Course on Design of Steel Structures
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Lecture 18
Module 4
Eccentric Connection (Load Lying Perpendicular to Plane of Welded Joint)

Hello today will be the last lecture on the module eccentric connection, in last few lectures we have seen the design procedure of eccentric connections where load was lying in the plane of joint also load is lying on the plane of perpendicular to the plane of joint in both the case that means in plane loading and out of plane loading.

But one case we have not consider where load is lying perpendicular the plane of joint but the connection is welded connections so toady we will discuss that, that when a welded joint is under eccentric load and load is perpendicular to that welded perpendicular to that welded joint then how to design that joint that will be explained in today's lecture.

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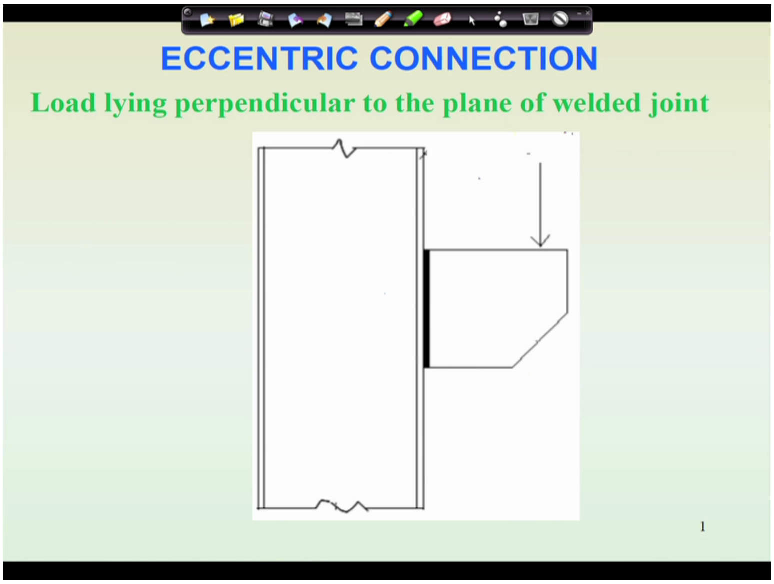

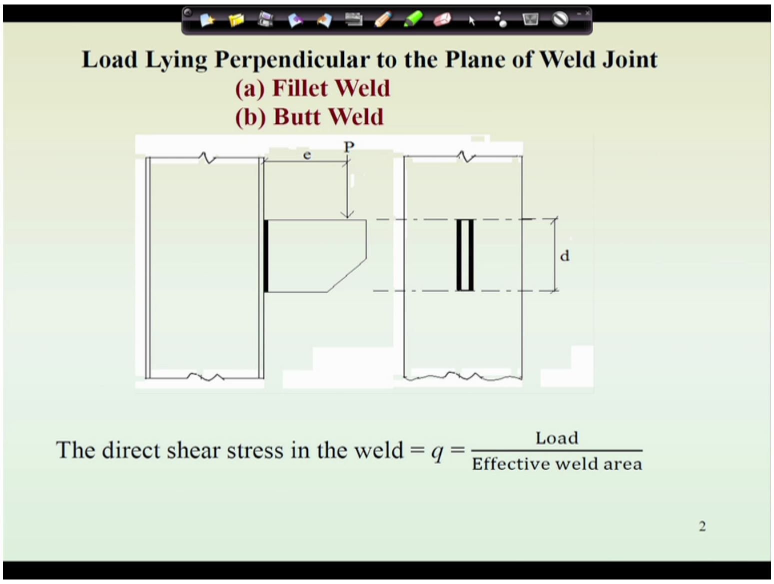

And you know that joint means welded joint means it will be fillet weld and butt weld, the two type of weld joint will be so that we can calculate the stress develop on the fillet weld and stress develop on the butt weld in two cases will come into picture we will discuss two cases.

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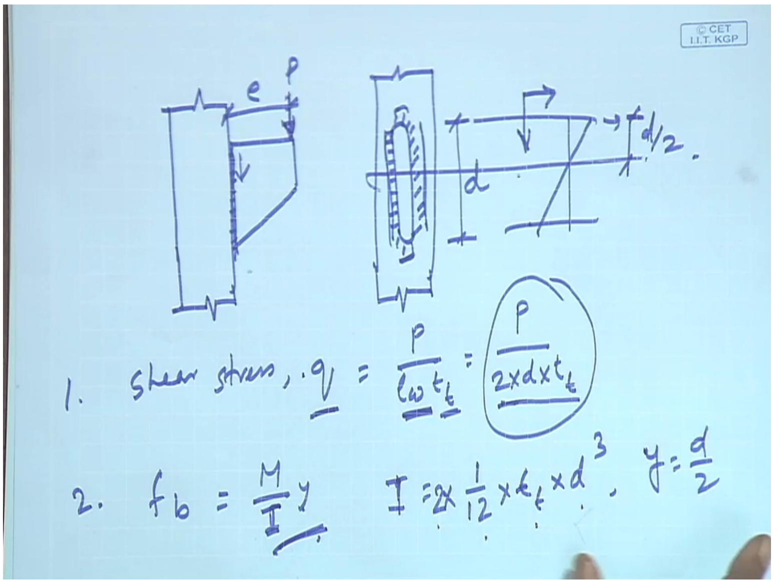

