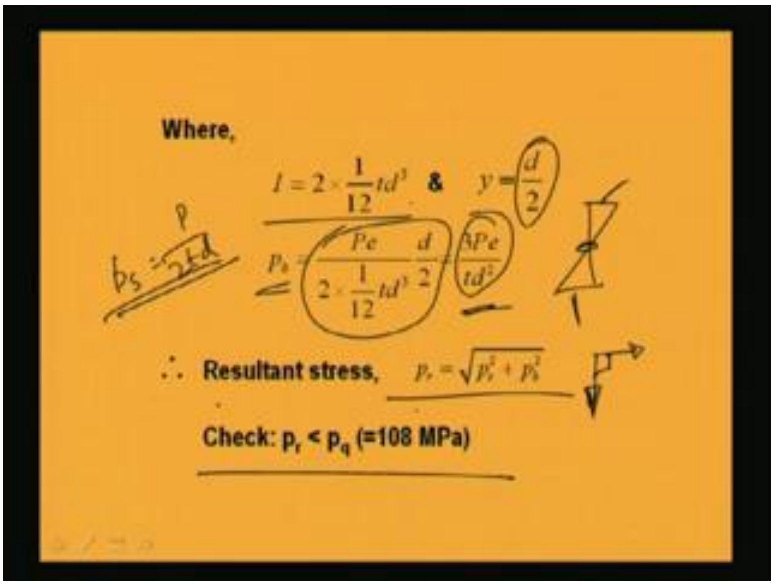

So, now we can find out the resultant; P r we can write square root of P s square plus P b square because both are acting perpendicular to each other. P b will be acting horizontally, and P s will be acting vertically. So, to calculate P b, let us see what is I. I will be nothing but this one 1 by 12 b. B means here t d cube. I will be this one for one side. So, for two side, this will be two into this. So, I will become 2 into 1 by 12; that means 1 by 6 t d cube.

So, 2 into 1 by 12 t d cube and y the maximum y will be d by 2. And this P b will be 0 at the CG here and maximum will be here or here at d by 2 distance. So, P b can be calculated from this equation finally that is M by I into y which is coming 3 P by t d square. So, I know P s. P s is equal to P by 2 t d, where we have calculated P s equal to P by 2 t d.

So, this we have P s and P b we have as a 3 P e by t d square. So, I can find out the resultant stress as P r is equal to P s square plus P b square as both the stresses are acting perpendicular to each other; that means if this is 90 degree, okay. Now what we have to do? We have to check whether this resultant stress is less than the permissible stresses or not. Permissible stress for fillet weld is generally considered as 108 MPa, right.

So, means if it crosses the permissible stress if the resultant stress is more than the permissible stress, then we have to redesign. Either we have to increase the depth or you have to increase the size of the weld to carry that much load with that eccentricity, okay. So, accordingly you have to design, right. And this also will be clear if we go through one example.

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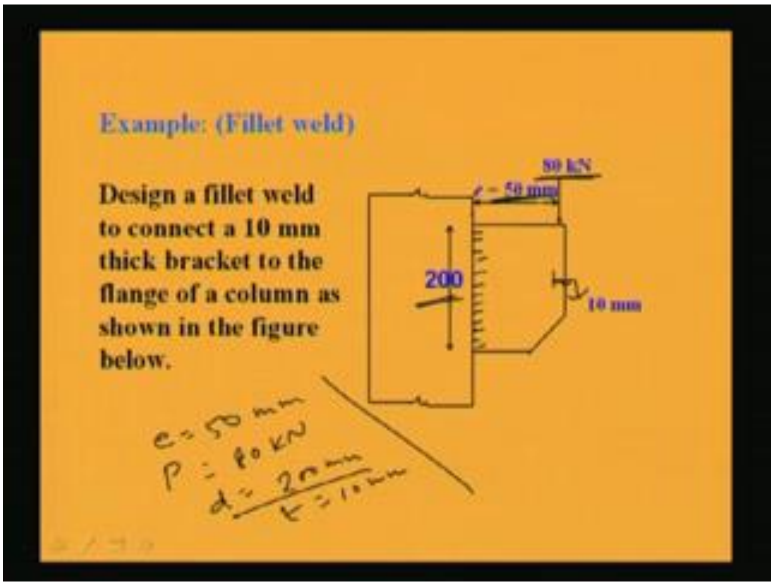

So, example is given this design a fillet weld to connect a 10 mm thick bracket to the flange of a column as shown in the figure below. So, what is the question? 80 kiloNewton of load is acting at a distance of 50 mm away from the column phase. So, eccentricity e is 50 and P is 50 mm and P is 80 kiloNewton. These are given, and the depth of the weld can be made as 200 mm means if we make fully welding, okay.

