Course on Design of Steel Structures
Professor Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Lecture 06
Module 2
Design of Ordinary Black Bolts

Hello today I am going to discuss the design procedure of bolts, bolt may be two types which are commonly used one is ordinary black bolt and another is high strength friction built bolt. Now today at first I will discuss about the design procedure of ordinary black bolt.

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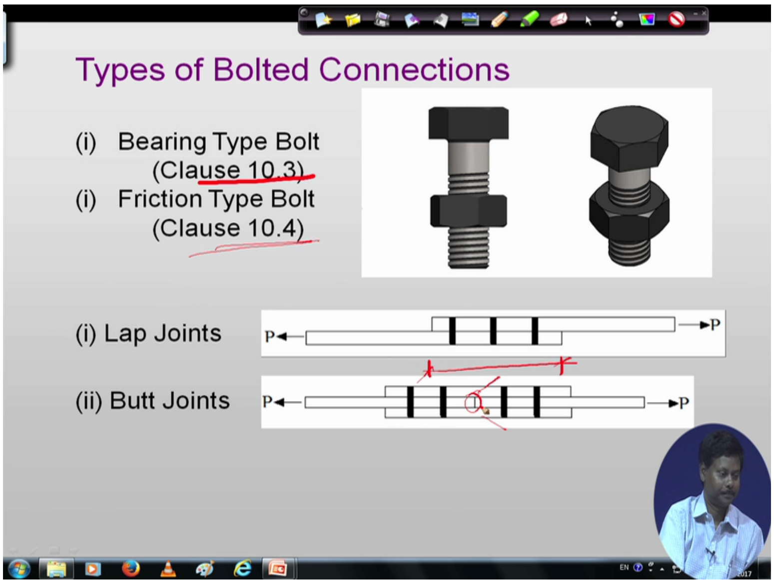

Now as we know that one is bearing type of bolt which is given in clause 10.3 of IS: 800-2007 and another design procedure is friction type bolt which is given in clause 10.4. So while we will see the design procedure I would suggest the participants to follow the codal provisions also to open their code and to open this clause 10.3 while designing the ordinary black bolt and when we are going to design we will see the two type of joints will come across openly that is one is lap joint where the two plates are overlapped together at a certain length which is called lap joint and another is butt joint where two plates are in same plane are joint with some cover may be single cover or may be double cover which is called butt joint. So these two types of joints will be covered in todays lecture.

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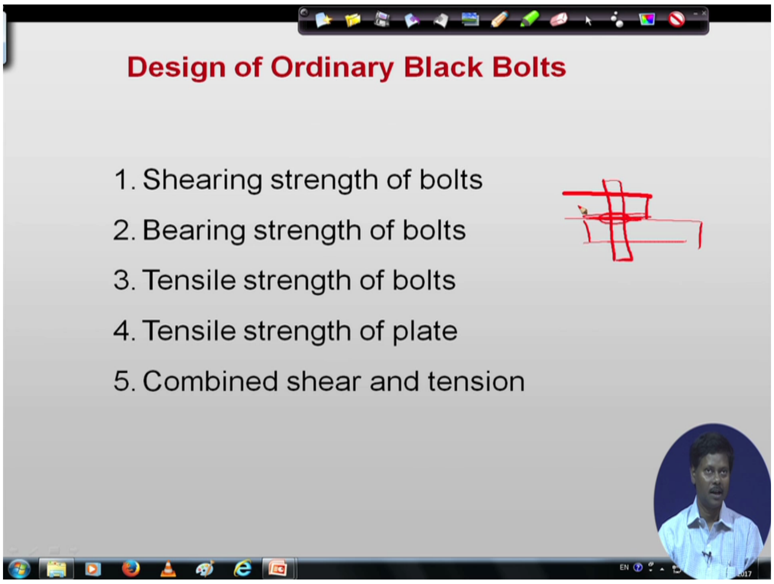

Now for designing of ordinary black bolt we will see that what are the failure criteria and from that failure criteria (what are the shearings) what are the strength like it may fail due to shear. We know the black bolt when we are going to design suppose the plates are here and another plates are connected here and we are designing a bolt then there is a chance of failure in this shear plane.

So in this plane the shear failure may come into picture for which we have to find out what is the strength of the shear of the bolt then we will go for bearing strength of bolt means bolt may fail due to bearing also as I have discussed earlier so what will be the strength calculation for bearing failure that we will discuss.

Next is the failure due to tension in the bolt bolt may occur under tension so that also has to be calculated. Next we will go for tensile strength of plate, means plates are made hole for inserting the bolt. So the net strength of the plate will be reduced because of the presence of hole, so that also we will try to find out what is the net strength of the plate and another aspect is that combined shear and tension means sometimes bolt exerts under combined shear and tension.

So that also we will check and out of this 5 we will see which one is the least strength and least strength will be the bolt strength, so we will try to find out the bolt strength for different failure criteria one is shearing, then bearing and then tensile strength and then tensile strength of plate and combined shear and tension.

