Course on Design of Steel Structures
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Module 4
Lecture No 16
Eccentric Connection (Load Lying Perpendicular to Plane of Bolted Joint)

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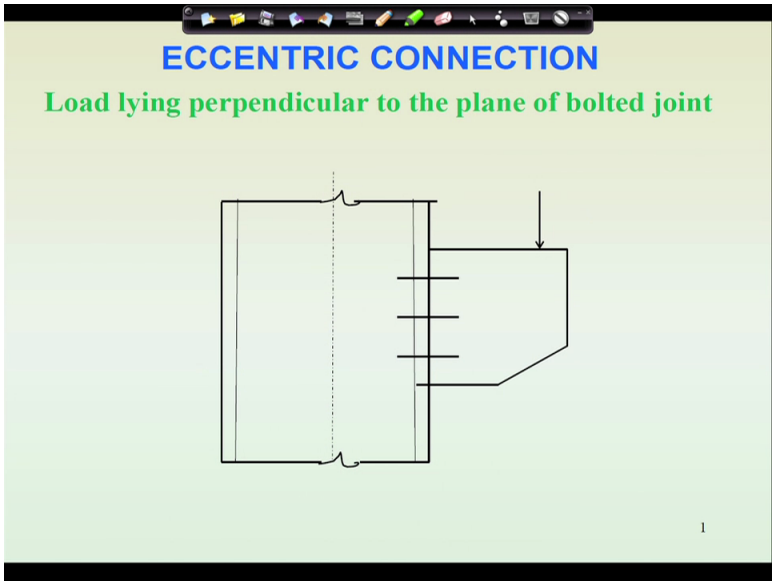

Hello and today we are going to discuss about the load line perpendicular to the plane of bolted joint, that means when loaded in out of plane then how reactions on the bolt will be coming in to picture that we will try to understand and in each bolt we know that due to this eccentricity of the load the moment will come in the bold group as well as direct force will come. Now as it is out of plane loading that is why here if we see the 2 type of stresses will develop. One is the shear stress due to direct load and another is the tensile stress due to moment.

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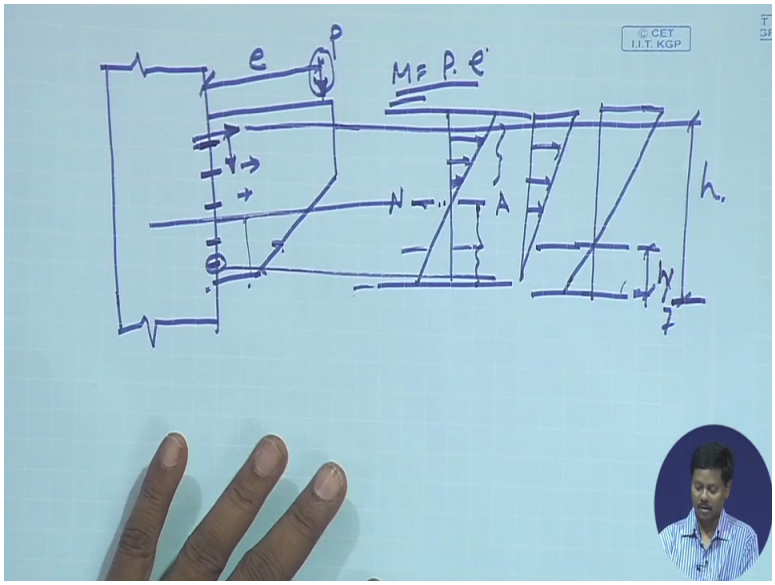

So if we draw the diagram say for example a bolt group is connected with certain bracket say for example this is connected here and we have bolt group at different positions. Now a load of magnitude P is acting at a distant of e so moment will be basically P into e, this moment will come into picture and because of this P the shear stress will develop in this direction and because of this moment another force tensile force will come in this direction and we know this tensile force will be in this top portion and in bottom portion there will be compressive force.

