Course on Design of Steel Structures
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Lecture 07
Module 2
Worked Out Examples on Design of Ordinary Black Bolts

Hello in last class we have discussed the design philosophy of ordinary black bolt and we have seen that how to calculate the design shear strength of black bolt, the bearing strength, tensile strength and tensile strength of plate and combination of shear and tension. So how to calculate the strength due to different force occurring that has been discussed in last class and a small example we have gone through in last class that is how to calculate the design shear strength of a ordinary black bolt.

Now today I will go through two examples of ordinary black bolt this bearing type of bolt and we will see how to calculate different type of strength due to shear, due to bearing, due to tension that we will go through this example and we will see another example that means that if a plate is connected with different number of bolts how to calculate the efficiency of that bolt that means the strength of bolt and the strength of the solid plate that that we will try to find out and we will see how the efficiency is calculated and in first example we will try to see how to calculate the bolt strength of joint strength of lap joint and also butt joint. So this is what we will cover in today's lecture.

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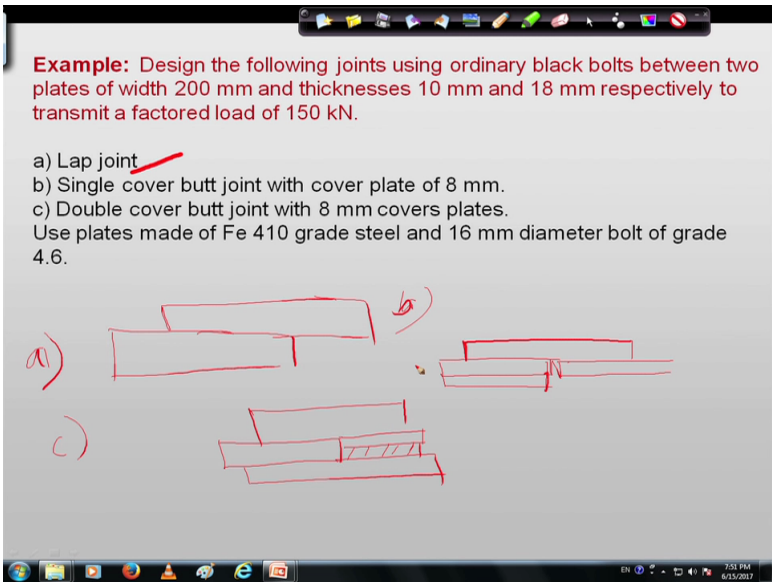

So two example as I told we will be going through one is this example this is design the following joints using ordinary black bolts between two plates of width 200 mm and thickness 10 mm and 18 mm respectively that means two plates of 10 mm and 18 mm to transmit a factored load of 150 kilonewton.

So we will design if these are under lap joint means due to lap joint lap joint means we know that if we have a plate and another plate then this is case A lap joint and then single cover butt joint that means we will provide plates in same axis and we will provide a cover plate of course this thickness is more, one plate thickness is more and plate thickness of another one is less so there will be a gap, right and third this is second case.

And third case we will use double cover butt joint double cover butt joint means suppose this is a plate and this is another plate, so we will provide a cover plate here and we will provide a cover plate here of course we have to fill up this with packing plates, right so we will see how to calculate.

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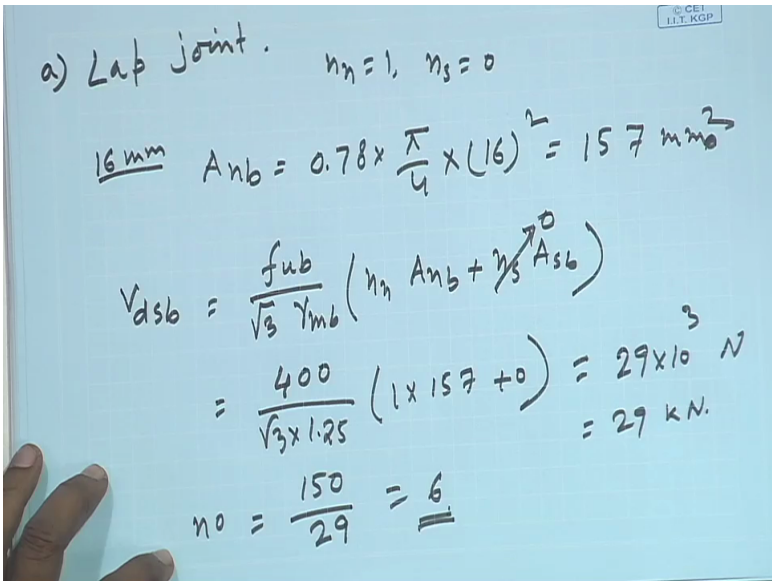