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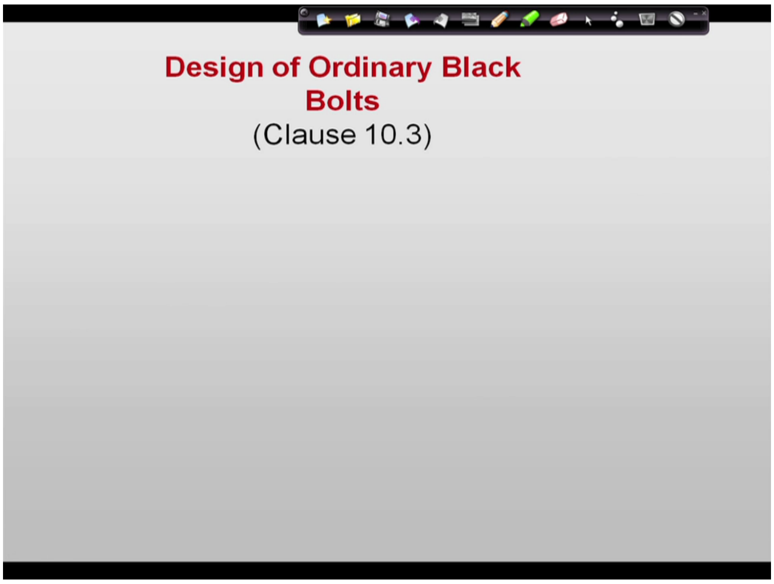

Next let us come to design of ordinary black bolt.

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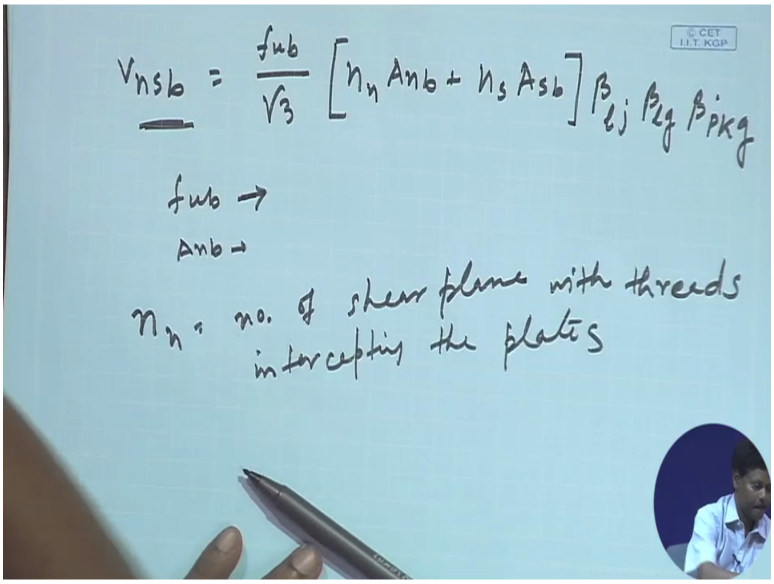

Now in clause 10.3 you will see that bolt in shear Vnsb are given in the code as fub by root 3 into nn into Anb plus ns into Asb this is nominal capacity of bolt in shear into some reduction factor which is called beta lj then beta lg and beta PKg. So this Vnsb is nothing but the nominal capacity of bolts in shear and fub fub is the ultimate tensile strength of bolt.

So for different type of bolts the ultimate tensile strength of bolt will be different that we can find out from the code and this Anb and Ansb I am coming, Anb is the net tensile area of bolt to be consider at the root of the thread.

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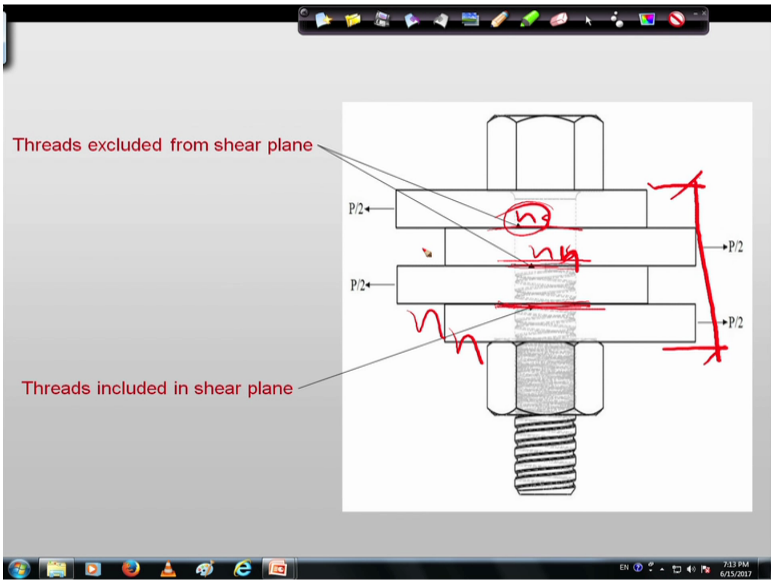

That means if we go next page you will see here the entire if we see that entire bolt grip is this much sorry this is the entire bolt grip. Now say for example in this case the thread included in shear plane is this one this shear plane is included by that threads. Now the threads excluded in shear plane is this one or this one. So this is nn and nb, so nn and nb we can define as nn as number of shear planes without thread intercepting the plate.

