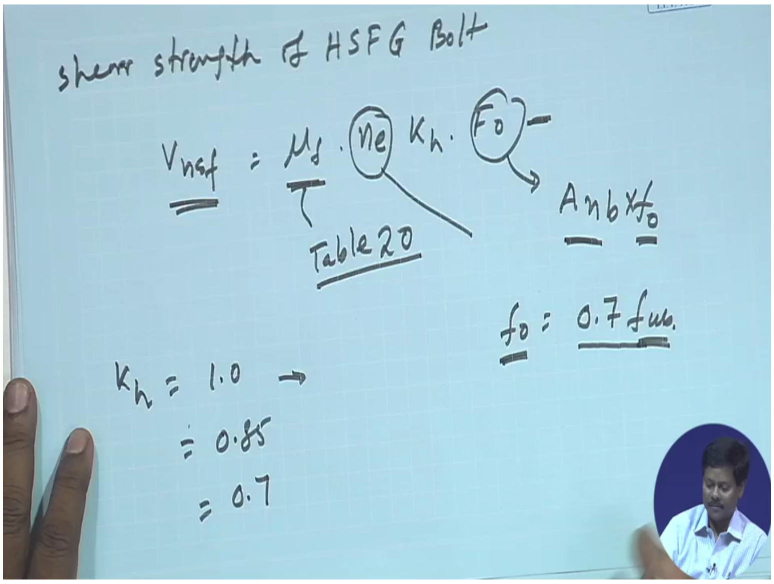
Course on Design of Steel Structures
Prof. Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Mod 02 lec08
Design of High Strength Friction Grip Bolts

Hello, in last lecture, I have discussed the design methodology of ordinary black bolt (()) (0:25). Now today I will discuss the design principle of high strength friction grip bolt. Now in case of high strength friction grip bolt, the friction will be coming into picture for calculating the design strength of the bolt. Now as I told earlier also that high strength friction grip bolt is used when the external force is quite high. To accommodate the bolt in a shorter length of the joint, we may have to reduce the number of bolt. So in that case, generally we go for high strength friction grip bolt, with laser number of friction grip bolt we can design the joint. Now I will come to the design philosophy and first we will see that the shear strength of high stain friction grip bolt how to calculate.

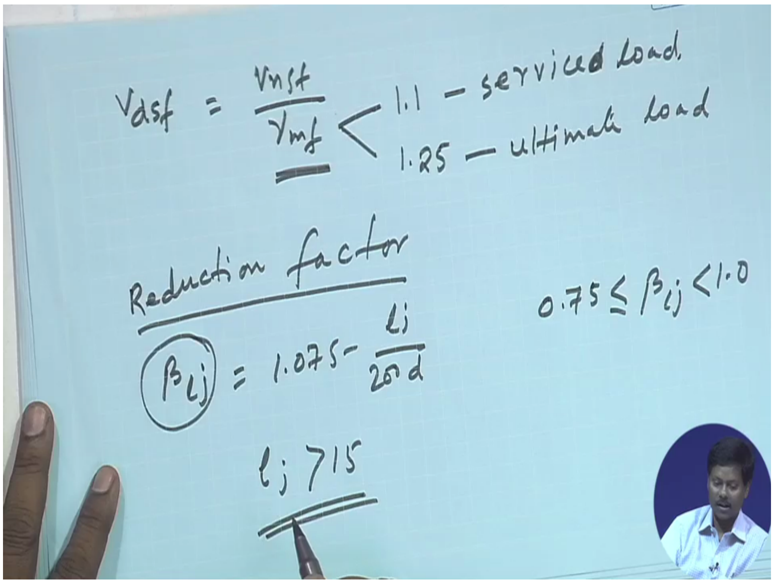
(Refer Slide Time: 1:33)



Shear strength of HSFG bolt. Now as per the codal provision the formula is given that Vnsf is equal to Muf into ne into Kh into F0. Now this Vnsf is the nominal shear capacity of the bolt and this Muf is the coefficient of friction. This is given in table 20 of IS 800 and in clause 10.4.3, it is described. The value of Kh are also given in the code that is taken as 1.0 when fascinates in (())(2:32) and it is taken as 0.85 for (())(2:38) in oversized and short slotted holes and long slotted holes loaded perpendicular to the slots and this Kh value can be taken as 0.7 for (())(2:49) in long slotted holes loaded parallel to the slots.

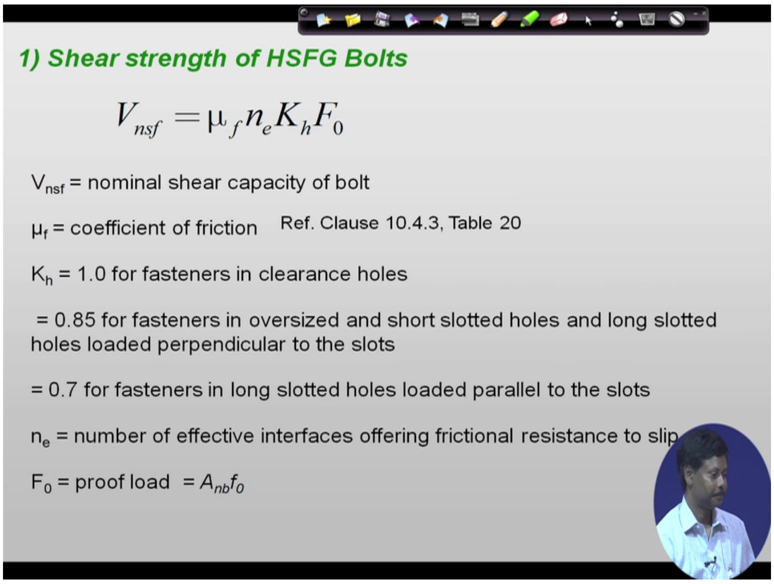
And this ne value ne is the number of effective interfaces offering frictional resistance to (()) (3:01) and F0, F0 is the proof load that can be calculated as Anb into f0 small f0. So Anb into small f0 where Anb is the net area of bolt and f0 is the proof stress, this is proof load and this is proof stress and this f0 can be calculated as 0.7 times fub, fub is the ultimate tensile stress in bolt. So the proof stress f0 can be calculated from this formula 0. 7 times fub.