So, depth is can be made at 200 mm and thickness of this bracket plate is given as 10 mm. So, these are the given things. Now on the basis of this, we have to find out the size of the weld. Design the fillet weld means we have to find out the size; what should be the size of the weld.

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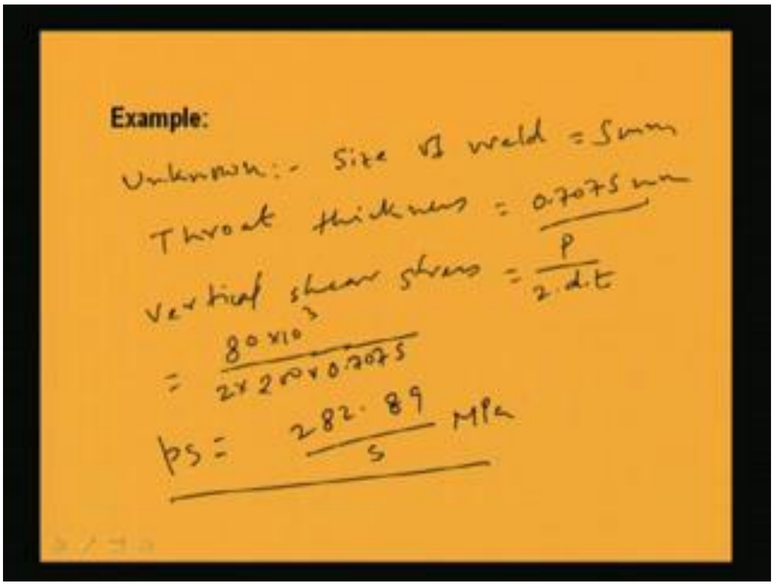

So, unknown is. Unknown thing is that size, size of weld; that means, say, suppose S. So, throat thickness can be calculated. Throat thickness will be 0.707 S, say, S millimeter let us make. So, throat thickness will be 0.707 S millimeter. So, vertical shear stress means this will become P by 2 into d into t, right. So, P is given as 80 KiloNewton by 2 into d is given as 200 because d is given as 200, okay. So, 200 into t is 0.707 S.

So, from this I can find out the value; this will become 282.89 by S MPa. So, the vertical shear stress, say, P s has been found as two 282.89 by S MPa. What else we will do? We will find out next is horizontal stresses due to the bending.

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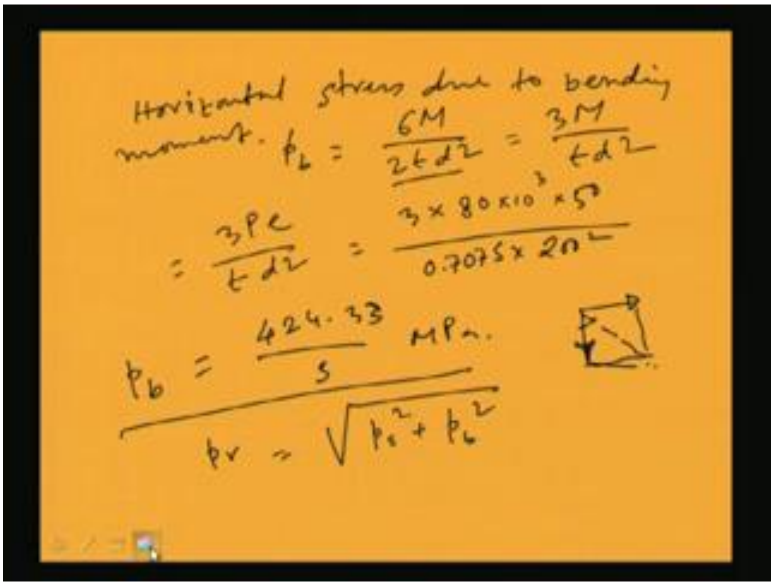

That is horizontal stress due to bending moment that will be denoted as P b that is coming 6 M by 2 t d square, okay, and for two side that is 2 t d square, okay. That means 3 M by t d square; that means 3 P e by t into d square. Now if we put the value 3 P is 80 KiloNewton. E has been given here that is 50 mm. So, e can be put as 50 P e by t is nothing but 707 S and d square. D is 200, the depth of the weld or length of the weld.