So nn will be number of shear plane with threads intercepting the plate. That means this will be the nn intercepting the plate this is nn and ns number of means here in in this case ns is sorry this is ns is nn is one and if I consider this is also intercepting in thread then this is another one nn and this is ns, right. So similarly ns is equal to number of shear plane with threads without threads intercepting the plates. I will start once again the last page from last page sorry I will start from this so now ok.

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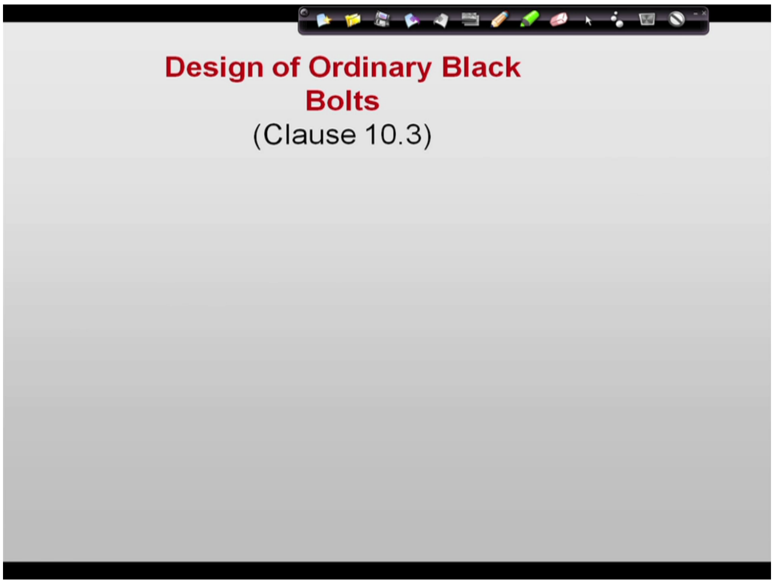

So now I am going to discuss about the design of ordinary black bolts, this is given in clause 10.3 of IS: 800 now as I told that design of ordinary black bolts has to be designed under shear tension and bearing and tension of the plate. So we will go through one by one and we will see what are the codal provisions made and accordingly we will try to find out the design strength of the bolt under shear, under bearing and under tension. Now this is available in clause 10.3 of IS: 800-2007.

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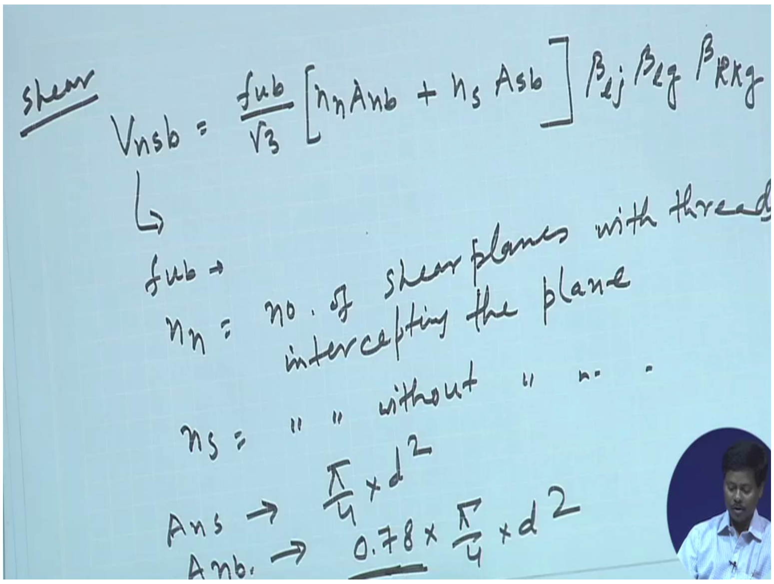

So clause 10.3 if you open you will see a formula is given for bolt in shear for shear the formula is given as Vnsb is equal to fub by root 3 into nn Anb plus ns Asb into beta lj these are some reduction factor I will come into this reduction factor how to calculate and then beta P beta PKg.

So this Vnsb is basically nominal shear capacity of bolt and fub is the ultimate tensile strength of bolt and this ultimate tensile strength depends on the material property of the bolt. So what type of material property we are going to use depending on that we can find out the value of fub. Then nn nn is the number of shear plane number of shear planes with threads intercepting the plane what is that intercepting the plane.

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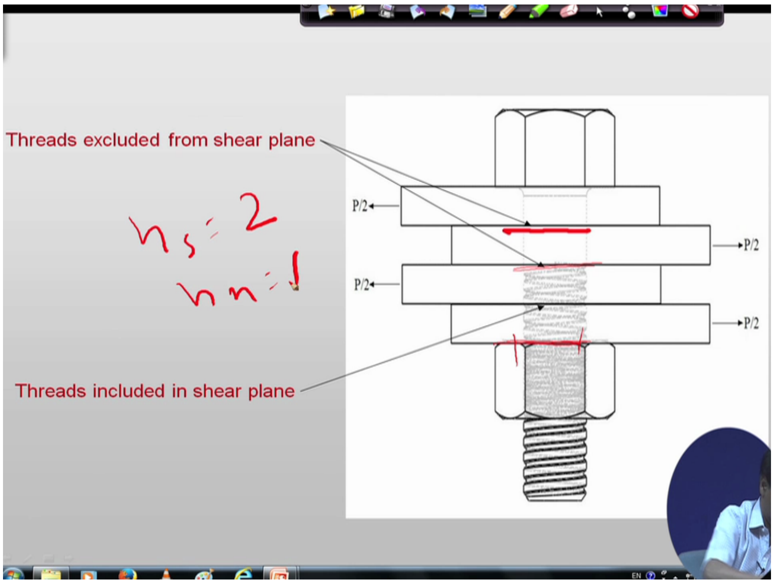