So let us consider the first case that is when a column is loaded with the eccentric load say of e and this P and this portion is of fillet weld this portion is fillet weld means in the plane if we see this will be like this, right. So this will be fillet weld and then we have to find out the stresses stresses means two type of stresses will come into picture in such type of connection one is shear stress and another is stress due to bending, right one will be bending and another will be shear and both will be perpendicular to each other one will be in this direction, another will be in this direction so we have to find out.

So first if we see shear stress shear stress means this is due to direct load load is coming in this direction so shear stress will come. So this shear stress we can find out in the fillet weld as q is equal to P by lw into t, so here lw is the length of weld length of weld will be in this case will be if this is called the length of weld d then we can find out 2 into d into t because in this side d and in this side d so 2d into t, neglecting this width which is very small, ok.

So here P is the applied load with an eccentricity e and d is the depth of bracket plate or welding depth. So lw basically is the effective length of the weld and t means actually t tt throat thickness because strength it calculated on the basis of the throat thickness of the fillet weld, so t into t like lw is the effective width length and tt is the effective throat thickness, right. So q the shear stress we can find out from this formula that is P by 2d into tt, this one.

Second is the bending stress bending stress we can calculate fb stress due to bending that we can calculate that M by I into y, right. So if we see the bending stress will develop in this way and at the center of this it will go, so this will be tension and this will be compression right. So bending stress fb I can find out from this M by I into y, now what is I I is equal to Bdq by 12 means 1 by 12 into B means tt into d cube, right this is I of one one set and in other set also it is so 2 into 1 by 12 into tt into d d cube by d cube sorry, right. So I will be basically 1 by 12 2 into 1 by 12 into tt into d cube and y this y will be d by 2 because this is d by 2, right. So if I put this value here M by I into y.

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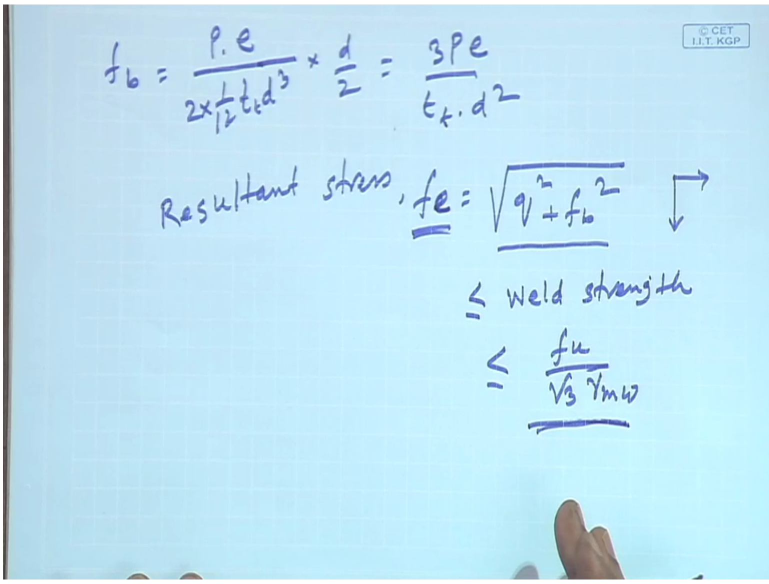

Then I can find out the fb value as M is P into e by I was 2 into 1 by 12 tt into d cube into t by t, so if we find out this value it will be 3 P e by tt into d square right. So 3 P into tt into d square fb, so resultant stress we can find out resultant stress will be fe is equal to q square the shear stress plus bending stress fb square, right.

So resultant stress in the weld will develop as square root of q square plus fb square because both are acting perpendicular to each other and it has to be less than equal to weld strength weld strength means what will be the weld strength that will be fu by root 3 gamma mw that is the strength of the fillet weld fu by root 3 into gamma mw, so we will calculate the resultant stress and then we we can find out what is the strength means permissible stress in the weld and then we can find out whether it is ok or not, right.