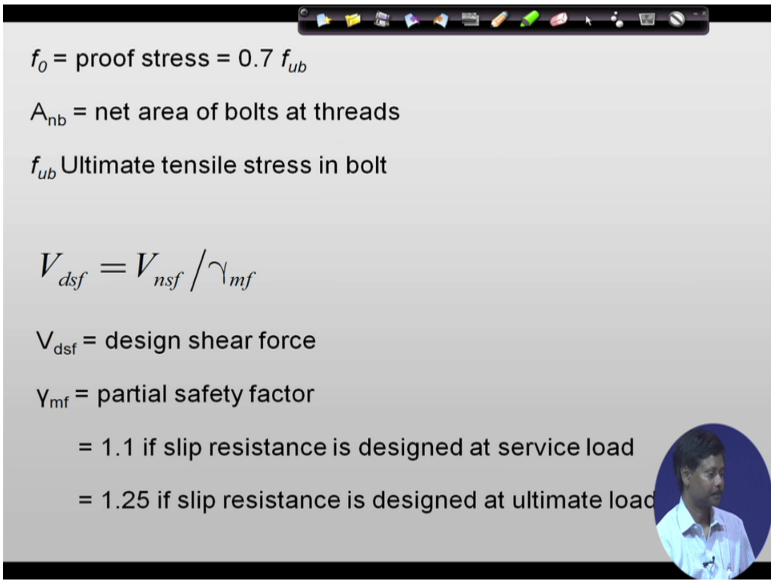
(Refer Slide Time: 3:44)

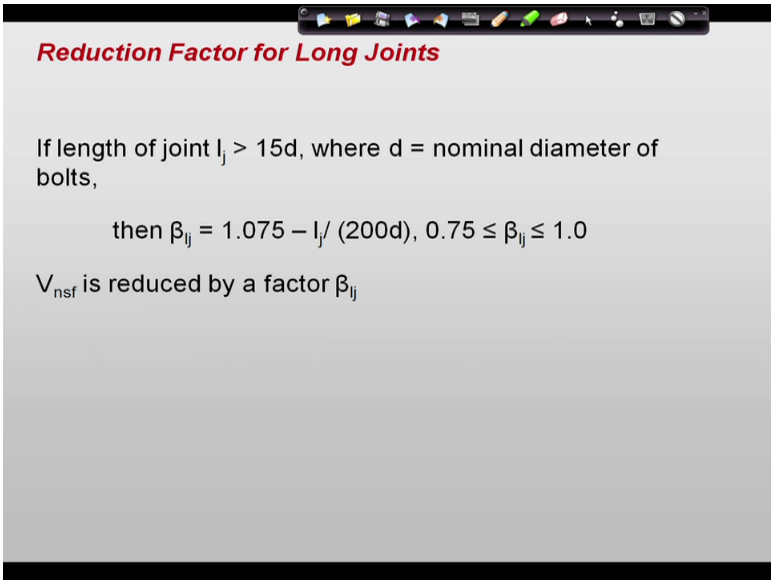


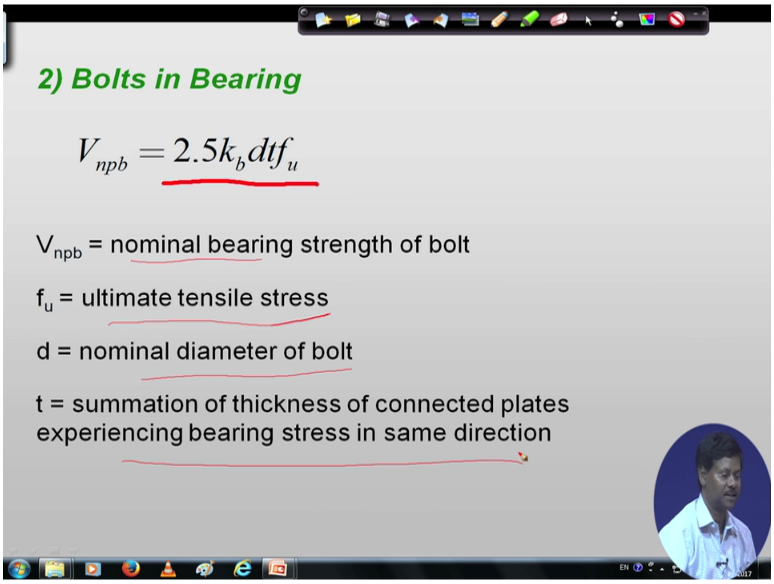
Now the design shear force Vdsf will become Vnsf nominal shear force divided by gamma. Gamma mf is the partial safety factor. This can be taken as 1.1 if strip resistance is designed at service load, at service load if it is designed then we will take 1.1 and we can take 1.25 if strip resistance is designed at ultimate load, at ultimate load it is designed then we consider 1.25 and like bearing type bolt here, also reduction factor for long joints are consider, for long joints reduction factor reduction factor for long joints. So that beta lj as we calculated earlier that will be 1.075 minus lj by 200d and this value should not be less than 0.75 and more than 1.0 and this length of joint if it is more than 15d then only we will apply this reaction factor beta lj otherwise we will not consider.