So, after calculating this, we will get 424.33 by S MPa, right. So, we are going to get 424.33 by S. This is the stress due to bending, right. So, these two we are going to get. Now what we will do? Now we will find out resultant stress. Resultant stress P r this will be basically P s square plus P b square, because P s is always acting vertically downward, and P b is acting horizontally, okay. So, the resultant will be this one P b square plus P s square, okay.

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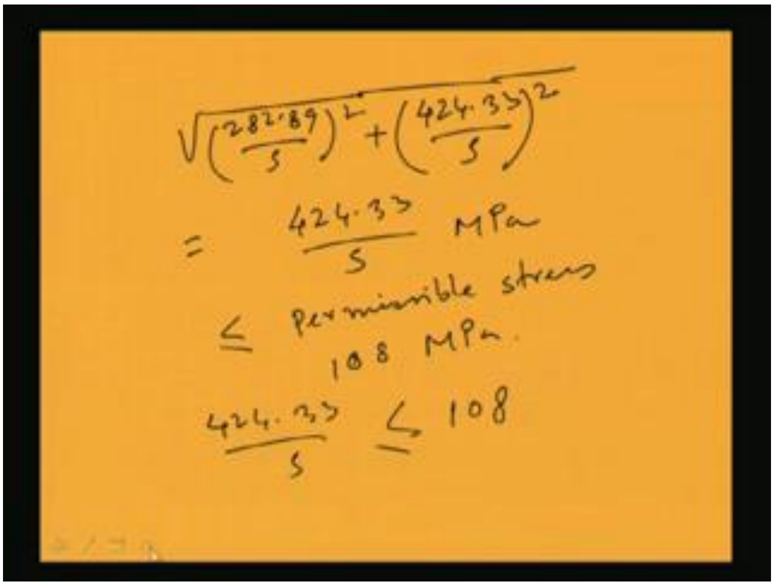

So, if we calculate now that will be P b P s square is 282.89 by S square plus four 424.33 by S square, right. So, after calculating this we can find out the value as 424.33 by S MPa, okay. So, resultant stress at the extreme point will become 424.33 by S MPa. Now this should be less than or equal to the permissible stress. Permissible stress is basically 108 MPa. So, basically 424.33 by S should be less than or equal to 108. So, from this I can find out.

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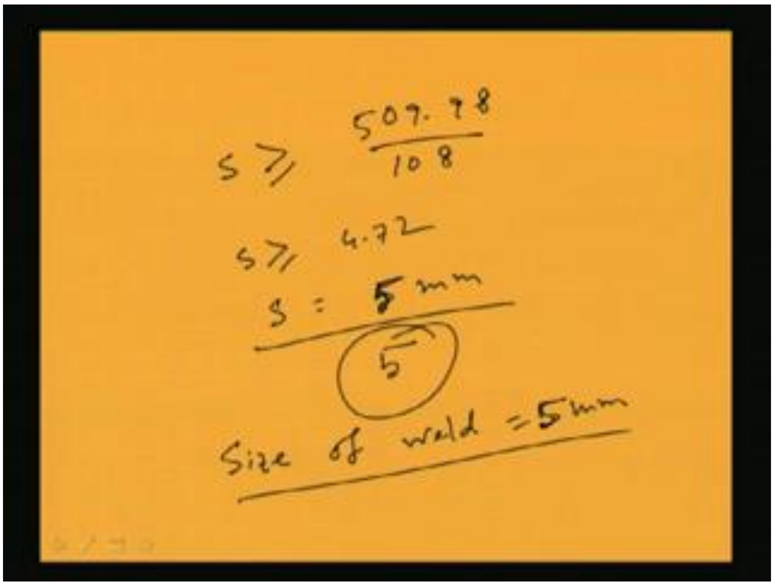

S should be greater than or equal to 509.98 by 108. From this we can find out S should be greater than or equal to 4.72. So, we can use S as 5 mm, and we know the minimum size of weld can become 5 mm. So, the size of the weld will become 5 mm. So, the final answer is that we have to find out the size of weld not the throat thickness, size of weld that is coming 5 mm, right. So, it seems quite easy to find out such stresses, right.