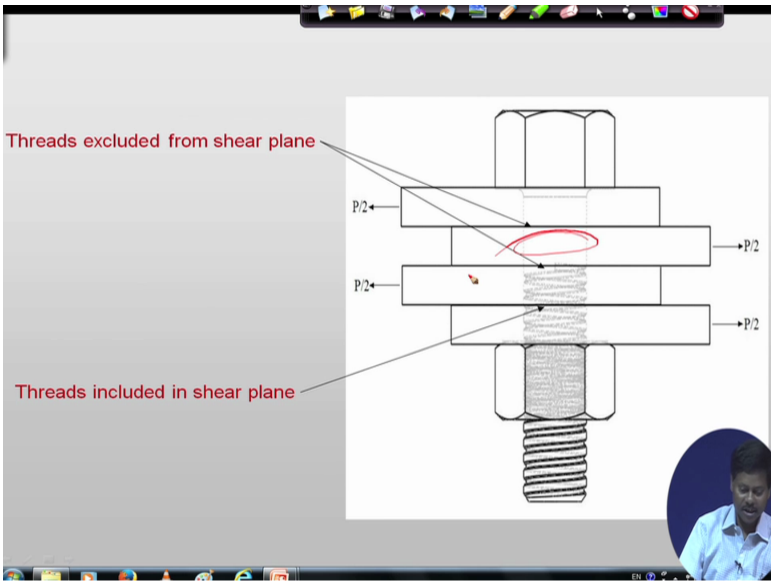

This is we can find out from this figure this is the figure where you see we have one type of plane that is thread excluded from shear plane that means thread is not there in this two and another is thread included in shear plane that means this thread threaded portion is included in shear plane.

So nn will be when threads intercepting the plane and similarly ns will be number of shear planes without without threads intercepting the plane without threads intercepting. So in this case ns will be 2 and nn will be in this case 1 and accordingly we have to find out the Anb and Anb and Ans that how do we find out that is Ans is the cross sectional area of the plane shank cross sectional area of the plane shank that means this portion cross sectional area of the plane shank this portion and the threaded portion the cross sectional area we can consider as Anb, so this is how we can calculate.

Now this threaded portion when we will calculate what will be the cross sectional area, now we know the cross sectional area of the shank portion will be pi by 4 into d square, where d is the nominal diameter of the bolt but when we are going to calculate the net area of the threaded portion we will reduce to to a certain extent which is suggested by your code as 0.78 times the cross sectional area of the shank area, that means this will be reduced to 0.78 times of pi by 4 d square. So Anb the net area of the threaded portion we will consider in this way.

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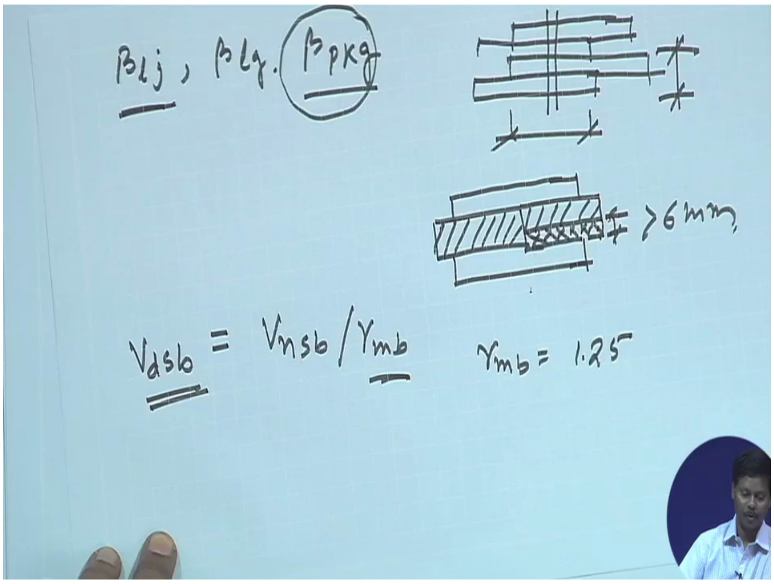

That one is beta lj, then beta lg and beta PKg. Now beta lj is the reduction factor which allows the overloading of n bolts that occur in long connection. If a connection is quite long if a connection is quite long then there will be a factor which we have to multiply with the capacity whatever is coming this factor is called beta lj which is a reduction factor.

Similarly beta lg is the reduction factor due to large grip length, if the grip length is large that means plate thickness if it is high or several plates are given then grip length increases, say suppose I am increasing the number of plates and joining with a bolt.

So if grip length is more then we have to multiply a factor which is called reduction factor for large grip lengths and also beta PKg beta PKg is the reduction factor for packing plates suppose we have a (gusset at) sorry butt joint we have two plates of different thickness now we have to join with certain number of bolts we have to make to join the two plates this is one plate and this is another plate.