(Refer Slide Time: 5:40)



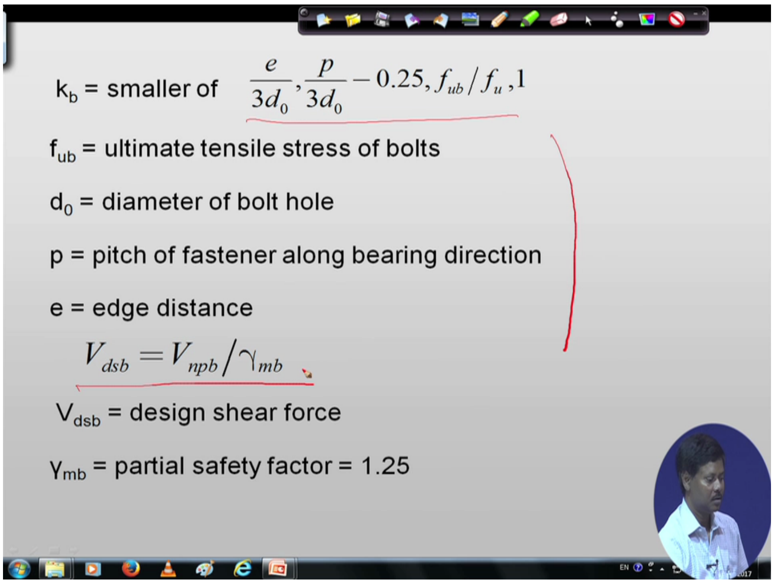






Now in case of HSFG bolt, we also consider the bearing failure. So this bearing failure we can calculate as we have calculated in case of bearing type of bolt. So if we see the Vnpb is becoming 2.5 Kb into d into t into fu where Vnpb is a nominal bearing strength and fu is the ultimate tensile stress, d is the nominal diameter of bolt and t is the summation of thickness of connected plates experiencing bearing stress in same direction. So this is what we have discussed earlier also, now also the same formula we are using.

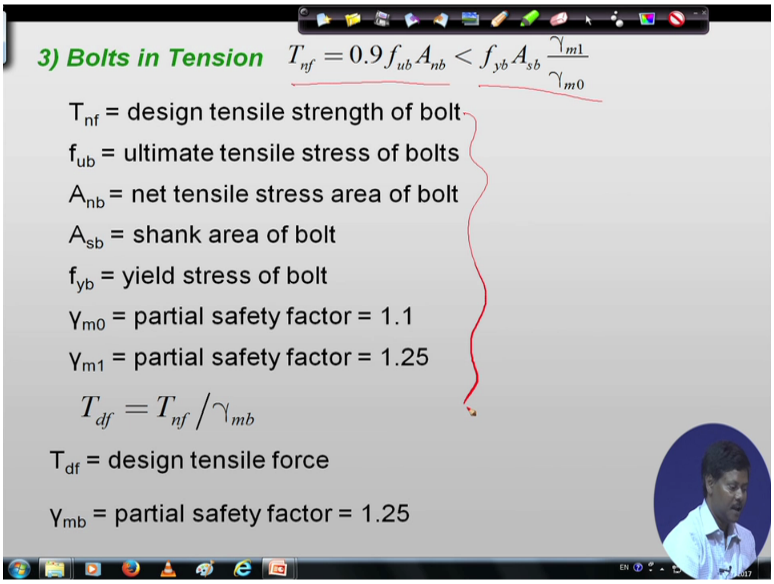
(Refer Slide Time: 6:37)



Similarly, we can calculate the strength due to bearing using this value of Kb and this Kb value will be based on this, e by 3d0, P by 3d0 minus 0.25, fub by fu and 1. So this we know.

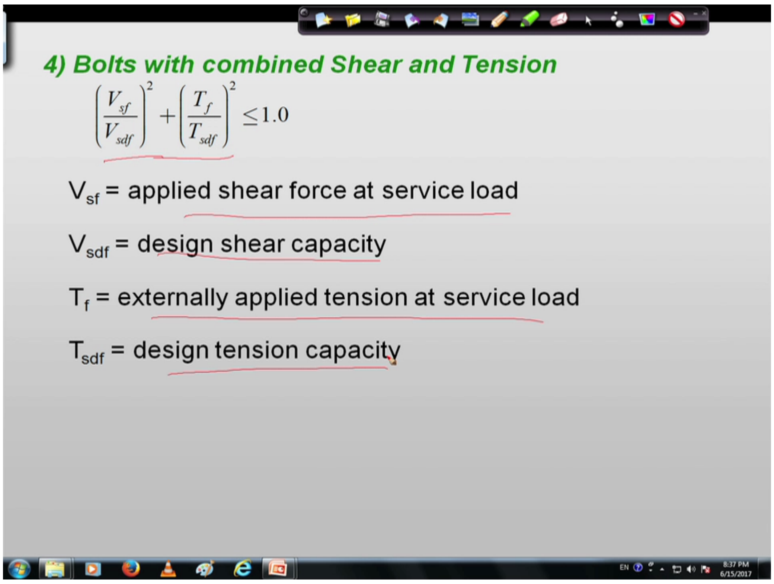
What are the parameters we have consider in case of bearing type of bolt same thing and the design shear force we can calculate Vdsb as Vnpb by gamma mb where gamma mb will be 1.25.