Now another typical example we will go through through which will be able to make some idea about the design of fillet weld means for the eccentric load. So, here one typical case we will show for the fillet weld problem. Say, first before going to solve the problem.

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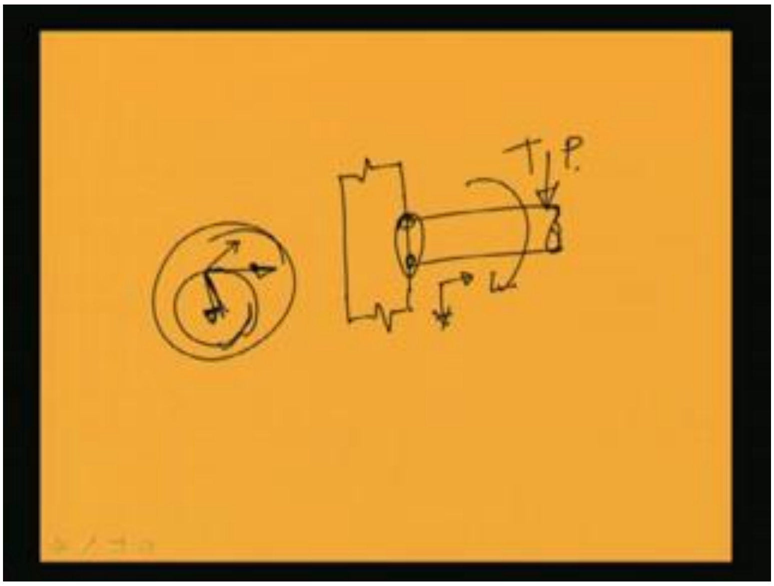

Let us see suppose we have a, say, column, and we have a, say, bracket here, right. Now suppose this is circular, and now some torsion is given. So, what will happen? So, for torsion also some sort of stresses will come in this area. Again if the P is given force is given, then due to force vertical stress will come as well as the horizontal stress will come, right. So, if we see in the plane.

So, stresses will come in different way; one horizontal always, another is vertical always, another is perpendicular to the radial distance, okay. So, three types of stresses will come into picture. So, how to check, how to take care and what will be the possible cases of stress development; that we will discuss in this example.

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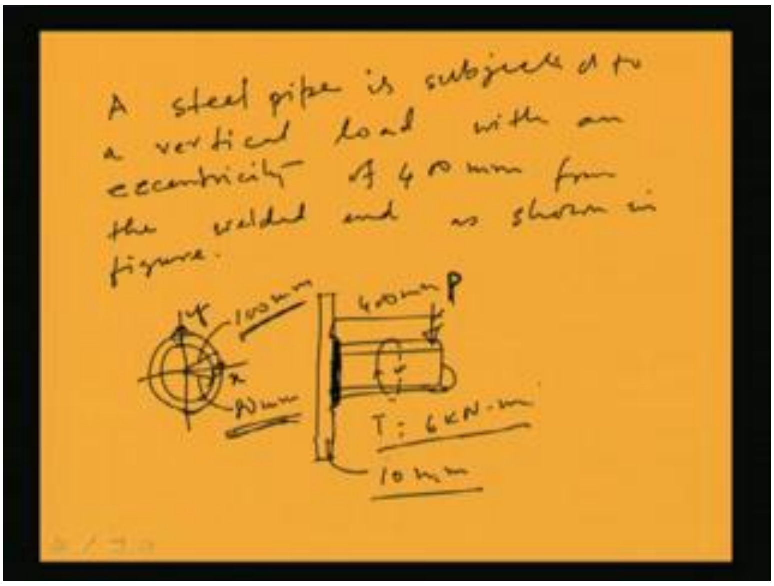

That is, say, a steel pipe is subjected to a vertical load with an eccentricity of 400 mm from the welded and as shown in figure; what is that? Say, this is a plate which is connected with another one. This is circular. Now force is P with 400 mm eccentricity and another torsion is also here, right. T is equal to, say, 6 kiloNewton meter. Now welding has been done throughout this, okay. Now the steel pipe is subjected to a vertical load with an eccentricity of 400 mm from the welded end as shown in the figure. So, the pipe is connected to the rectangular plate of 10 mm thickness.