If we draw the stress diagram this will develop in this way, may be this way. Now where will be the center of line center of rotation that means the neutral axis, so there are different opinions for finding out the neutral axis because it will not be at the sigi of the bolt group. This is because this portion this bolt means bolt lying on the above the neutral axis will be in tension but in this portion this portion the bracket if we see draw this the bracket is going to take the compression, so they amount of compressive force will be huge in this direction compared to the bolt force in as a tension therefore the center of rotation cannot be at the center of gravity at the mid-point. It will be somewhat below the midpoint somewhat here but where it is, how to find out?

Another opinion has come that it may be at the bottom of the (())(3:27) bottom of the bolt but this is also not true because the bottom (())(3:33) of the bracket and the tension are not perfectly (())(3:38) so if it is not perfectly (())(3:40) we cannot consider that all the (compliments) all that bolts are going to be carry by carry out by the tension, this is not also practicable, so what it is come across that we actually we need to make some trial and error.

Trial and error means we have to find out where it can lie so through trial and error analysis we can find out otherwise there is an opinion that we can consider at a distance of h by 7, where h is the height from the topmost bracket sorry for the most bracket to the top most topmost bolt position that means this, this will be h, right so this will be h by 7. I am drawing once again if I see bolts are there say for example these are the bolts.

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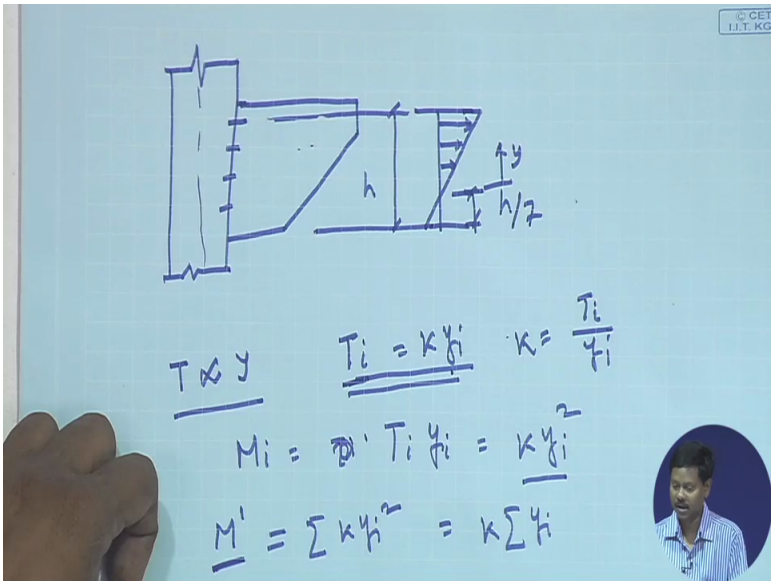

Sorry I am going another page, say this is the bracket and if we have if we have a bracket connected to in this tension and bolts are like this then h will be the bottommost bracket to the topmost bolt which are in tension, so this is h and the stress development will be happening somewhat like this where this neutral axis will be lying at a distance of h by 7, these are the assumptions. So if we consider the neutral axis at h by 7 then we can find out the total tensile force on the on the bolt and total compressive force on the bracket, so and we can make equal to find out the equilibrium equation.

So the assumption is here that the tensile force develop on the bracket will be proportionate to the distance from NA, that means t will be meeting with distance at NA, say if this is distance y then t will be vary with y or I can write Ti is equal to K into yI. Where Ti is the tensile force developed at i bolt and yi is the perpendicular distance from center of rotation or from neutral axis to that center of the particular bolt.

So this is what we can assumed and then we can find out the constant which is called elastic constant or proportionality constant that I can write as ti by yi and because of this the moment we can find out movement of individual group means due to individual group moment

develop will be ti into ti into yi, so that will be k into yi square because ti is equal to again k into yi, so kyi square, so total movement of resistance provided by the bolt group due to tension if I write M dash then this will become summation of kyi square where i equal to 1 to n means n is the number of bolt facing on tension so k into yi square that means we can write k into summation yi square. So movement of resistance provided by the bolt intension we can write down in this way.