(Refer Slide Time: 7:24)



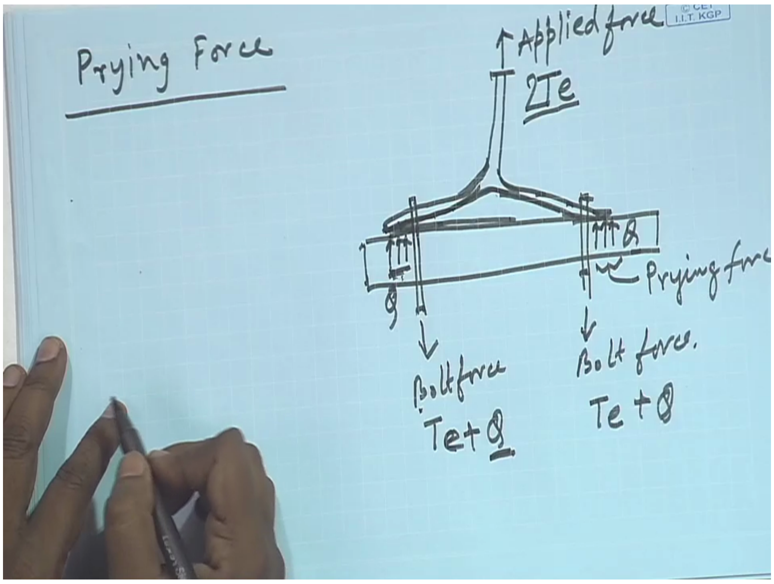
Now bolt in tension, in case of bolt in exerted in tension we can calculate the tensile strength of the bolt as Tnf as this 0.9 fub into Anb and it has to be less than fyb Asb into gamma m1 by gamma m0, where the parameters defined here has the usual meaning as defined in case of bearing type of bolt that means fub is the ultimate tensile stress of bolt, Anb is the net tensile stress area of bolt, Asb is the shank area of bolt like this here and the design tensile force will become Tnf by gamma mb. So similar way whatever we have done here same process we are following in case of HSFG bolt except the shear strength calculation.

(Refer Slide Time: 8:31)



And if bolts are in combine shear and tension then also we have to check the interaction formula that means Vsf by Vsdf whole square plus Tf by Tsdf whole square should be less than 1 where Vsf is applied shear force at the service load and Vsdf is the design shear capacity. Similarly Tf is the externally applied tension at service load and Tsdf is the design tension capacity. So this is what we have. So in this way we can calculate the strength of bolt, bolt means HSFG bolt due to shear due to bearing due tension and due to combined (())(9:25) effect. So what new things we have learned here that the shear capacity shear strength capacity of the bolt due to friction due to bearing and tension are same.

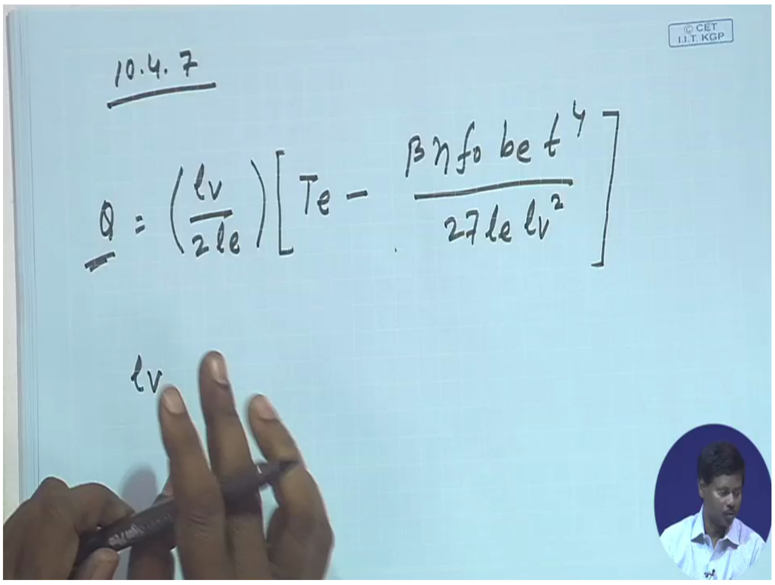
(Refer Slide Time: 9:52)