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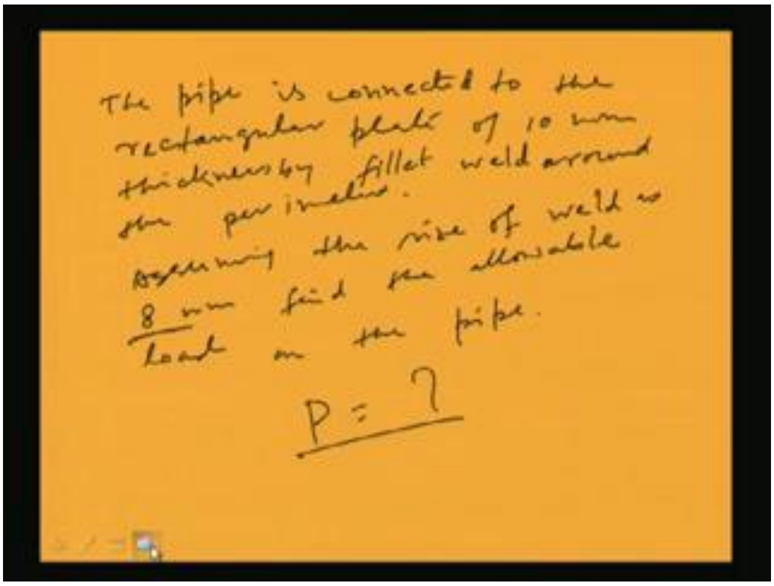

So, this thickness is 10 mm. Let me write down the pipe is connected to the rectangular plate of 10 mm thickness, right, by fillet weld the perimeter, and suppose this is the pipe. Now inner and outer radius is, say, 100 mm and 80 mm. This is 80, and this is 100 mm. So, inner radius is 80 mm, and outer radius is 100 mm. Now the pipe is also subjected to torsion of 6 kiloNewton; this is also subjected to torsion, right. So, now assuming the size of weld as 8 mm, find the allowable load on the pipe.

So, let me review the question once again. That one pipe is connected to a rectangular plate of 10 mm thickness. The pipe is undergoing a load P which is unknown and with a torsional force as 6 kiloNewton meter. This torsion is also applied and the force is at a distance of 400 mm from the weld phase. And the pipe diameter is 100 mm external diameter and 80 mm internal diameter. So, these are the things have been given and also the weld size has been given as 8 mm; weld size has been given.

Now we have to find the solution. Solution means we have to find the value of P. That means what will do? We will try to the find out the different type of stresses at different point. Then we will find out the worst condition. Different point means basically we will see if this x point and this is y point. These are the most critical section where the stresses may develop more. So, we will see in both the cases and we will see what should be the load carrying capacity.

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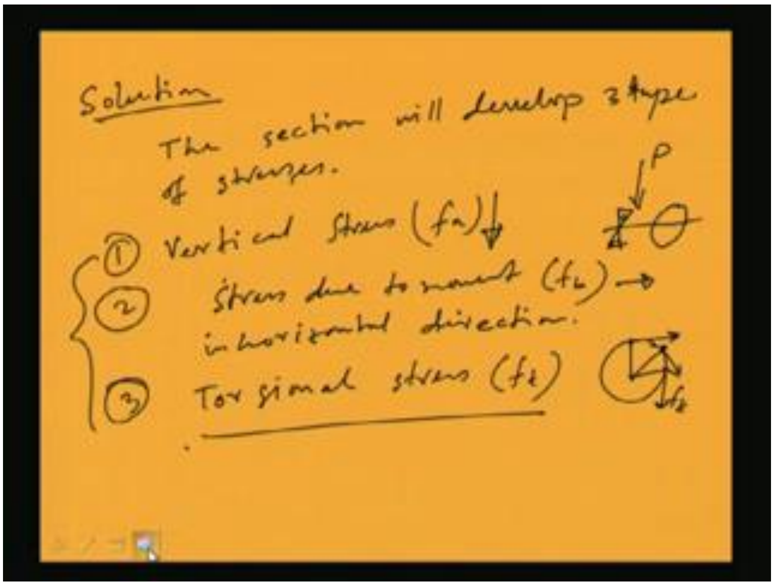

So, if I go for solution, basically, the section will be subjected to three stresses. The section will develop three types of stresses, okay. So, what is those? One is vertical stress f a, one is vertical stress due to the vertical load because P is in vertical, P was vertical direction. So, at every point we will see the vertical stress is there. Another stresses is due to the moment. So, due to moment means stress due to moment that is say f b and this will be if this is the diameter, the stress will develop like this.