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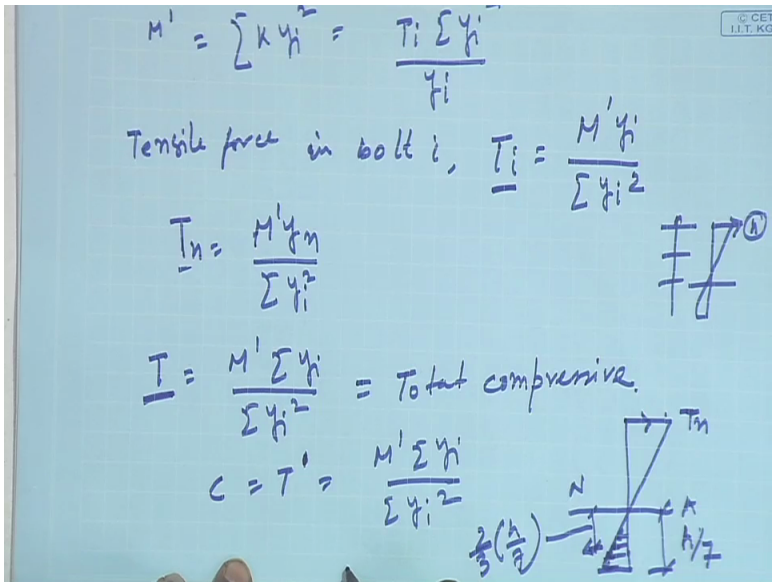

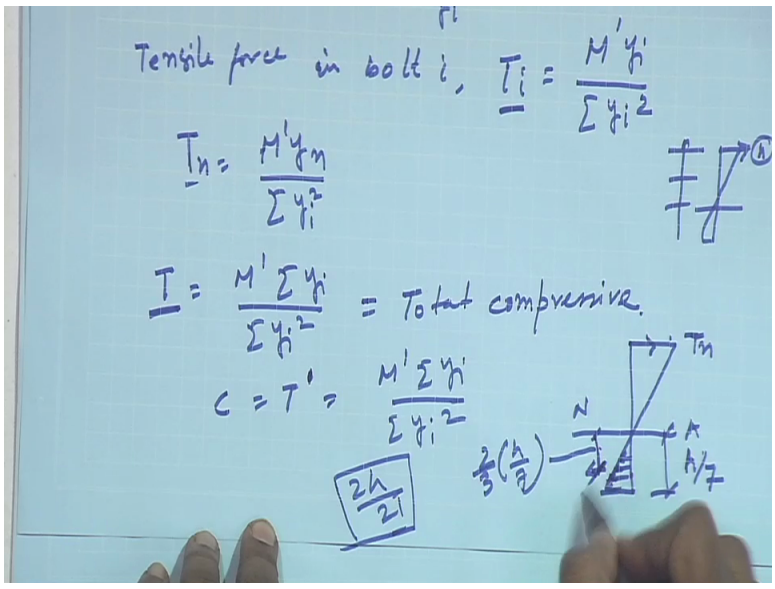

So therefore we can find out the value of moment in terms of its tensile force that means I can write movement is equal to summation of kyi square that means this I can write as Ti into summation yi square by yi, right. So tensile force means the Ti tensile force in bolt i, I can

find out as Ti is equal to M dash yi by summation yi square, right. So we can find out the tensile force at i bolt will be M dash into yi by y yi square summation of yi square.

Now tensile force at the extreme bolt that I can find out in this way also M dash into yn by summation yi square, extreme bolt means if we have bolt in this direction different direction then at different position and if this is the neutral axis then this is the maximum tensile force develop in the bolt, so if at n position n number of bolt then Tn will be M dash yn by yi square, right. So for equilibrium equation we can find out that this T means this total force in tension we can find out that T is equal to M dash into summation yi by summation yi square.

This is the total tensile force exerted by the bolt and these has to be equal to the total compressive force because we know about neutral axis the total tensile force and total compressive force has to be equal, so total compressive force I can find out indirectly from this equation that is C is equal to be can find out the same C is equal to T is equal to M dash yi by summation yi square, right.