So first we will come to the first case that is lap joint, so in this case we can assume that shear plane is including in the threads so nn is 1 and ns as 0 and for 16 mm bolt diameter 16 mm bolt diameter the Anb the net shear area of the bolt at thread we can calculate that is 0.78 into pi by 4 into d square d square means this is 16, so this will become 157 millimeter square, ok.

So from this we can calculate the design shear strength of the bolt that is Vdsb that will be fub by root 3 gamma mb into nn Anb plus ns Asb, I am not writing the reduction factor due to large grip length, due to large joint and due to packing plates this I am excluding because

reduction factor has not been means joint length has not been given, grip length has not been given, so we do not know whether we have to reduce or not that is why we are omitting these three reduction factors.

Now here again ns will be 0 ns will be 0 so we can find out d value as fub value is 400 by root 3 into gamma mb is 1.25 into 1 into 157 plus 0, so this will get 29 into 10 cube newton or 29 kilonewton, right. So number of bolt number of bolts will be how much because 150 kilonewton was the force so if we divide by the bolt strength number of bolt we can find out as 6, right form shear point of view we can find out the 6 number of bolt is required.

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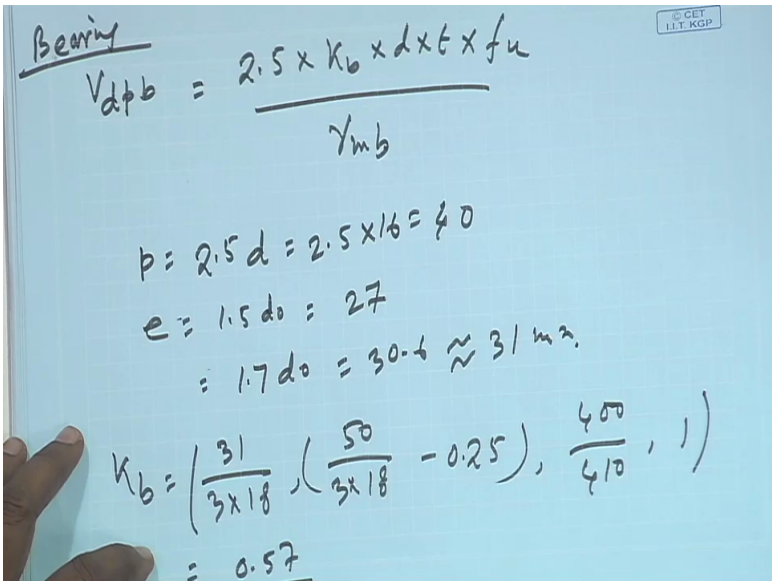

Now if we go for bearing, we can find out Vdpb due to bearing bearing strength if we want to calculate so we know that is 2.5 into kb into d into t into fu by gamma mb, right. Now we have to find out the value of kb, now we can provide the pitch distance and edge distance suitably, the pitch distance we know minimum pitch distance is 2.5d, so we can find out it will be 2.5 into 16 it will be around 40 and e is 1.5 into d0 that is for bolt edge is coming around 27 and and if we consider hand flame cartage then that will be 1.7d0 this is given in the codal provision that is 30.6 means 31 mm, right.

So now we can find out the value of kb as we know kb is the e by 3d0 that means 31 by 3 into 18 and p by 3 dd 0minus 0.25 this is another one, 400 by 410 and 1 and smaller of this will become 0.57 smaller of all this is becoming 0.57.