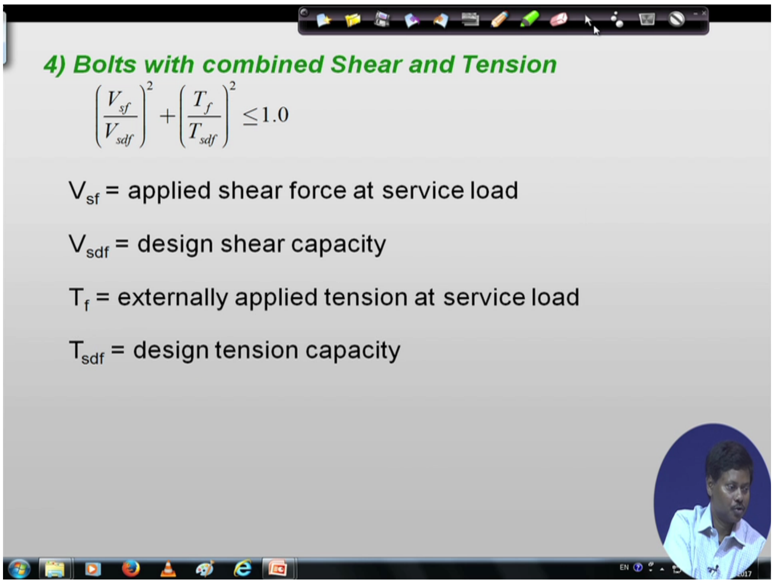


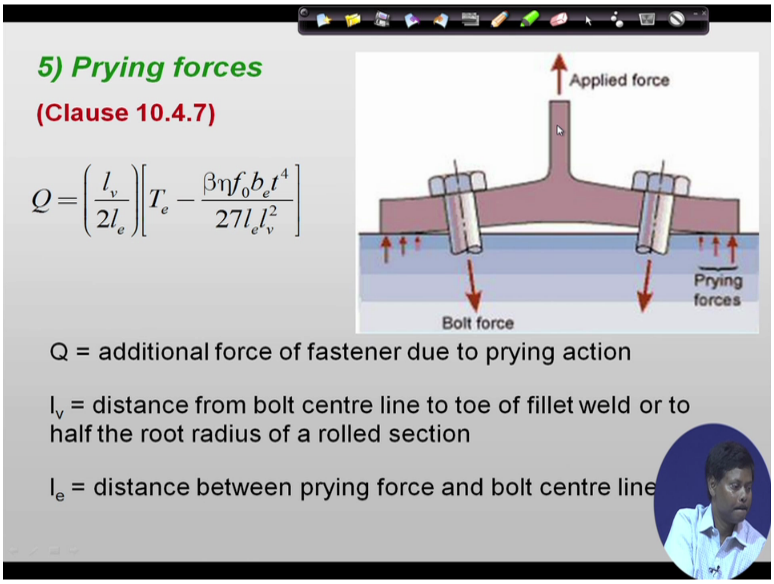
Now for high strength friction grip bolt, I will high strength friction grip bolt another force comes which is call prying force. This is very important prying force. Prying force is the additional force coming into picture in case of tension and if the deformation is allowed between two plates then prying force develops. Let me show through some figure, say one plate is like this which is attached with a say suppose I section, right.

So I section, right and bolting connection has been done here, right. So what we can see here that it has a applied force and in this direction said bolt force is coming, right. So if this is Te of 2Te then this is Te and this is Te, this equation is true if this is not detached (())(11:43) that means this deformation if it is not allowed. If deformation is allowed then what will happen that some forces at this portion will be developed, some additional forces will be developed. This additional force is called prying force that means due to application of load of 2Te, the bolt is getting force as Te but if we allow the deformation of the flange then additional prying force will come into picture. So if this is Q then this will be Te plus Q if this force is called Q. So Q is the prying force we can say and this prying force will be developed here and to withstand that force bolt will face extra force of amount Q and this Q value has been calculated and reported in clause 10.4.7.

(Refer Slide Time: 13:10)

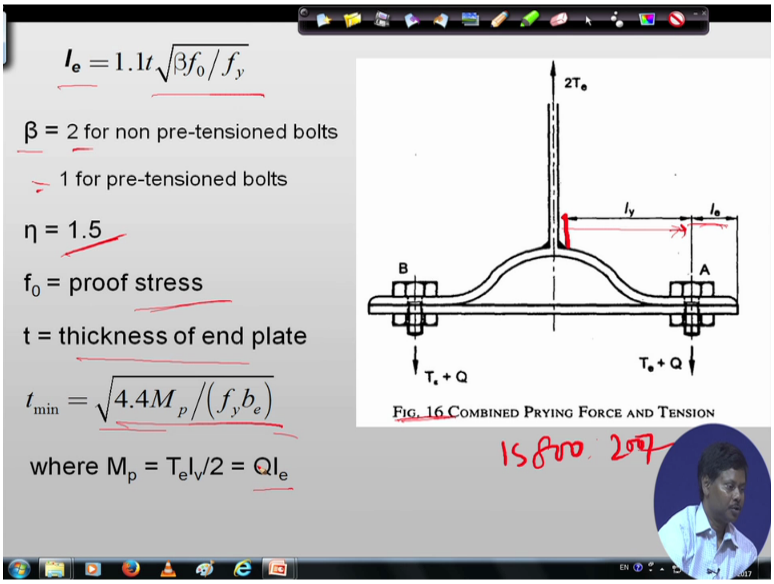






In clause 10.4.7 you will get the details of the prying force where it is mention that Q is equal to lv by 2le into Te minus beta into eta of be t to the power 4 by 27 le lv square, right. So this Q is the additional force (())(13:44) due to prying action and lv is the distance from bolt to center line to toe of fillet weld or to half the root radius of a rolled section that I will show in the figure.