And this C will be acting means if I draw the stress distribution this is the neutral axis and this is the extreme bolt where tensile force Tn is developing and here this is this portion is compressive force and carried by the bracket so this will this distance has been assumed that h by 7 while h is the total distance from bottom bracket to the center of the topmost bolt h by 7 so the sigi of this distance will be this much and that will be 2/3rd h by 7 2/3rd h by 7.That means it will be acting at a distance of 2h by 21, 2h by 21. So the sigi will act at 2/3rd of (()) (11:26) that means 2h by 21.

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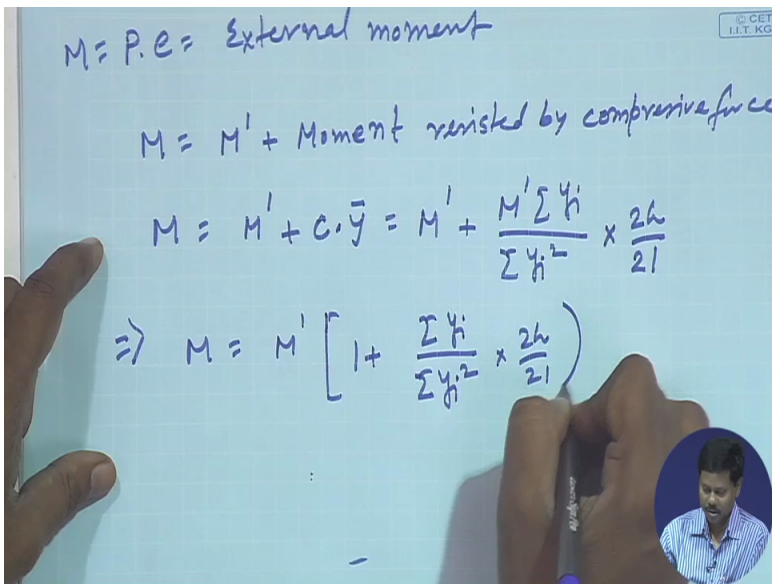

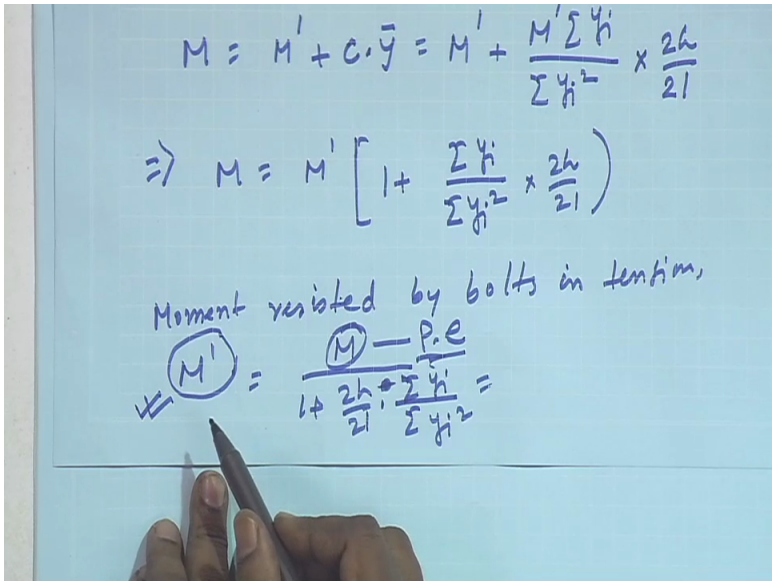

Now we can find out the external movement which is P into e, P into e is the external moment and this external moment we can equal with the moment resistance by the bolt in tension and compression. That means total moment I can find out that moment resisted by the bolt intension that is M dash plus moment resistance by the compressive force moment resisted by compressive force, right.

So this will be the total moment, that means M will be equal to M dash plus C is the total compressive force into y bar, y bar is what? y bar is 2/3rd of h by 7 that means I can find out M dash plus C we can we found already that is M dash into yi by summation yi square, which is nothing but the total compressive force or the total tensile force and into 2h by 21. This is the sigi distance of the compressive force from neutral axis, right? So from these I can find out M is equal to M dash into one plus submission yi by summation yi square into 2h by 21, right.