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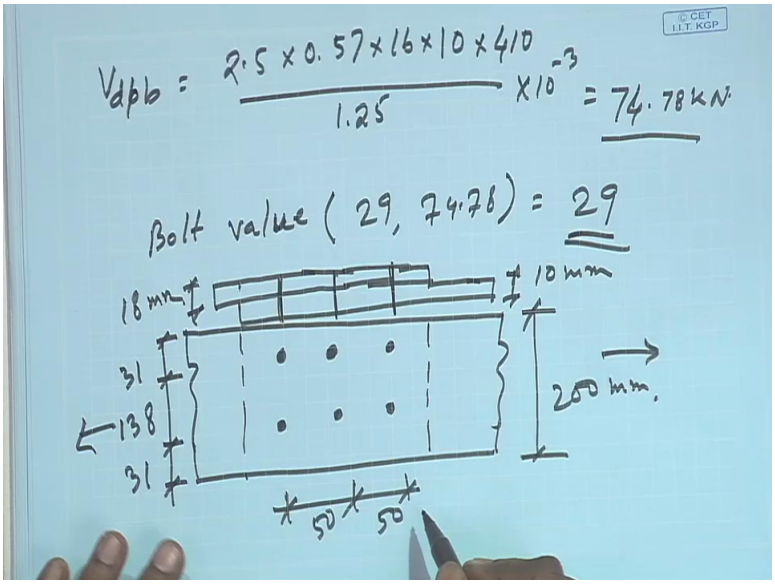

So now we can find out the value of Vdpb, so the Vdpb value will become 2.5 into kb value is 0.57 and into d into t t is the thickness of the plate that is 10 mm, thickness of the thinner plate we will consider and then fu by gamma mb into 10 to minus 3 if I do then it will be in kilonewton, so this is coming 74.78 kilonewton, that means Vdpb the design bearing strength of bolt is coming 74.78 kilonewton, that means the bolt value will be minimum of bolt value will be minimum of two that is 29 and 74.78 kilonewton that means 29 kilonewton minimum of this two.

Now so we require number of bolts actually we require 5 or 6 sorry 6. So we can arrange the bolts in this way in two line we can arrange say if we have the first case the lap joint so we can provide a bolt here so six bolts we can provide in this way and we can provide may be this we can provide 31 mm, this is coming 138 mm and this is coming 31 mm and this we we can make may be 50, 50 all of in millimeter because this total is 200 mm width of the plate is 200 mm, right and in elevation if you see the bolts are jointed like this so this is one line, this is another line this is another and one plate is of 10 mm thickness, another plate is of 18 mm thickness and directional force is in this direction, right. So this is how we can design the bolt connection under lap joint.

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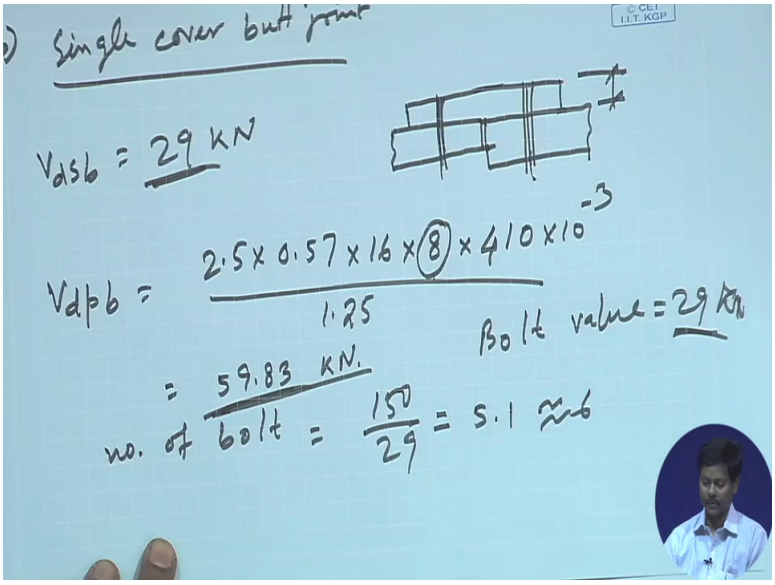

Now we will go to second case second case is single cover butt joint single cover butt joint. So in this case things will be like this two plates may be another plate is this two plates are joint with a cover right. So we have to provide certain bolts here and we have to provide certain bolts here. So for this case also the design shear strength of bolt Vdsb will be 29 kilonewton because this is also in single shear, right.