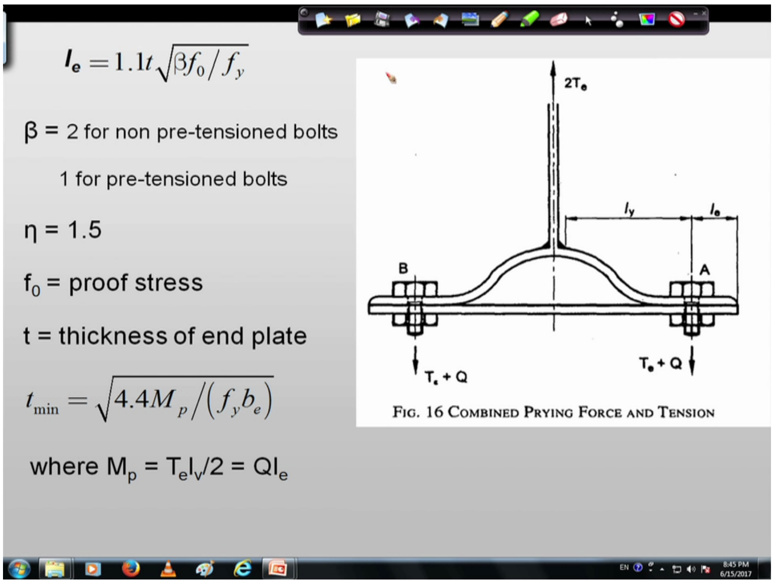
(Refer Slide Time: 14:014)

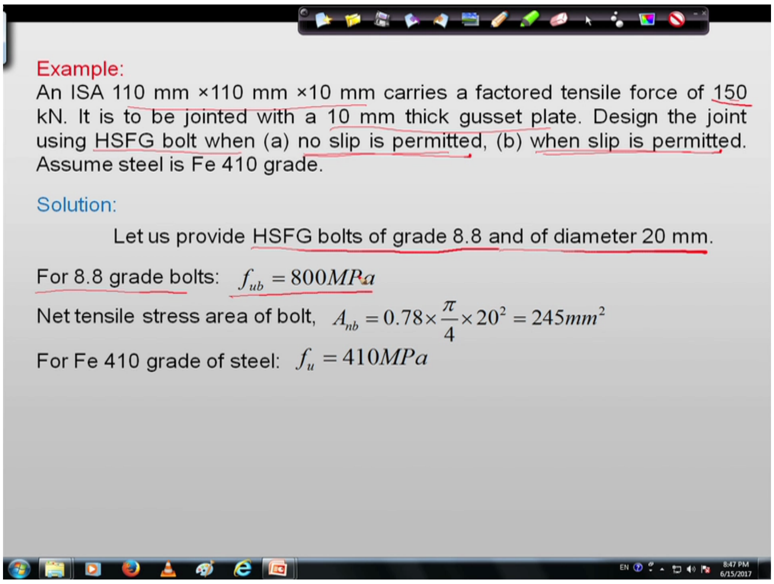


This is lv, so this is called lv, the distance from bolt center line to tow of fillet weld or to half the root radius of the rolled section, this is lv and le is the distance between prying force and bolt center line le. Distance of the prying force to bolt center line this is le, right, this figure I have taken from IS 800-2007. This figure number is 16, you can find out details there. Then le we can calculate from this formula where le is equal to 1.1 into t into beta f0 by fy and this beta value will become 2 for non-pretension bolt and we can consider 1 for pre-tension bolt. So beta value varies according to pre-tension or non-pretension bolt and Eta is taken as 1.5 f0 we know already that is proof stress and t can be calculated t is the basically thickness of the end plate and minimum t has to be this where Mp will be Telv by 2 or is equal to Q into le, right. So this is how one can find out the prying force Q.

So in case of HSFG bolt apart from shearing bearing and tension prying force may also come into picture. It depends on case to case that means if the plates are detached (())(16:21) means allow deformation then prying action will happen and because of that additional force, which is called prying force has to be calculated. So the bolt we supposed to take the value, it will have some additional value of Q that means if Te is the external force on bolt then actual force will be Te plus Q where Q is a prying force. Now we will go through one example of HSFG bolt and we will see how to calculate the shear strength and other strength means bearing strength etcetera for HSFG bolt then it will be clear to us.

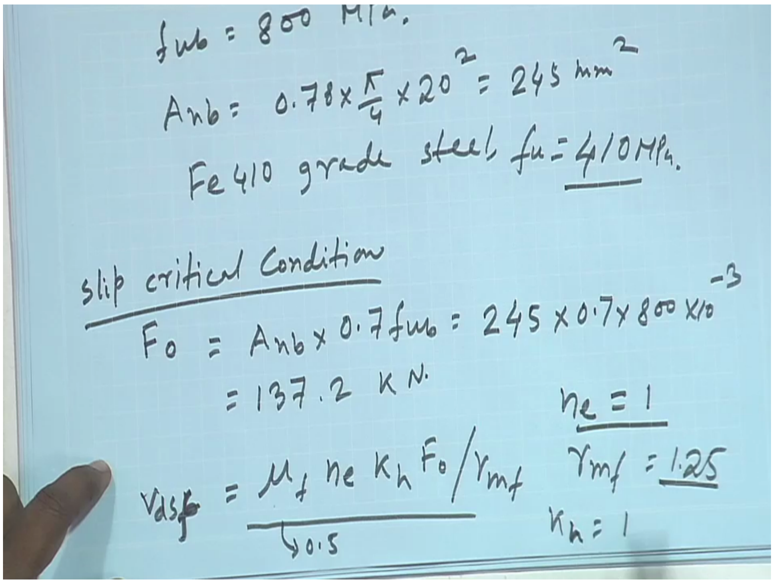
(Refer Slide Time: 17:22)