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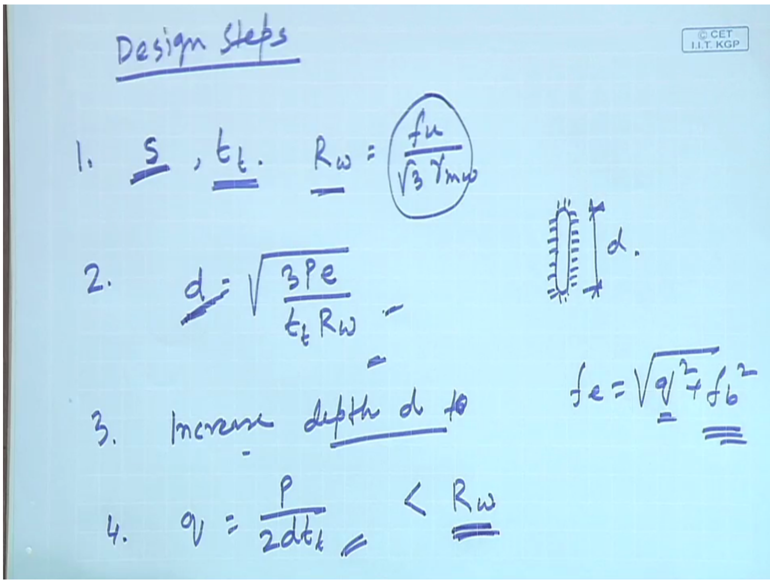

Now we will go to design steps so how to start the design design means basically we have to find out we have to find out the depth of the weld that means weld length we have to find out and we have to assume certain thickness of the weld that is throat thickness or size of the weld.

So these two things we have to find out designing of the weld joint means we have to find out two things one is effective length of the weld that is lw or we can find out the depth of weld then lw we can find out lw will be 2 into d and another is size of the weld from tt throat thickness size of the weld, these two we have to find out but in this case also as it is not known so what we can do we can assume certain size of the weld and we can assume certain depth of the weld then we can go go and we can check whether it is less than or not permissible stress or not that we can check or we can assume certain depth.

And on that basis for a particular throat thickness we can find out the shear stress and the bending stress, then once we find out the shear stress and bending stress we can make equivalent to the weld strength and making equivalent to the weld strength then we can find out what will be the value of tt the throat thickness and then what will be the value of of the size of the weld that also we can find out.

So let us start one by one first we can select a suitable size of the weld size of the weld we can find out first select the suitable size and then we can find out the throat thickness and then we can find out the weld strength weld strength is basically fu by root 3 into gamma mw, right. So first we can find out the size of the weld means we can assume certain size of the weld, we can find out the throat thickness and then also we can find out the weld strength.

Then in second step what we can do we can find out the d value d means depth of weld that is 3Pe by tt into Rw this is what we found earlier means earlier from earlier equation we could see that d value can be found d means the depth of the weld, this portion right. So depth of the weld we can approximately calculate. So this we can calculate and this depth has been calculated from the moment point of view due to bending moment.

Now also we have shear so we have to increase depth d to a certain percent to accommodate the shear stress so what we will do that we will increase the whatever depth is coming we will increase to a certain amount amount so that the shear stress also can be accommodated because the equivalent stress fe will be simply q square plus fb square, now on the basis of fb if we do then q also has to be taken care. So therefore we are increasing depth to accommodate the both the stress.

In next step what we can do we can find out the direct shear stress that is q q we know we can find out from P by 2d into tt from this we can find out and it has to be less than Rw, right Rw means what Rw is the weld strength. So it has to be less than the weld strength, right.

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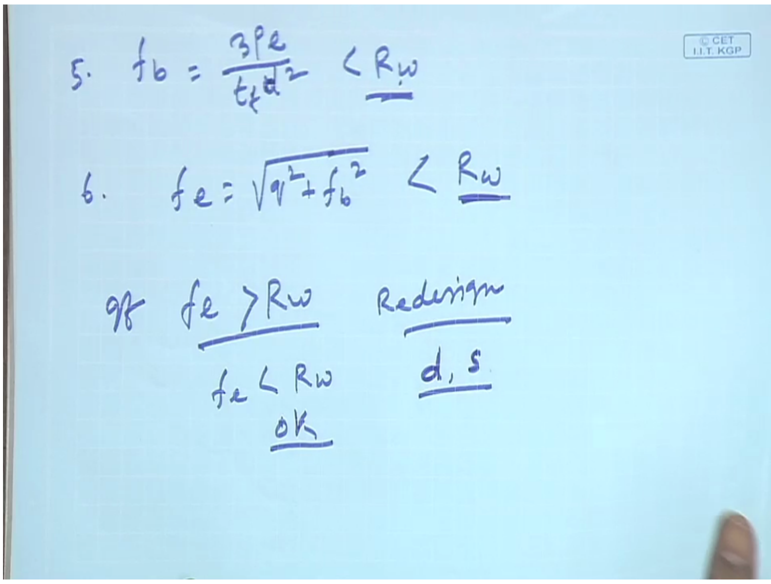

Then we can find out fb fb fb also has to be less than 3Pe by tt into d square right and it has to be also less than Rw means weld strength individually both the components has to be less than Rw and obviously it will be less than Rw otherwise we have to increase the size of the weld or we have to increase the depth, right.