Now we have to calculate the Vdpb value Vdpb value here we can calculate as 2.5 into kb will be same if we consider the same pitch and edge distance then the value of kb will be same like earlier. So kb value 0.57 into d into t into fu 10 to the power minus 3 I am taking and 1.25 is the gamma mb value. Now remember this 8 mm is the thickness of cover plate and when we are going to design we have to take the thickness of the thinner plate that is why 8 mm value has been consider.

So this is coming 59.83 kilonewton and here also the number of bolts require will be will be 150 by 29 because the bolt value will be 29 kilonewton, right bolt value will be 29 kilonewton because smaller of this two. So we can find out the number of bolt that will be 5.1 that means 6, right so this case also arrangement will be same in this case arrangement also will be same or we can change the arrangement like the edge distance and pitch distance we can little change.

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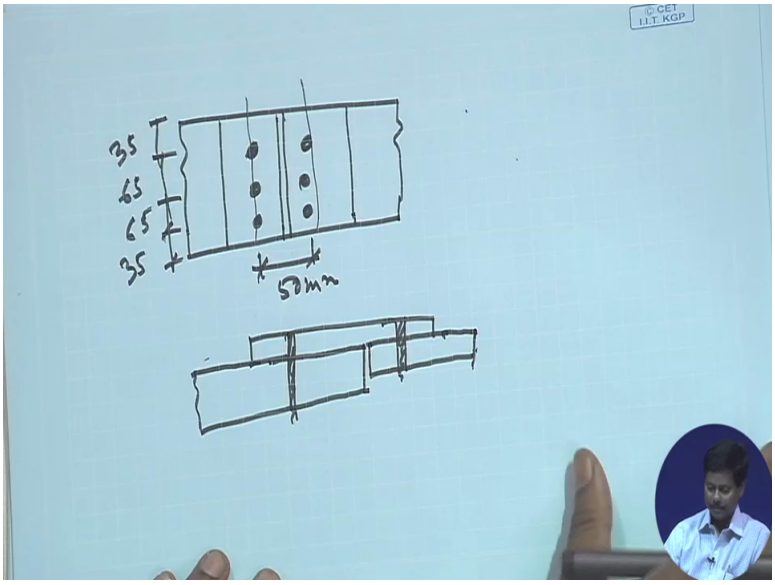

Say for example let us consider this I am drawing the plan of the joint so we can make in this way also and then this is 50 mm though we have taken 31 mm edge distance we can increase little more say 35 it will be (()) (15:46) then we can provide 65 this we can provide 65 and then 35 or we can provide 31 also, right and if we see from the other site means elevation of the joint this will be like this if this is thicker plate and if this is thinner plate then if we provide the cover plate of this then joints are made that means single cover single line butt joint.

So bolt we are providing in single line in each case here and plates are connected, right so this is how we can arrange the bolts in three lines and we can find out the arrangement of the bolts in this way.

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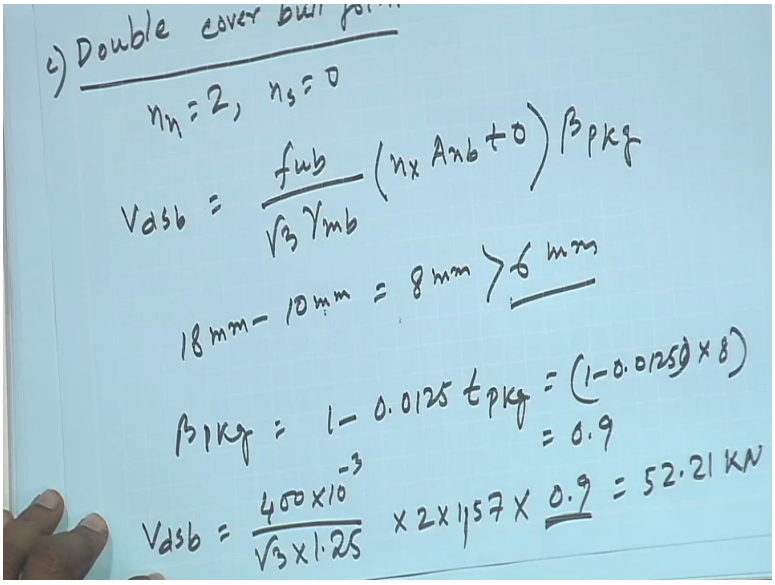