So we will go through one example, this is example that and ISA 110 by 110 by 10 mm means indian standard angle carries a factor tensile force of 150 kilo newton. It is to be jointed with a 10 mm thick gusset plate. Design the joint using HSFG bolt when no slip is permitted and when slip is permitted. No slip is permitted means friction is there and slip is permitted means friction is not there. So it will be like bearing type. So here we can see we can use HSFG bolt of grade, let us provide HSFG bolt of grade 8.8 and let use 20 mm diameter, because nothing has been told, so we can assume suitable data. So as grade is 8.8 bolt means bolt grade is 8.8. So fub value will become 800 MPa, right.

(Refer Slide Time: 18:46)

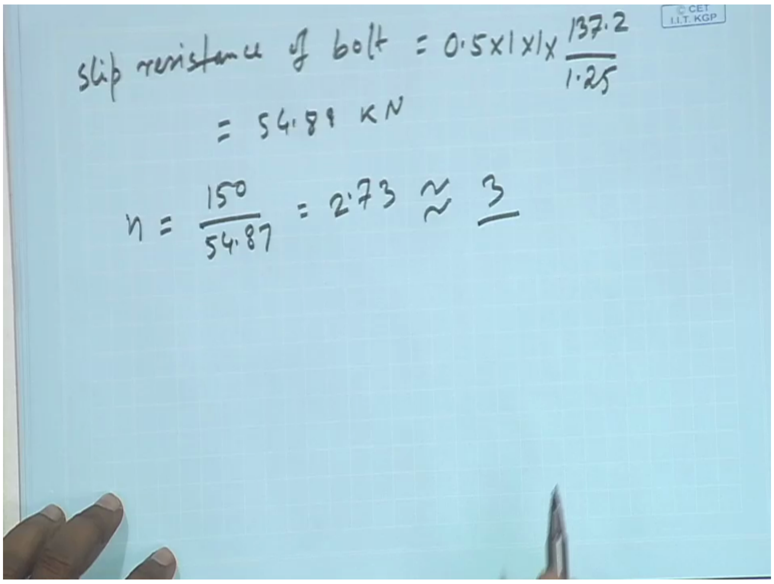


So fub value we can find out for 8.8 grade bolt as 800 MPa and now Anb which we have to calculate the net tensile stress area of bolt that will be 0.78 times pi by 4 into d square. So this is becoming 245 millimeter square and the gusset plate will be as usual Fe 410 type steel Fe 410 grade steel if we use then the tensile stress of the gusset plate will be 410 MPa, right. So these are the data we have assumed.

Now let us come to the first case that slip critical condition, so that means slip is not permitted slip critical condition means slip is not permitted. So here through put F0 will become Anb into 0.7 fub, right so we can calculate the value Anb is 245 and 0.7 into fub is 800 and to make it kilo newton we multiply 10 to the minus 3. So this is becoming 137.2 kilo newton. Now slip resistance of bolt we can find out that is the vdsb we can make Vdsf right, mu f into ne into Kh F0 by gamma magnetic field, right.

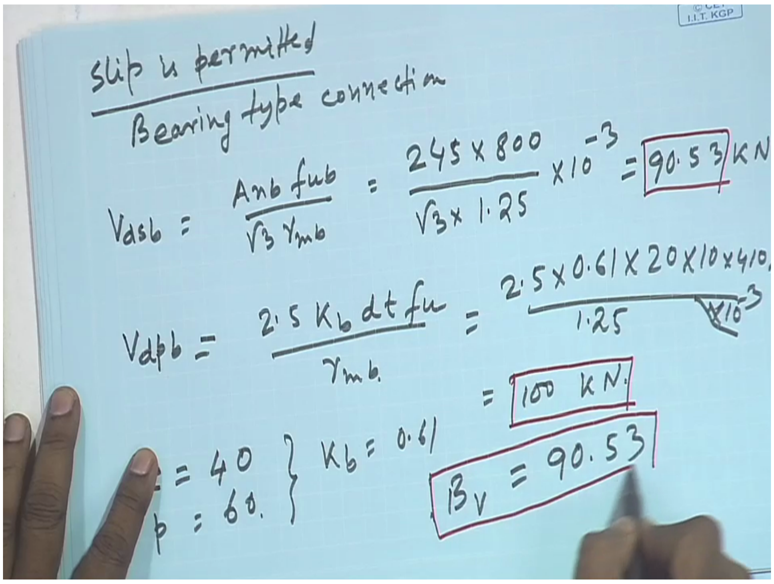
Now we have to assume certain data if it is not given like Mu f is not given it. So Mu f the coefficient of friction we can assume as 0.5 we can assume. Now ne ne is a number of effective interface offering frictional resistance to slip that we can considered as 1 in number of effective interface offering friction resistance that we can assume 1. Now gamma mf at ultimate load is 1.25, we can consider gamma mf as 1.25 we can consider and Kh value we have seen either 1 or 0.7. So here we are considering 1 assuming bolts (())(21:51) in clearance (())(21:50), Kh value we are considering 1.