And this will be in horizontal direction, always in horizontal direction it will be. So, stress due to moment f b will be in horizontal direction, right. Another is the torsional stress f t. This torsional stress due to torsion will come into picture because torsion is there, and this will act perpendicular to the radius vector. Suppose this is the radius. So, if it is here perpendicular. So, ft will be in this direction. If it is here, it will be in this direction. If it is here, it will be in this direction; like this it will go on.

So, torsional stress due to torsion will be developed. So, these three types of stresses will develop; we have to calculate these three types of stress. Then we can find out the maximum stress where it is coming and accordingly we can find out the allowable load, right.

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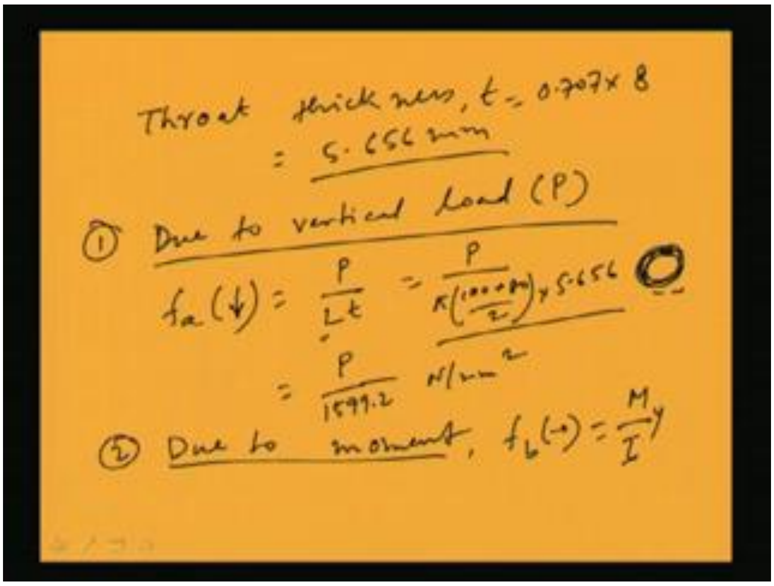

So, what we will do? First is we have to find out throat thickness. So, throat thickness will be 0.707 into S. S is nothing but 8 mm it has been given. So, this is coming 5.656 mm. So, throat thickness we have. Now let us come to the stresses at different point, say, due to vertical load, what will be the stresses? Due to vertical load P, what will be the stresses? Which will be same throughout the section; in every point it will be same. So, vertical stress, say, this will be downward. So, this will be basically P by L into t.

So, P by L means length of the welding. So, L will be basically the total length means this area we have to calculate. So, that can be calculated pi d. L is nothing but pi d. So, pi into d means 100 plus 80 by 2, average of these two into t 5.656, okay. So, the stress due to vertical load can be calculated from this equation which is becoming P by 1599.2 Newton per millimeter square. So, this is one. Another is due to moment. Due to moment what I will do? Due to moment we know f b which will be basically in horizontal direction that will be M by I into y M by I into y M means.

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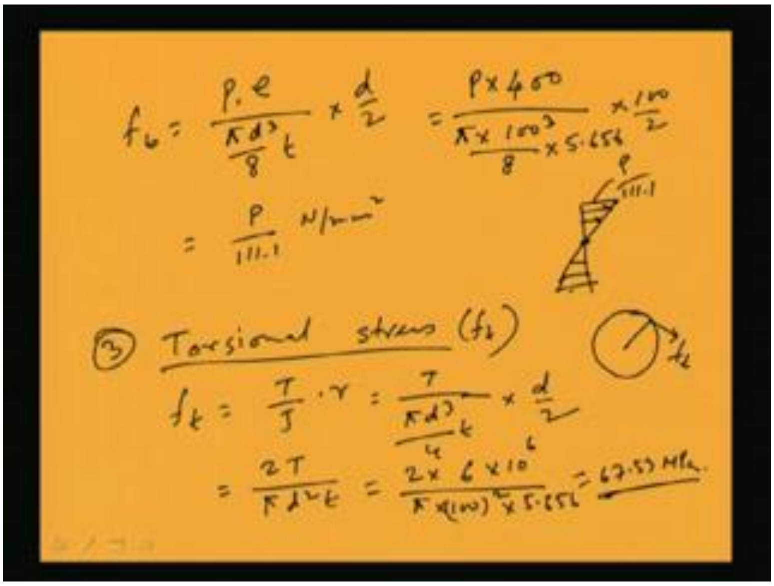

So, f b will be M means P into e by I. I will be for this type of hollow section; this will be pi d cube by 8 into t. This is I and y is d by 2 at the maximum distance. So, this will become P into e is nothing but 400 mm it was into pi into d is 100 by 8 into t is 5.656 into d by 2. So, after calculating this, we are going to get P by 111.1 Newton per millimeter square.