Therefore I can find out the M dash, M dash is basically moment resisted by the bolt intension, so moment resisted by bolt in tension that is M dash that I can write M dash is equal to M by 1 plus 2h by 21 into summation of yi by summation of yi square, so this is what I can find out. That means what we found here that this M is basically p into e that actual load means sorry the particle load which are coming into at a distance of e from the interface of bracket and (())(14:23) so this pe is the total external movement and M dash is the moment resisted by the bolt intension.

So the moment (())(14:33) by the bolt in tension can be found in terms of its external moment that is M dash is equal to M by certain factor, right so where M is the total moment means

external moment and M by 1 plus 2h by 21 into summation yy yi by summation yi square, so that means the fraction of moment taken by the bolt group will depend on the position of the bolts that yi and yi square. Number of bolts position of the bolt and depending on that we can find out what is the fraction of moment is carrying by the bolts, so this is how we can analyze.

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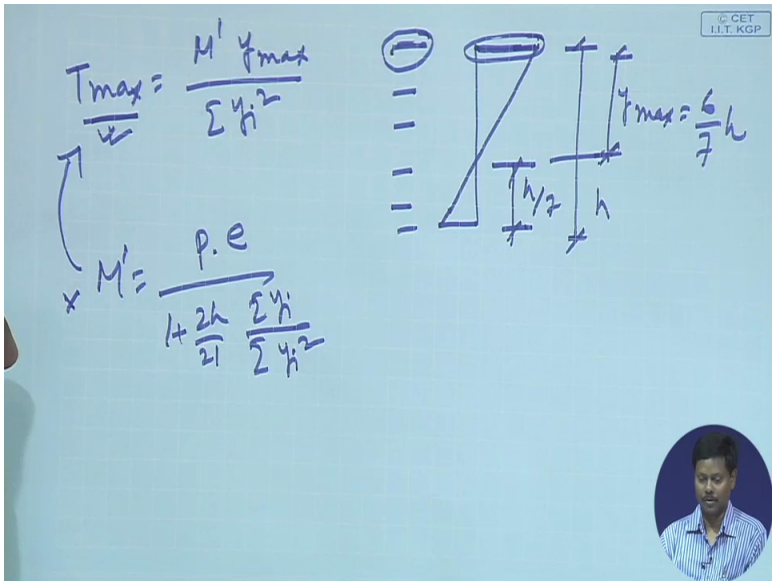

Now we will find out the maximum tensile force at the bolt, what will be the maximum tensile force? Maximum tensile force will develop at the extreme bolt that means if we see. This is h by 7 and total is h and if we see here that bolts are in this position 1 this position like this it is somewhere here. Now the maximum tensile force will develop on the extreme bolt because we told that bolt tension is assumed to be proportional to the distance from the neutral axis. So it will vary with distance that means the maximum will develop in this extreme bolt and that I can calculate T max as M dash into y max by summation yi square right, so from this formula y max is this one.

This y max will be this one and this value will be nothing but 6 by 7 into h 6 by 7 into h because y max will be if this is h by 7 then this will be 6 into 7 into h right. So maximum tension in the bolt I can find out from this formula and where M dash already we have found out M dash will be is equal to p into e by 1 plus 2h by 21 into summation yi by summation yi square. This will be the M dash, so this is how we can mean M dash right so once I found out M dash value then I can find out the maximum tensile force on the bolt, right.

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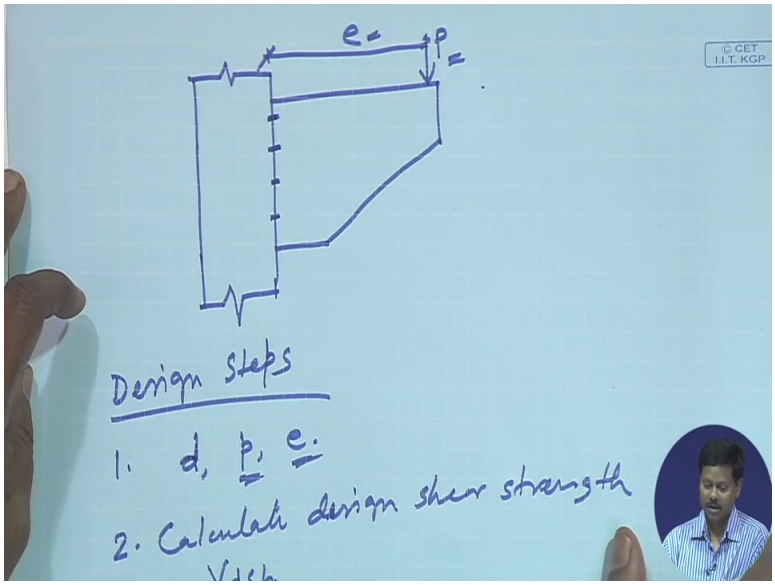