So for this to reduce the gap we may have to provide packing plates, so this is called packing plates. So these packing plates when we are going to consider we are using a reduction factor for packing plates however if it is thicker than 6 mm if this packing plate is thicker than 6 mm then we have to multiply a reduction factor of beta PKg.

Now the design shear force which is called Vdsb, I am taking the parameter name as given in the code same parameter I am using. Vdsb is equal to Vnsb by gamma mb, this Vdsb is the design shear force and gamma mb is the partial safety factor, this gamma mb is given in IS code in table 5, in table 5 you will get a different type of partial factor for bolted connection, for welded connection and for different cases the value of partial safety factor of the bolt or rivet bolt or welded according to the material it has been given. Now this gamma mb we consider here as for bolt we use 1.25, right.

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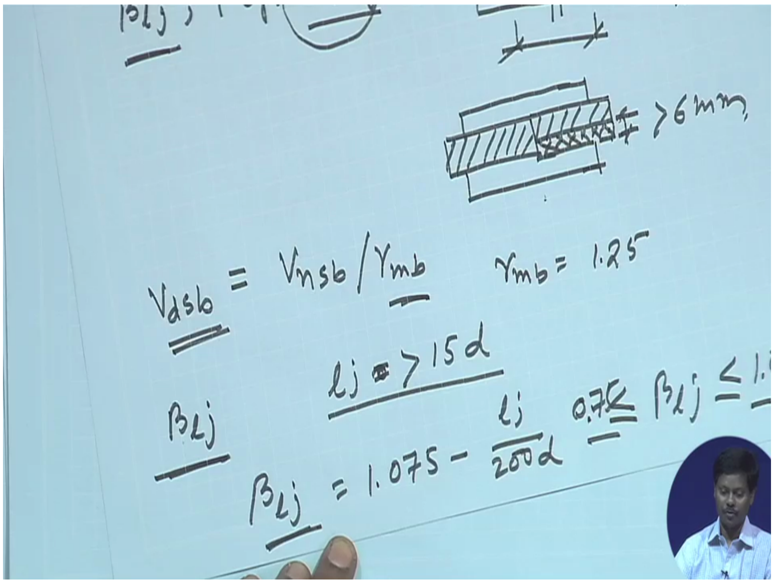

Now let us come to the reduction factor how do we calculate beta lj this is reduction factor due to long joint. So long joint means what long joint means if this length of joint become more than 15 times of nominal diameter of the bolt if this length of joint become more than 15 times of nominal diameter of the bolt then we can calculate beta lj as this 1.075 minus lj by 200d.

So from this formula we can find out the reduction factor due to long joint beta lj and this beta lj should not be less than 0.75 and should not be more than 1.0, so beta lj will vary from 0.075 to 1.0 this is how we can calculate the value of beta lj.

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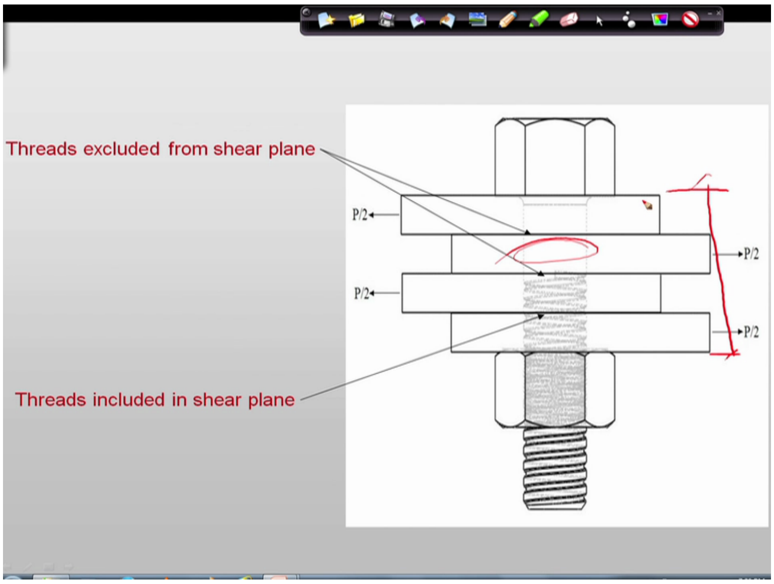