And this stress will be developing as I told if this is the center, then it will be going on increasing towards the end, and this will be the maximum which is P by 111.1. So, this can be found out. Now this stress will be in horizontal direction always. Now we will go for the another stress which is called torsional stress f t. So, torsional stress how it will develop? If we see it will be perpendicular to the radial directions, right. Ft will be this.

So, this f t can be calculated from this formula F t is equal to we know t by j into r. So, t j means basically polar moment of inertia which can be right pi d cube by 4 into t for this case into r means d by 2. So, after simplification, this is coming 2 t by pi d square into t. So, 2 t by pi d square into t is equal to I can write 2 into t is 6 KiloNewton meter it was given.

So, in Newton millimeter, it will be into 10 to the 6 pi into 100 square pi d square into t 5.656. So, in this way I can find out the f t which is coming 67.53 MPa. So, the torsional stress due to torsional moment has been calculated. Now let us see the stresses.

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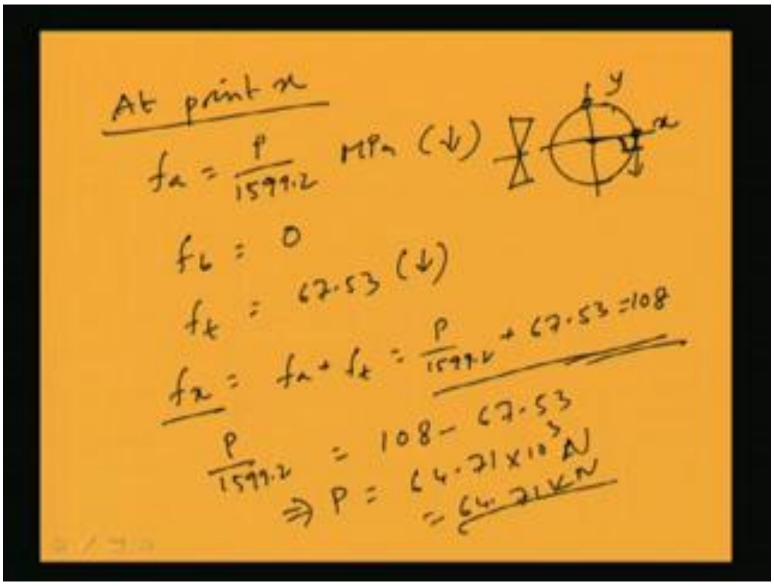

Say, at point x, x means if I see this. This I am denoting as x, and this I am denoting as y. So, at point x, it will be f a is equal to p by 1599.2 MPa which is this direction. F b will be equal to 0, because at this point, the bending moment will be zero. And f t will be 67.53, and this will be f t will be also in vertical because it is perpendicular to the radial distance. So, this should be also okay.

So, I can find out the resultant stress at x, say, f x will be f a plus f t finally; so, P by 1599.2 plus 67.53, okay. And this has to be less than the allowable stress. The stress developed at point x in any case should not exceed the limiting value which is 108. So, if i make equal for critical condition, then I can find out the value of P. So, P by 1599.2 will become 108 minus 67.53. So, from this I can find out the value of P.

So, from this equation P will become 64.71 into 10 cube Newton; that means 64.71 kiloNewton. So, at point x the value which can be taken by the joint is 64.71 KiloNewton. So, the permissible load is 64.71 KiloNewton from the x point of view means at x if you consider.