In next step we can find out the fe which is the equivalent stress due to shear and due to moment, so due to bending and due to shear the equivalent stress we can find out and it has to be less than the combined force has to be less than the weld strength, so this is what we can do. If we see if fe is greater than Rw then we have to redesign redesign means what we will do we will increase the depth or size either of this depth of the weld can be increased or size of the weld can be increased to ensure the safety of the joint that means when fe will be less than Rw then it is ok, right.

So unless it is satisfying this criteria we have to go on increasing the depth of weld or size of weld or both to make sure that design is ok, right.

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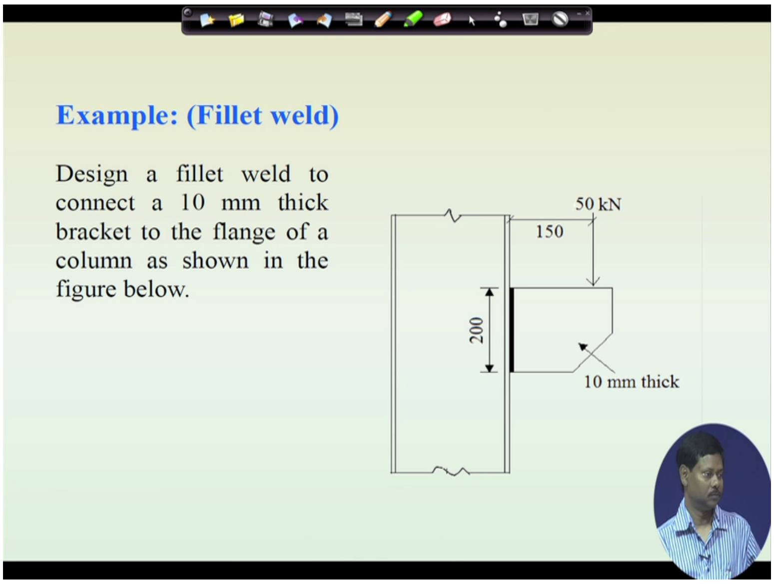

Now we will go through one example to understand this this is the example. So here if we see that a bracket is connected to a column with a 10 mm thick means thickness of bracket was 10 mm, load is consider as 50 kilonewton at a distance of 150 and depth is given means 200 now design a fillet weld that means here depth is given you have to find out the size of the weld, ok.

There are three cases we will come either size of the weld is given you have to find out the depth or depth is given you have to find out the size of weld or depth and size of the weld is not given nothing is given you have to find both. So in case of finding both we have to go for try learn error means we have to assume certain size of the weld from the basis of the thickness etc minimum size of the weld and from maximum size of the weld, we have to find the suitable size and then we have to find the depth and then we have to check. So both cases can be done, right.

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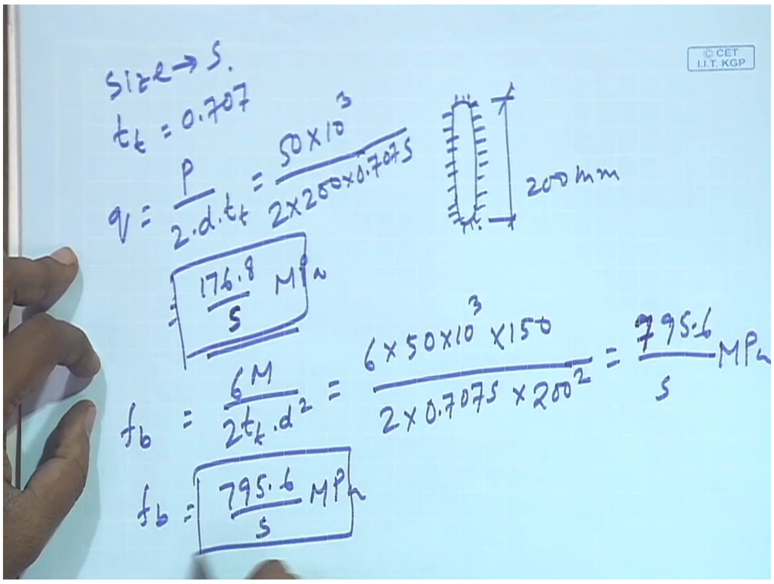

So in this case if we see in plane this d is given as 200 and this weld we do not know the size but depth is known so if we consider size of the weld as S then we can find out thickness of the weld as 0.707S, right so now if we find out the shear stress q q will become P by 2d into tt, so by putting the value P is 50 kilonewton by 2 into d d was given 200 and tt basically 0.707S right. So from this we can find out as 176.8 by S MPa. So shear stress are coming which is vertical shear stress are coming 176.8 by S MPa.