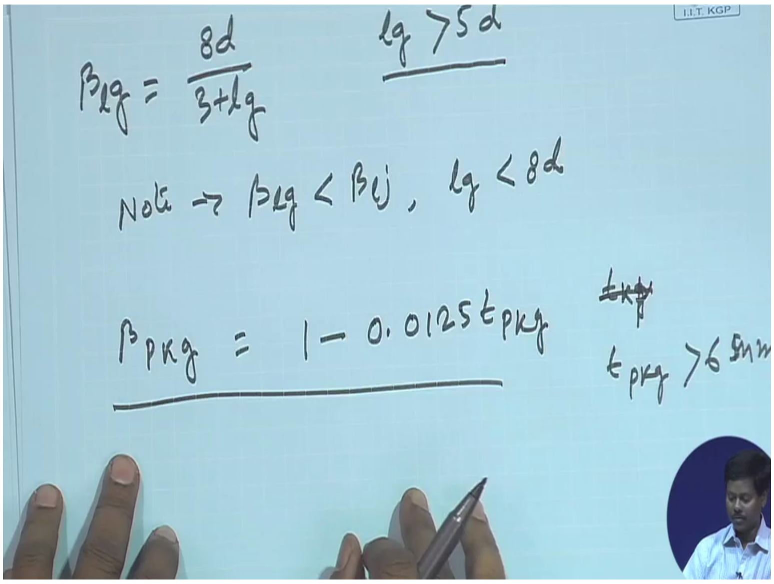

Next we will calculate the value of beta lg which is reduction factor due to large grip length, as I told large grip length means when this length is becoming high and when this lg large grip length is more than 5d d is the nominal diameter of the bolt. So when lg become more than 5d than I can calculate the beta lg value as 8d by 3 plus lg, right and note that that beta lg should be less than beta lj and lg should be less than 8d then we can use this formula.

Another reduction factor is for packing plates that is beta PKg this is calculated from this formula that is 1 minus 0.125tPkg. Now if packing plates is more (tpk) I am sorry tPkg if this is more than 6 mm then we can use a reduction factor of beta Pkg as this, if it is less than 6 mm we do not have to multiply the reduction factor this is how we can calculate.

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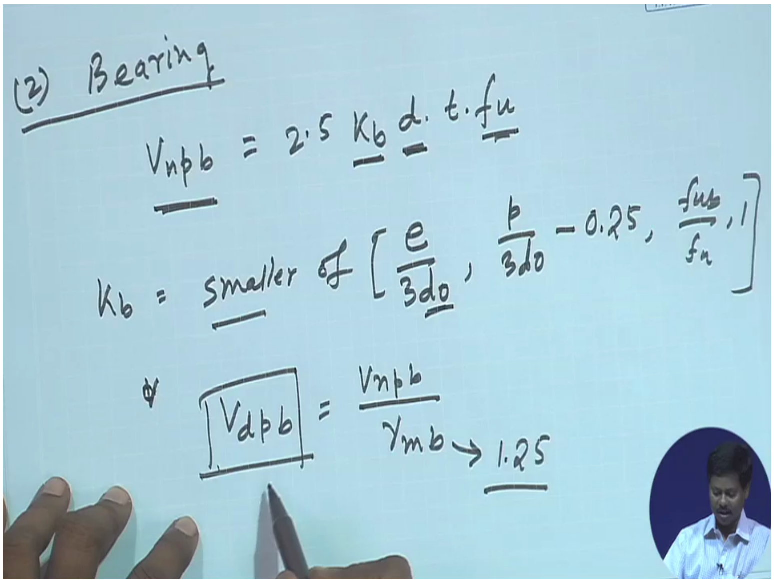

We have seen first is that bolt in shear now for bearing as I told that bolt may fail due to shearing effect and due to bearing effect and bolt may fail due to tension also the joint may fail due to tension of the plate tension failure of the plate that has also have to be consider.

So shearing strength how to calculate we have seen now we will find out the bearing strength that is calculated from this formula that is Vnpb is equal to 2.5 kb d into t into fu, here this Vnpb is the nominal bearing strength of bolt nominal bearing strength of bolt and fu is the ultimate tensile stress of plate not bolt remember, earlier we have calculated the ultimate tensile stress ultimate stress of bolt in earlier formula but here it is ultimate tensile strength of plate because it is bearing on plate.

And d is the nominal diameter of bolt d is the nominal diameter of bolt and t is the summation of thickness of connected plates that means the total thickness of the connected plate will be the thickness t. Now another factor is a constant which is Kb and this Kb can be calculated form smaller value of this few parameters e by 3d0, p by 3d0 minus 0.25, fub by fu and 1 whichever is less, so smaller of this few what is d0, d0 is the hole diameter that means nominal diameter plus clearance hole diameter d0.

Sometimes we represent as dh in some books you will find dh and sometimes it is d0 and e is the edge distance and p is the pitch distance and fub and fu we know so smaller of all these quantity will be the value of Kb. So Kb we can find out now the design shear force Vdpb you can calculate from the nominal shear force Vnpb by gamma mb, gamma mb is the partial safety factor of (bear) bolt and this value is 1.25 which we can find out from table 5 of IS: 800-2007. So we can find out the value of gamma mb from table 5 and we can find out the design shear force sorry design bearing force.

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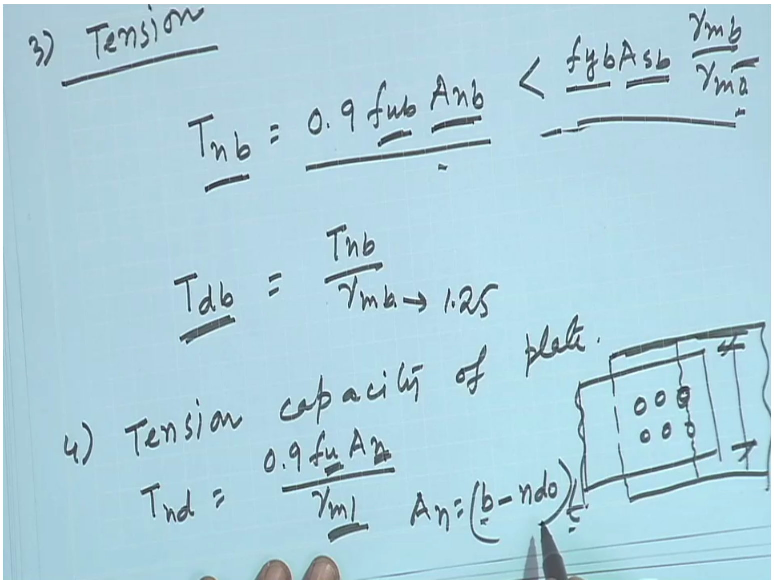