Now I will go to the design steps means I did not know. I have been given a tension and which is connected to a bracket and then this bracket is carrying an means eccentric load of say p at a distance of e. Now what should be the number of bolt means I do not know what should be the number of bolts, I have to find out. So if p and e is given then how to find out the number of bolts. So how to start with, so what we can do we can write as design steps, so 1st what we will can do that we can select a nominal diameter of bolt means when selected diameter of bolts.

1st the diameter of bolts we have to select because on that basis we can select the p distance and h distance. So p distance and h distance as per the (())(18:30) we can find out so d will means according to the nominal diameter we can find out p 2.5 d and e is equal to 1.5 d 0 like this, right. Then we can find out in next step we can find out the design shear strength, calculate design shear strength. This design shear strength be the (())(19:02) calculate as per the nominal diameter we can find out the design shear strength due to sharing and other actions, so BDSP can be found.

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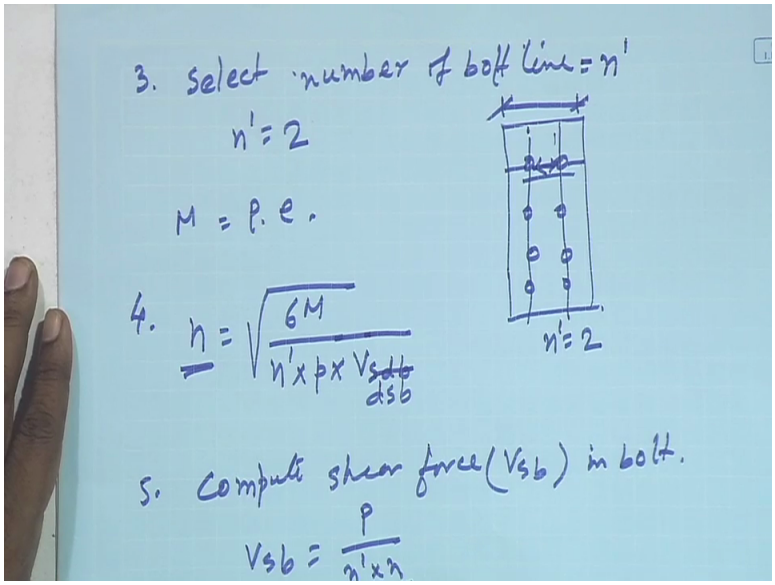

Next in 3rd stage we can select the number of bolts, how do we select? Select number of bolts. Now select number of bolt line that means in plan if we see then how many number of bolt line will be there, so in this case this is one this is another line, means in this case in n dash will be 2, so number of bolt line N dash we can select. This depends number of bolts line we can decide on the basis of this width, what is the width available and we have to provide certain n distance and certain gaps the spacing which have to provide and accordingly either we can provide good to bolt line or 3 bolt line means as per the type of structure means (()) (20:13) of member we are going to select depending on that we have to decide number of bolts.

Generally we consider number of bolts as 2 in general and then once we know this we can find out moment, External movement due to eccentricity that also we can find out. M will be equal to p into e. In next step we can find out the number of bolt per line approximately from this formula. This formula is known to you from the earlier class lecture when bolt groups are subjected to load eccentric load then how to find out the number of bolts when sorry when bolts are subjected to means in plane load then how do calculate the number of bolts per line that also we have discussed earlier.