Now horizontal shear stress due to bending fb horizonal shear stress will be how much that will be 6M by 2 into tt into d square, so that if you if we find out that 6 into M means P into e, P is 50 into 10 cube, e is 150 by 2 into d is 200 d square. So after calculation of this we can find out the value as 795.6 by S 795 795.6 by S MPa, right. So fb also we could find out as 795.6 by S MPa, so q is found, fb is found.

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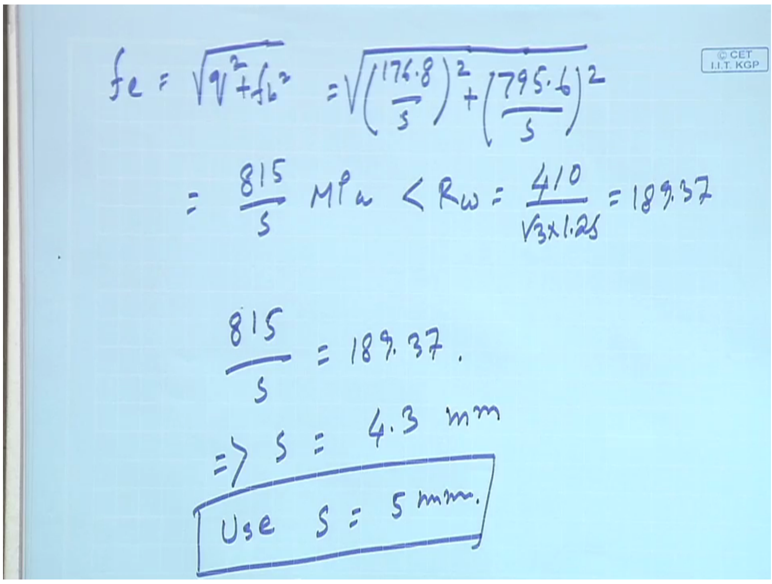

Now we can find out the equivalent one. So equivalent one will be fe will be equal to q square plus fb square, so if we put this value 176.8 by S the shear stress vertical shear stress and this is 795.6 by S is stress due to bending and if we calculate we will find out 815 by S and it has to be less than Rw Rw is the fu by root 3 gamma mw that means fu by root 3 into 1.25 that means 189.37.

So by calculating 815 by S as 189.37 then we can find out the value of S S will become 4.3, right. So we can adapt a weld size of 5 mm (()) (18:42) 4.3 mm we cannot provide, so use S as 5 mm. So what we have seen in this example that the depth of weld is given but size of weld was not known so designing this what we have found we have assumed certain size of weld and then we have make equivalent the external means equivalent stresses equivalent stresses due to external forces equal to the weld strength. So by making equal of this we could find out the size of the weld, right.

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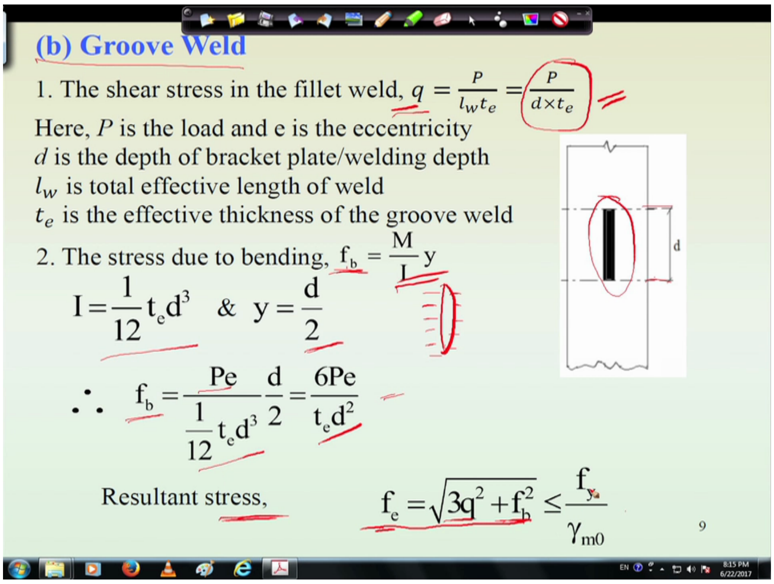

Now the second case is groove weld as I told there are two case one is fillet weld another is groove weld so in case of groove weld you see here the weld has been done by grooving in the plate. So here if we consider the depth of weld as d and thickness as t then we can find out the shear stress and the bending stress in a similar fashion. You see here q is P by lw into te that means here P by d into t not 2d.