Next will come bolt in tension, so for tension we can calculate the nominal capacity of bolt in tension as Tnb is equal to 0.9 fub into Anb and it has to be less than fyb Asb into gamma mb by gamma m0, right. So Tnb we can calculate from this formula also we will calculate this and we have to check that Tnb is becoming less than this otherwise you will calculate this value.

So as we told fub is the ultimate tensile stress of bolt fub and Anb is the shank area sorry Anb is the net area at the thread and Asb is the cross sectional area at the shank and gamma m0 is 1.1 which again we can find out from table 5 of IS: 800 and then gamma mb also we can find out from similar table form same table table 5 of IS: 800 which is 1.25 and this is how we can find out the value of Tnb and Fyb is the yield stress of the bolt yield stress of the bolt material we have to find out which is called fyb.

Then we can find out Tdb the design tensile force that will be Tnb by gamma mb. So and we know gamma mb is basically 1.25 and we can find out the design tensile force as Tnb by gamma mb. So what we have seen that the strength of bolt due to shearing, due to bearing and due to tension we have calculated.

Now another aspect is that bolt may fail means the joint may fail due to tensile failure of the plate. So if plate fails then the joint is going to fail. So the tension capacity of the plate also has to be calculated while calculating the bolt strength of the joint. So we will calculate now tension capacity of plate.

So in this case we can find out the tension capacity of plate Tnd as 0.9 fu An by gamma m1 and we know fu is the ultimate tensile stress of plate and gamma m1 is the partial safety factor which is 1.25 and An is the net effective area of plate. Suppose a plate is joint like this, two plates are joint like this, right. Now we have bolt here so one scope is that it may fail due to tensile force exerted on the plate and so when we are going to calculate the tensile strength of plate we will calculate the net area of the plate net effective area.

So what will be the effective area An, An will be b if this is b width of the plate then b minus n into d0 into t, because b if we have to calculate the tensile strength of the solid plate then simply we can find out b into t, but because of the presence of hole the net area is going to be reduced, when net area is going to be reduced, so the tensile capacity of the plate also is going to be reduced because in tension the bolt area has to be reduced means hole area hole area has to be deducted and hole area is the d0, that means bolt nominal bolt diameter plus clearance of the clearance on the hole.

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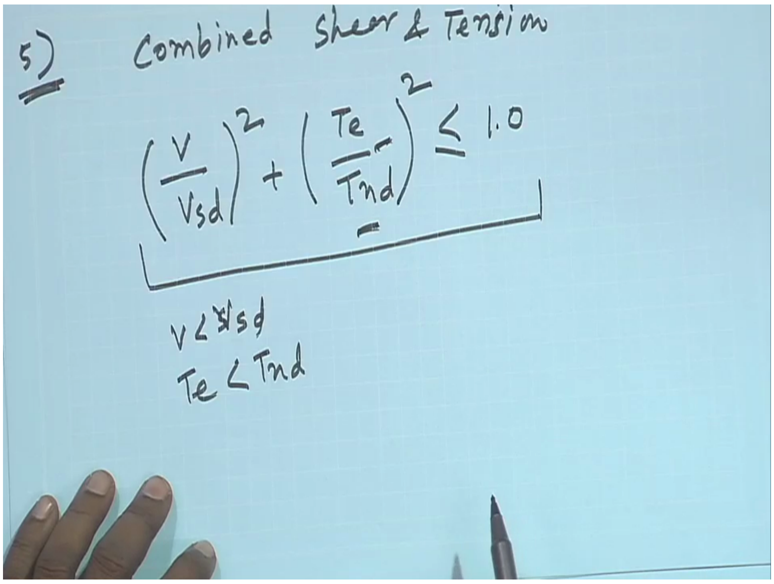

Now another failure may come which is 5th one that is bolt with combined shear and tension, sometimes bolt are exerted to combined shear and tension. So when we are calculating individually the shear strength and tension strength of the bolt we have to also calculate that if both the shear and tension acts then what will be the combined strength of the bolt and that is found from this formula from this interaction formula that it has to fulfill this criteria and it has to be less than 1.0.

So here V is the applied shear force, Vsd is the design shear capacity, Te is the externally applied tension Tnd is the design tension capacity. So not only V should be less than Vsd it has to maintain Te should be less than Tnd but also it has to follow this means this check has to be conducted and the summation of these two will be less than 1.