Now we will go the third case that is double cover butt joint. So what will be the difference from earlier one that in this case the as double cover butt joint so can assume that it is a actually it is a double shear as double cover butt joint so it will be double shear. So if we assume the threads are in the shear planes than nn we can assume 2 and ns as 0, therefore we can find out the value of design strength of bolt in double shear that we can find out as Vdsb is equal to (fu) by fub by root 3 gamma mb into nn into Anb plus 0 because ns is 0 into beta Pkg because packing is require, in case of double cover butt joint as the thickness of the plates two plates are different and we are providing in two sites we are providing cover plate so there will be a gap so we have to provide the packing packing plate we have to provide and this packing plate will be 18 millimeter minus 10 millimeter that means 8 millimeter which is greater than 6 mm.

So as the packing plate thickness is greater than 6 mm we have to provide the reduction factor for the packing plate so beta Pkg we have to calculate. Now the reduction factor due to packing plate we can calculate beta Pkg as 1 minus 0.0125 tPkg, so this is 1 minus 0.0125 into into 8, that means it is coming 0.9.

So design shear strength for this case will be little less than the earlier one that is 400 into 10 to the power minus 3 for making it kilonewton into 1.25 into 2 into (1.57) sorry 157 into 0.9, this is the beta Pkg. So if we put this value we will find out 52.21 kilonewton this is less than 29 into 2 that means 58 kilonewton.

If packing plates are not given than the shearing strength of the bolt due to double shear will become 29 into 2 that is 58 kilonewton but as we are providing packing plate which is more than 6 mm, so we have to reduce certain amount which was given as a reduction factor of beta Pkg and that value is coming 0.9, that is why in place of 58 this is coming 52.21 kilonewton.

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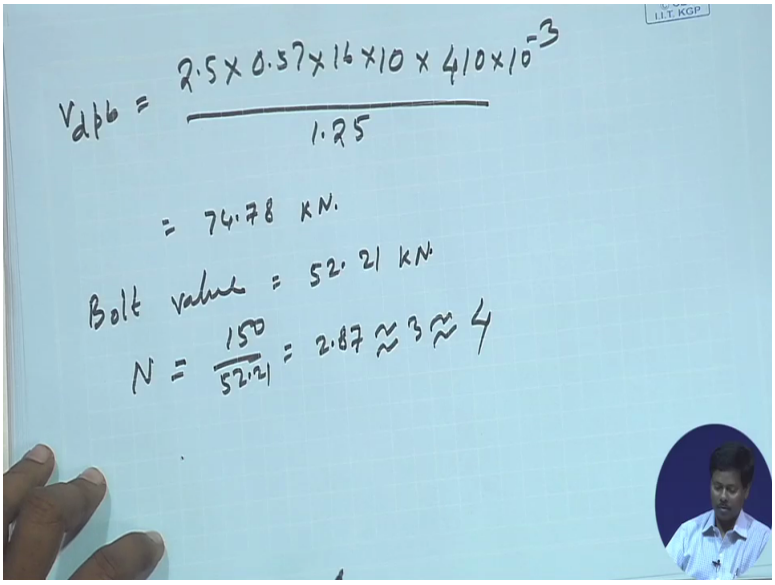

Now similarly we can find out Vdpb that will be same as earlier in this case we can find out 2.5 kb will be same that is 0.57 and d is 16 and t will be thickness of the thinner plate. So now as double cover butt joint has been provided that is why the cover plate thickness will become 8 into 2 that is 16 mm and thickness of other plates are 10 mm and 18 mm. So thickness of the thinner plate will be 10 mm so that is why we are providing 10 and if we multiple with fu and if we provide the value of gamma mb we will get 74.78 kilonewton.