In earlier case what we have seen earlier case we have consider 2d because in two places in two site periphery in periphery the weld joint has been done by fillet weld but in case of groove weld this will be only d so q we can find out from this formula that is P by d into te.

Similarly the fb the stress due to bending I can find out as M by I into y, where I is equal to 1 by 12 into te into the cube, here remember the t is the effective thickness of the groove weld right and y is equal to d by 2. So in a similar fashion if we provide means if we put the value of M by I into y, where M is equal to Pe into e and I is equal to 1 by 12 into te into d cube and y as d by 2 then we can find out fb as 6 Pe by te into d square fb as 6 Pe into te by d square, you can remember that in case of fillet weld was 3 Pe by te into d square 3t into the square, right.

And resultant stress is for groove weld we know that fe is equal to square root of 3q square plus fb square and it has to be less than fy by gamma m0, where fy is the yield strength, right not the ultimate strength. So resultant strength we can find out resultant stress as feature that is root of 3q square plus fb square and it has to be less than fy by gamma m0, we can calculate the equivalent stress.

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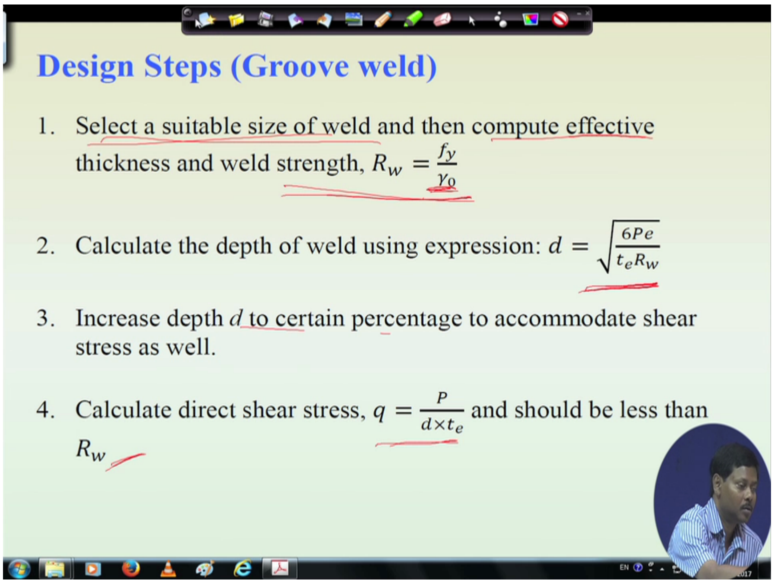

Now coming to the design steps, so for designing a groove weld if we see in a similar way we can move forward that is first we can select the size of the weld suitable size of the weld and then we can compute the effective thickness effective thickness of the groove weld can be found from the thickness of the member means if two plates are joint together then from the thickness of the member thickness of the thinner plate or in what way it is connected we have to see from that we can find out the groove weld thickness.

And also whether it is fully grooved or partially grooved that also we have to see and then we can find out the thickness of the weld and then we can find out weld strength also weld strength is basically Rw here will be fy by gamma m0, gamma 0, ok. So sorry this will be gamma m0 fy by gamma m0. Now we can calculate the depth of weld using expression d is equal to this square root of 6 Pe into te into Rw, earlier we used 3 Pe in case of fillet weld. So please remember this difference.

Now d we can find out again this d also can be increased to a certain amount to accommodate both the stresses then we can find out the actual stress coming in the weld that is q is equal to P by d into te, right and it should be less than obviously Rw if it is not then we have to increase the size of the weld or depth and similarly we can go for calculation of the bending stress.