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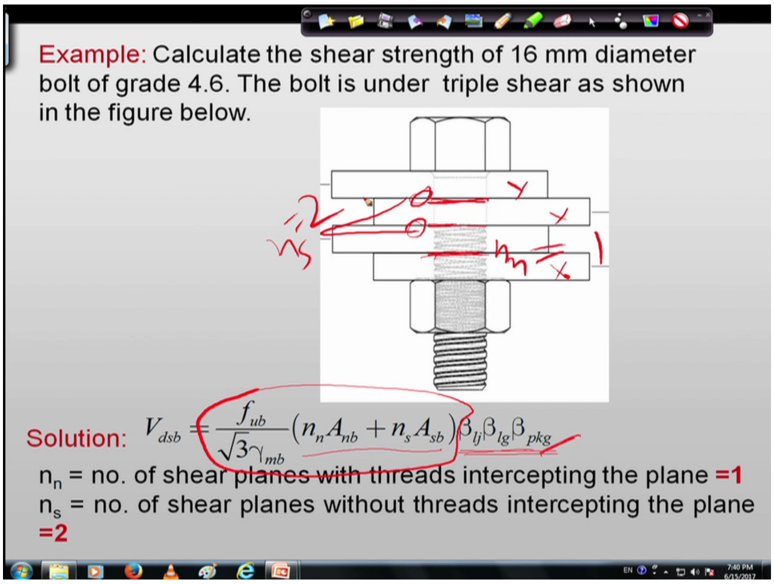

Now whatever we have discussed we will go through one example and we will try to understand that how to calculate the bolt strength. Here first we are giving an example of calculation of the shear strength of the bolt, say for example this is a connection where three plates one, two and three plates are joint by a bolt. So the problem is that calculate the shear strength of 16 mm diameter bolt of grade 4.6 and the bolt is under triple shear as shown in the figure below. So we can see here that shear plane is this is one, this is two and this is three.

So when calculating the shear strength we know the formula is this that Vdsb is equal to fub by root 3 gamma mb into (nn into Anb plus ns into Asb) into beta lg beta lj and beta pkg. Now suppose we have the joint of short joint means joint is not long and grip length is not larger and also packing plate is not given. So we can omit this three terms this reduction factors terms we can omit.

Another thing now we have to calculate then the value of Vdsb on the basis of this formula, right. Now what is nn as we know nn is the number of shear planes with threads intercepting the plane, so here nn is basically 1, number of shear plane with threads, this is only 1 nn, this is nn is equal to 1 and number of shear planes without threads intercepting the plane we have 2, this is 1 another is this this 2 we have ns, right. So while calculating the design strength of the bolt we will use nn as 1, ns as 2.

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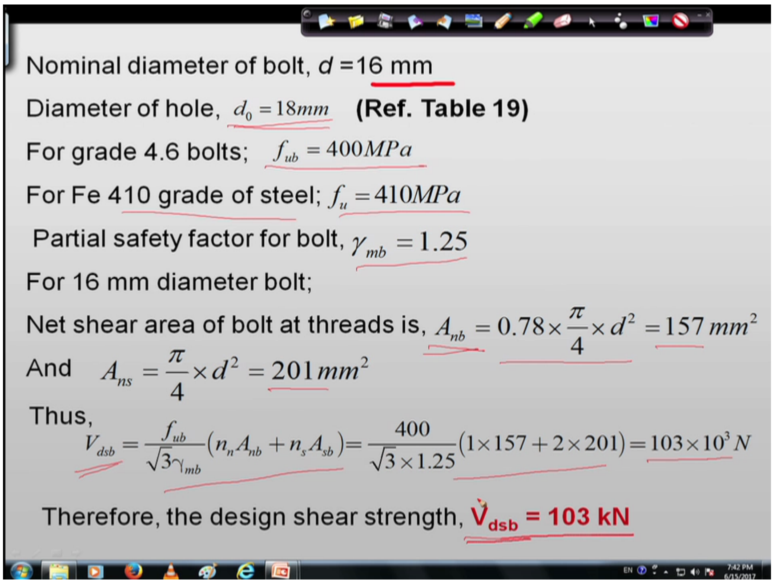

So if we see now that nominal diameter of bolt was given as 16 mm, so hole diameter will be d0 will be 16 plus 2, because as per table 19 the clearance of the bolt for 16 mm diameter will be 2 mm. So the whole diameter will become 18 mm and for 4.6 grade bolt we know fub the ultimate stress of bolt will be 400MPa and for Fe 410 grade of steel fu we know fu is the ultimate tensile strength of the plate that is 410MPa and partial safety factor from table 5 we can find out as gamma mb as 1.25.

So now we can find out the value of Anb Anb will become 0.78 into pi by 4 into the square which is 157 and Ans will become pi by 4 into d square which is coming 201. So thus Vdsb the design strength of the bolt due to shear we can calculate from this formula and if we put this value we can find out the value as 103 into 10 to the power 3 Newton or we can say the design shear strength of the bolt will become this much Vdsb will be 103 kilonewton.

So this is a small example we have shown where only shear strength has been calculated and shear strength has been calculated due to multiple shear that means we have tried to understand here that what will be the value of nn, how we will calculate the value of nn and ns and what will be the Anb and Ans and accordingly what will be the Vdsb the design shear strength due to shear in the bolt.

So due to multiple shear in this case the triple shear the example has been worked out and has been shown I hope you have understood this example, thank you very much.