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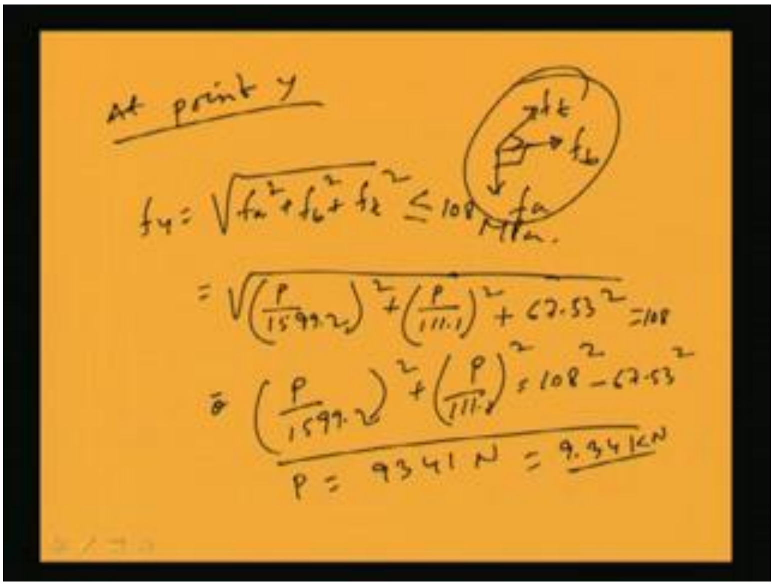

Now at y, now at y what will be? At y, the stress x perpendicular to each other means at y what will happen? This is f b. This is f a, and this is f t. So, these all are perpendicular to each other. In three dimensional figure I am showing here, okay. So, f y will be basically root over f a square plus f b square plus f t square, and this has to be less than 108 MPa. So, f y means stress developed at point y. So, if I calculate now f a is P by 1599.2.

F b is P by 111.1 and f t the torsional stress is 67.53, right. So, this will be the f y value. So, after calculating this and this, we can make as equal to 108 MPa. So, from this if I calculate, I will get P by 1599.2 whole square plus P by 111.1 whole square is equal to 108 square minus 7.53 square, right. So, from this I can find out P as 9341 Newton; that means 9.34 KiloNewton.

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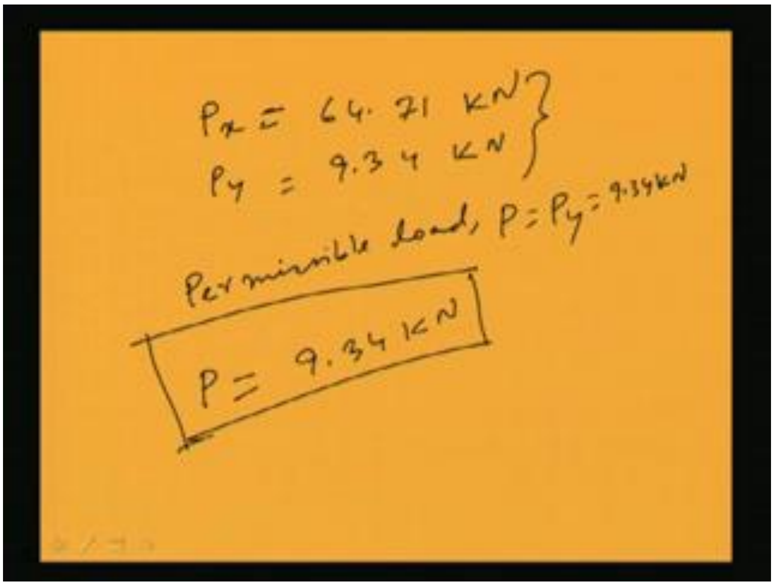

So, at point x we are getting the value as, say, P x if I say, this we are getting 64.71 KiloNewton. And at point y, the maximum load can be taken 9.34 KiloNewton. Now the permissible load what will be the list of these two? That means the permissible load P will become lesser value of P x and P y. That means P y; that means 9.34 kiloNewton. That means the permissible load the P will become 9.34 KiloNewton.

So, what we have seen here that the stresses are developing at different point in different way because its direction. And the magnitude is also changing particularly the stress due to bending moment. Magnitude is changing maximum is at the top or at the bottom. So, accordingly we have to check the point x and y which are most critical and then we can see what is the values are coming.

So, maximum values where it may happen we have checked, and we see that maximum load which can be carried by the joint is 9.34 KiloNewton. So, this is a typical example we have shown how to calculate different type of stress for a particular problem and how to check in a different way that we have shown. But in these cases we have shown that the load is lying to the perpendicular to the joint. So, in this way we have shown.

So, in this lecture basically we have concentrated our material on basically fillet weld, load either lying at the plane of the joint or load lying at the perpendicular to the plane of the joint but using fillet weld. In next class we will see some other example of both fillet weld and butt weld. Basically, we will focus on butt weld and also we will see some more examples on fillet weld.

Thank you.