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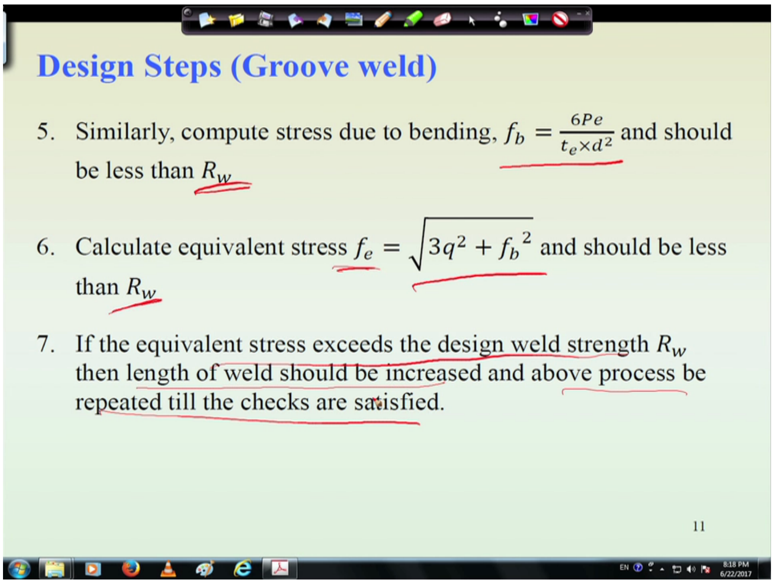

So bending stress also we can find out from this formula that is fb is equal to 6Pe by te into d square, so and depth also has to be less than Rw and then we can find out the equivalent stress equivalent stress will be square root of 3q square plus fb square and that has this equivalent stress has also has to be less than Rw.

So now if the equivalent stress exceeds the design weld strength then the length of weld should be increased and above process be repeated till the checks are satisfied which is as usual that means if the design strength is less than the equivalent strength or in other way if we see the equivalent strength is coming more than the permissible stress then we have to redesign redesign means we have to increase the weld length or weld depth or weld thickness then again we have to redesign and we have to check whether it is ok or not, if it is not ok again we have to go for the same steps.

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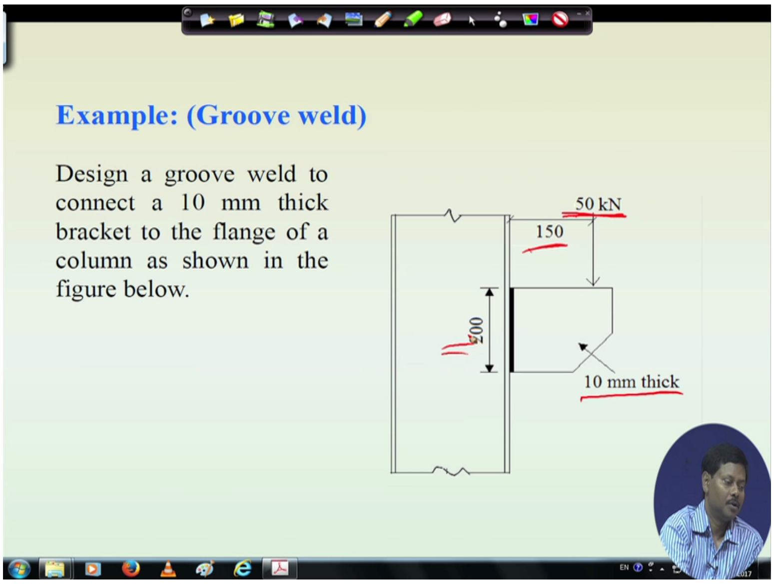

Now the same example which has been consider earlier will be done using the groove weld, right here if you see the example is exactly same that 150 means 50 kilonewton load is provided with 150 mm depth and same sort of bracket plate that is 10 mm thick bracket plate and also the depth is given that is 200 mm depth is given. So the example which we have done earlier the same example has been considered and in this case only difference is that we are using groove weld. So if we use groove weld how to design the connection that we will see.

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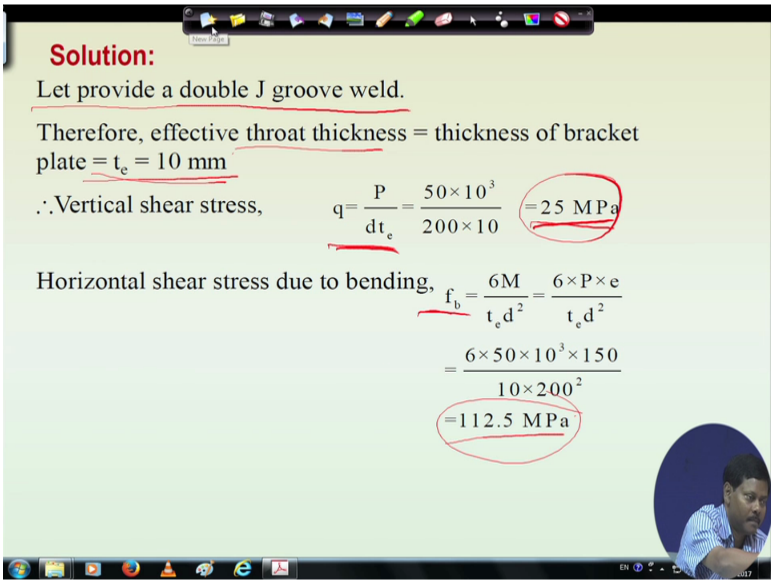

So here we can assume single or double groove weld so for example in this case we have consider the double J groove weld. So as it is double J groove weld, so what will happen means effective throat thickness will be the thickness of the bracket. So in this case thickness of the bracket is 10 mm, right so as it is a double J groove weld, so the thickness means effective thickness of the groove weld also will be 10 mm.