So in this case bolt value will become 52.21 kilonewton, so number of bolts will be require 150 by 52.21, 2.87 so that we can make as this is a double cover butt joint so atleast we have to provide means we cannot provide 3, so we have to provide 4 number of bolts.

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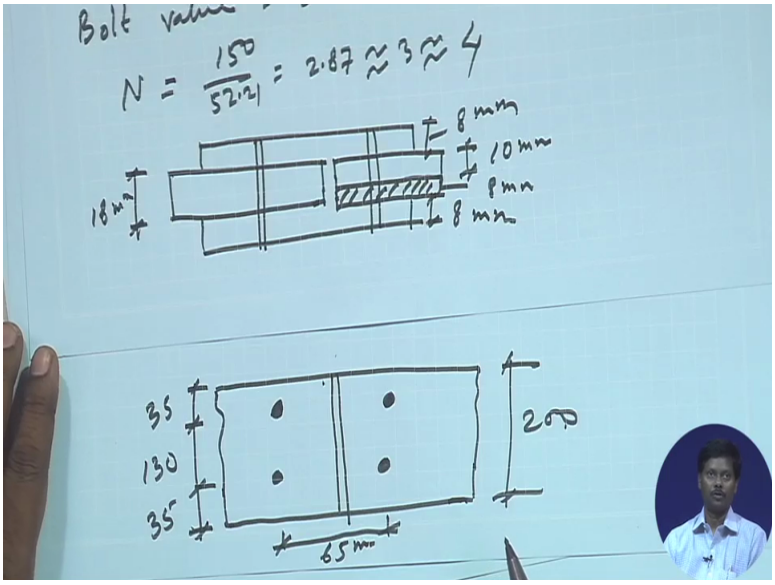

So if we draw this figure we can see that one is this is say suppose 18 mm and this is 10 mm and then we will provide some packing plate this is packing plate of 8 mm, this is 10 mm, this is 18 mm and we are providing cover plate of 8 mm, this is 8 mm, right.

Now atleast we can provide we have to provide a single line of bolt here and we have to provide a single line of bolt here right. So if we see these we can see that in plan it will look like this this is the two plates are joining here and bolts are connected here four number of bolts are there. So the detailing can be done in this way either we can consider 31 millimeter or we can provide 35 may be 130 and 35 to cover this total 200 mm thickness, right and this we can provide 65 mm or more whatever means suitably we have to provide, so this will be the this will be the arrangement of the bolts, right.

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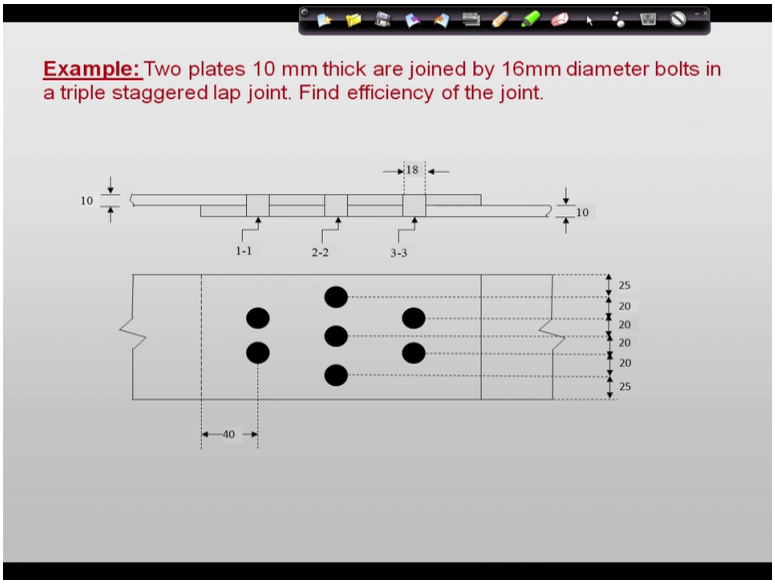

Now we will go through next problem next problem is we have this that is if you see the two plates of 10 mm thick are joint by 16 mm diameter bolts in a triple staggered lap joint. Find the efficiency of the joints.