So in the similar fashion we can find out here the number of bolts per line from this formula that is n is equal to root of 6M by n dash into p into Vs Vsdb sorry Vd Vdsb the (())(21:43), right. Then we can find out shear force in the bolt, compute shear force that means what is the shear force coming in the bolt Vsb that we can find out in bold, that to be how much the assumption is that each bolt are carrying equal amount of load. So if the total load is p and

total number of bolt is l then we can find out what is the force coming in the each bolt that is Vsb. That will be total number of P by n dash into n, where n dash is equal to number of bolt line and n is equal to number of bolts in each line, so from this we can find out the Vsb value.

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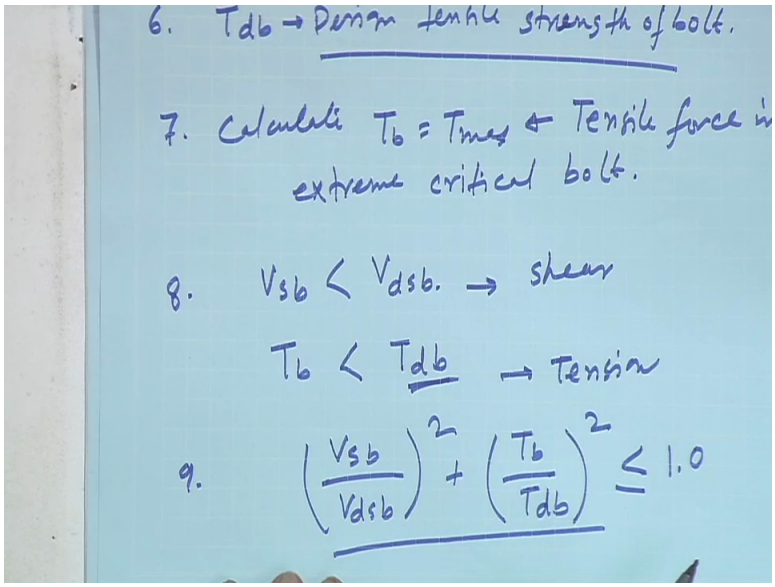

Next in 6 state we can find out the design tensile strength of bolt Tdb, Tdb is a design tensile strength of bolt, so design tensile strength of bolt also we can calculate then what we can find out we can calculate what is the tensile force on the extreme critical bolt, the Tb that means T max basically Tb is T max earlier we have calculated the T max that is tensile force calculate Tb, this is tensile force in extreme critical bolt, right.

So this we can make next we have to check whether Vsb the shear force develop on the bolt individually it should be less than the design shear force on the board Vdsb and Tb the maximum tensile force in the bolt that should be less than Tdb, this is the design tensile force on bolt and then hear what we can see one is shear this is shear and this is tension, so also you have to check, you have to check again combines shear and tension using the interaction formula that is Vsb by Vdsb whole square plus Tb by Tdb whole square that should be less than equal to 1. So once this is checked that means the assume number of bolts are okay, assume diameter of bolts are okay, so this is how we can go for a design steps, rights.

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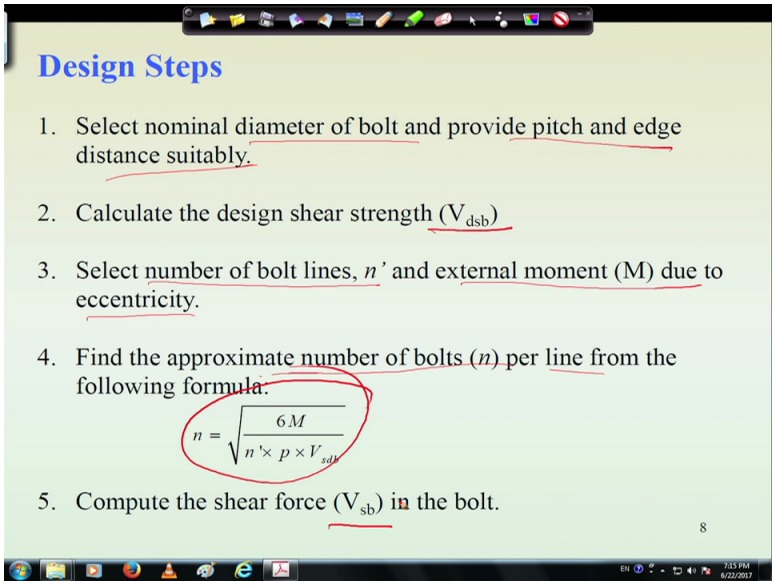

So to summarise this once again I will go through this in the slide that is the design steps will be 1st we will decide the luminal diameter of bolt and then provide. 1st we will select the luminal diameter of bolt and provide which an edge distance suitably. Then we will calculate the shear strength Vdsb, what I have discussed that I am repeating once again to remember the design steps so that we can properly designed the bolt group when the load is in out of plane to the bolt group.