So if this is 10 mm then vertical shear stress we can find out that q is equal to P by d into te, so vertical shear stress we are getting 25 MPa, again the horizontal shear stress due to bending fb we can find out that is 6M by te into d square, if we put the value of individual parameters like 6 into M means 50 into 150 by te is 10 and 200 is d, so if we put those value we will get the horizontal shear stress due to bending as 112.5 MPa.

So what we see the vertical shear stress we are getting this and horizontal shear stress we are getting this.

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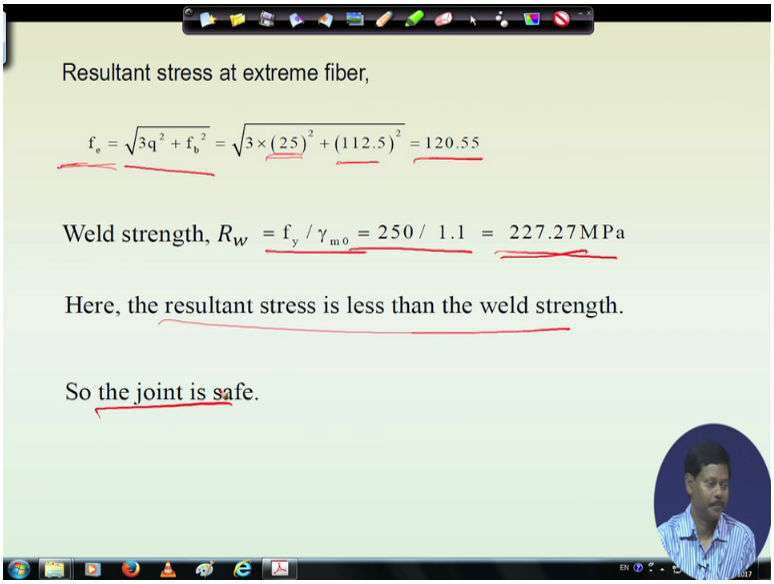

And of course we have to see what is the permissible stress permissible stress is fy by gamma m0, right permissible stress is we can find out fy by gamma m0 that is 250 by 1.1, so that is 227.27 MPa which is more than the individual stress due to shear shear stress and bending, ok.

Now the resultant stress at the extreme fiber will be square root of 3q square plus fb square. Now if we put this value q was coming 25 and fb was coming 112 so the resultant is coming 120.55, right. So if we put this means if we find the equivalent strength then we could see that the equivalent stress is much less than the weld strength. So the resultant stress is less than the weld strength that means the joint is safe, right.

So in this way we can design that means here what was given the length of weld was fixed length of weld or depth of weld was fixed and the thickness is also fixed because it was a double J groove weld and so the effective thickness was also fixed. So what we need to do here is the equivalent stress we have to find out and that equivalent stress whether it is less than the strength permissible strength or not that we have to check, if it is ok then find, if it is not ok then design is not safe.

However if the depth is not given then we can find out the depth also by try learn error method the way we have discussed earlier in the same method we will find out the approximate depth and then we can check whether it is ok or not, if it is requirement is means the equivalent stress is much less than the weld strength then we have to decrease the depth and we have to check again and if equivalent stress is more than the permissible stress then we have to increase the depth of the weld so that we can accommodate it.

So this is how we can find out the design strength of weld and we can find out the equivalent stress of the weld and we can check. So in last few lectures we have discussed the eccentric connections and in eccentric connections two type of connections will come basically one is due to in plane loading another is due to out of plane loading, in case of in plane loading we have seen what are the stresses we will develop and how to design and in case of out of plane loading also we have seen what are the stresses are coming and what are the equivalent stress and how to design, right.

And we could see here in all the cases the design procedure is basically a try learn error method we will assume certain parameters then we can find out the stresses developed on the joint whether it is bolt joint or weld joint, whether it is butt weld or fillet weld and then we have to see whether it is exceeding the permissible limit or not, if it is not exceeding the permissible limit then design is fine otherwise we have to redesign with the increase of number of bolts, diameter of bolts, or weld thickness, weld depth, etc as per the case required so this is how we will do.

So with this I would like to conclude the entire lecture of eccentric connections. In next class we will discuss about the design of tensile member, thank you.