(Refer Slide Time: 22:02)



So the slip resistance of bolt we can calculate, slip resistance bolt we can calculate as 0.5 into 1into 1 into 137.2 by 1.25. This is come in 54.88 kilo newton. So number of bolt required will be the load divided by force means design strength, which is coming 54.87 is equal to 2.73 or 3. So we can provide 3 numbers of HSFG bolt for this type of problem, if we use HSFG bolt to withstand 150 kilo newton load then we can provide 3 numbers of bolt.

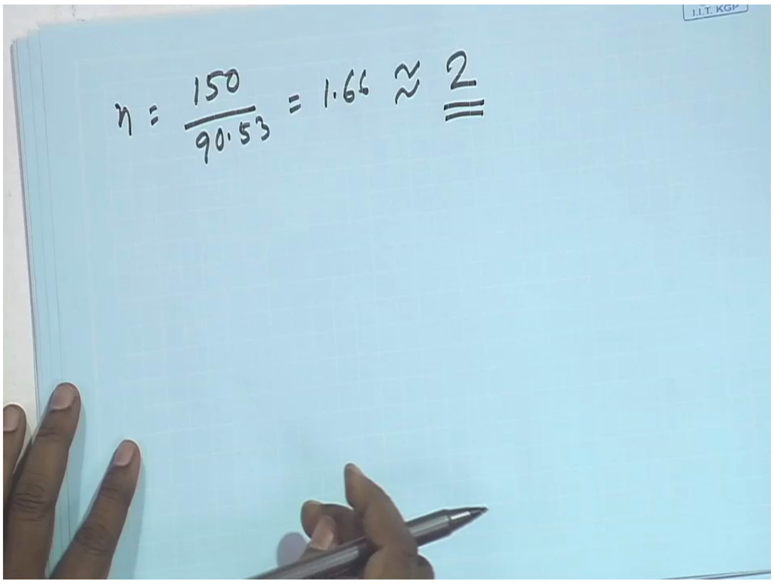
(Refer Slide Time: 23:18)



Now we will go for next one. This one is the slip critical condition where sleep is not permitted. Now if we permit the slip then if slip is permitted then this will become bearing type connection. So this will become bearing type connection if slip is permitted that means frictional resistance is not there. So there we can find out Vdsb as Anb fub by root 3 gamma mb, so this is 245 into fub means 800 by root 3 into the safety factor is 1.25 and we have multiply 10 to the minus 3 to make it in kilo newton. So this is becoming 90.53 kilo newton.

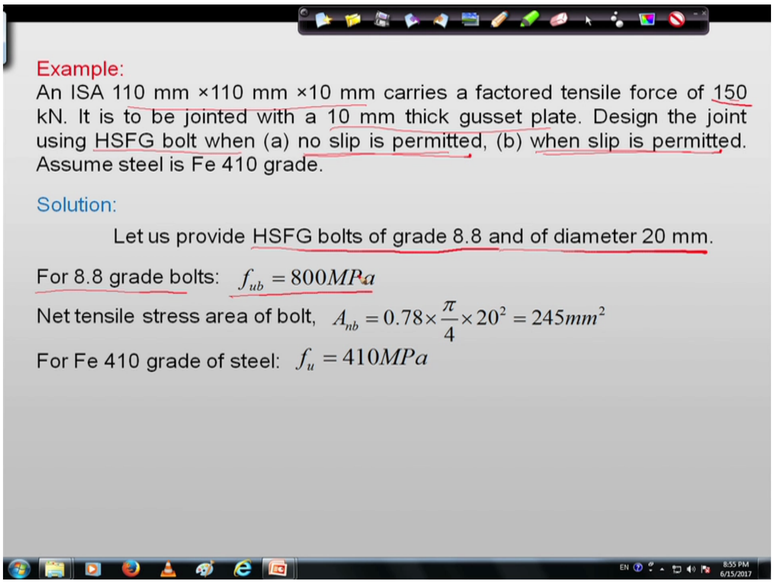
Now strength in bearing also we have to find out, Vdpb this will be 2.5 Kb dt fu by gamma mb. Now we have to find out the value of kb. Now Kb when we are going to find we have to find out means we have to assume some value of edge distance. So let us assume 40 mm and p is let us assumed 60 mm then the Kb value we can find out from this Kb as 0.61. So Vdpb we can find out 2.5 into 0.61 into 20 into t is 10 into 410 by 1.25 into 10 to the minus 3. So this is becoming 100 kilo newton that means the strength of the bolt will become 90.53, because due to shear this is coming this value and due to bearing it is coming 100. So the bolt value will become 90.53.

(Refer Slide Time: 26:12)



So number of bolt we can find out number of bolt will be 150 divided by 90.53 that means 1.66 that is 2, right. So 2 numbers of bolts require.

(Refer Slide Time: 26:33)



So here we have seen that if we consider slip critical and if we do not consider slip, if we allow slip and if we do not allow slip how the values are going to change. So design of high strength friction grip bolt is exactly similar to bearing type of bolt except the friction. Friction component if we had that means slip critical if we consider if we consider the slip resistance then we have to find out, the design shear strength accordingly, other things will be exactly similar to the bearing type, I hope this work out example will be helpful for understanding the design methodology of the ordinary black (())(27:29) bolt as well as the high strength friction grip bolt, thank you very much.