Then now select the number of bolt line that is n dash and the external moment we can calculate due to a centricity of the load. Then we can find out approximate number of bolts per line from this formula n is equal to square root of 6M by n dash into p into Vsdb. So we have to remember the design steps one by one so that I can find out suitably. Then one we can go for calculation of the shear force in the bolt.

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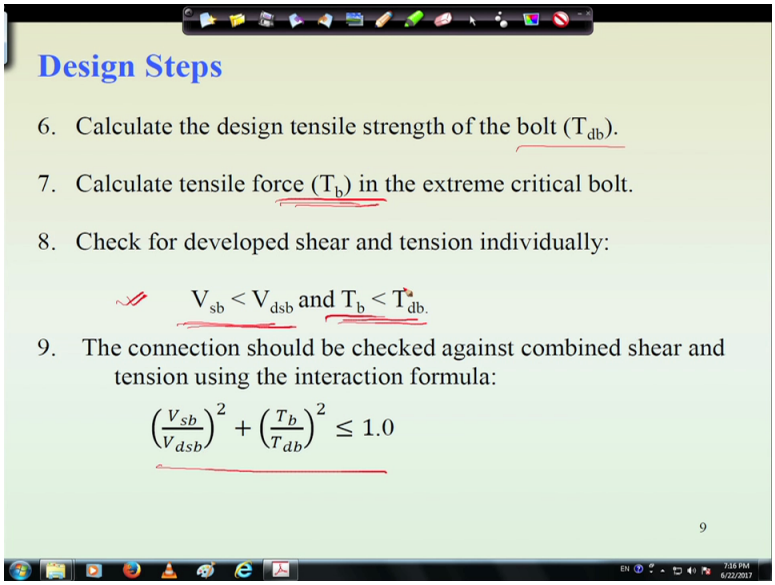

So once we calculate the shear force we can go to next step that is calculation of the design tensile strength of the bolt Tdb, that we can find out and next we can find out also the Tb, Tb is the tensile force on the extreme bolt, that means the topmost bolt which will carry the maximum tensile force, so Tb once we find out then individually we can check that Vsb has to be less Vdsb and Tb has to be less than Tdb and also you have to check the combine shear and tension using this interaction formula that is this Vsb by Vdsb whole square plus Tb by Tdb whole square less than equal to 1.

So if we find that Vsb is more than Vdsb or Tb is more than Tdb then we have to go for 2 nd round of interaction that means we have to go for we have to increase the number of bolts per bolt line. So if we see that individually the shear forces due to the load or tensile force due to the moment is more than the design capacity of the bolt intention and shear, then we have to increase the number of bolts or we have to increase the diameter of bolt, whatever feels suitable we can do likely means accordingly.

Then we have to ensure that Vsb is less than Vdsb and Tb is less than Tdb, that means the shear force coming on the bolt which is P by n should be less than the shear force coming on the means should be less than the design shear force, shear strength capacity and similarly the tensile capacity Tdb of the bolt should be more than the tensile force coming onto the extreme bolt, that individually we have to check.

Also we have to check the interaction formula, that means as the bolts are exerting shear and tension simultaneously means at a time, so we have to check for combine shear and tension

and if it is not less than 1 then again we have 2 increase the number of bolts or we have to increase the diameter of bolt and then we have to recheck all the things once again and we have to make sure it is coming less than 1. So this is how we can go for design, design is basically a trial and error method, so we will start with an approximate number of bolt per bolt line, then we will check whether it is okay or not. If it is not okay then we have to again increase the number of bolts, so it is an (())(29:22) process. Thank you.