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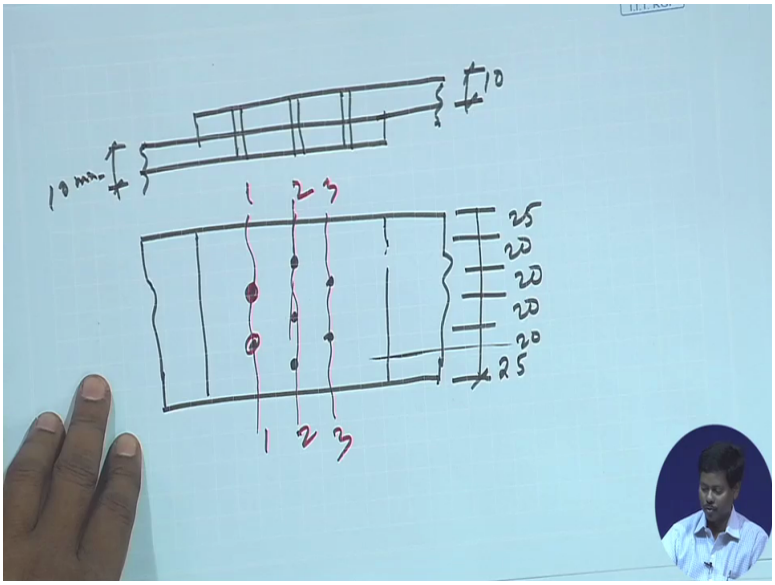

So if we draw the figure we will see this is a triple staggered lap joint. So bolt we can provide in this way triple staggered lap joint so may be this is how we can provide and we can provide the spacing which has given this is 25, than 20, 20, 20, 20 and this is 25 right and two plates are connected so this is one plate and this is another plate, thickness of this plate is 10 mm and 10 mm, right say this is this is one bolt line, this is another bolt line, this is another bolt line, right.

Now the failure may occur in this direction, in this direction, or in this direction. So if we make section 1, 1, 2, 2, 3, 3 then we have to consider first failure at 1, 1 that we will try to find out then 2, 2 again when 2, 2 is along 2, 2 when it is going to fail it has to fail the bolt at line 1. So when we are going to find out the strength at 2, 2 that means we have to find out strength at bolt at 1, 1 failure strength plus 2, 2. So it will be clear when we will be going through this example.

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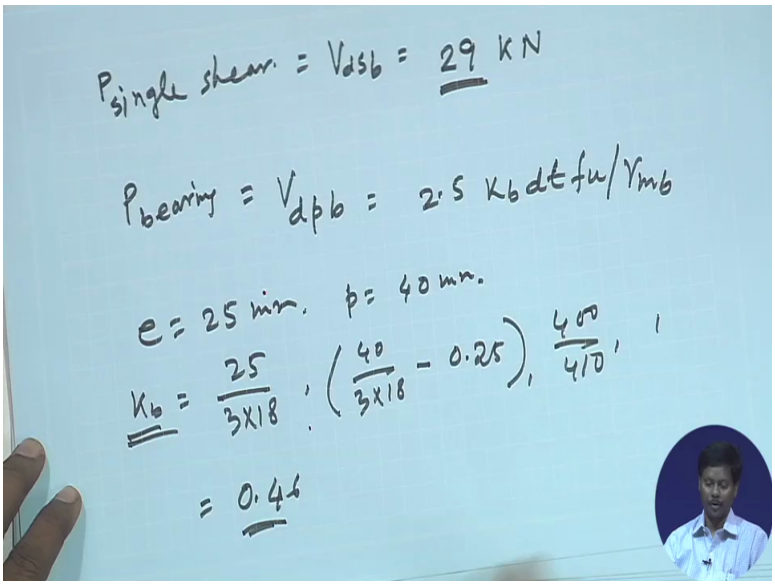

So first let us consider case means section 1, 1 means along 1, 1 if it fails how it looks. So there first we have to find out the this is in single shear so the P single shear if I write then due to single shear Vdsb will be same as earlier this will be 29 kilonewton, right and bearing will be I am not going into details because this 29 kilonewton we have already calculated in earlier case of 16 mm diameter because this is a single shear and diameter is (20) 16 mm diameter so 29 will be the single shear strength shear strength due to single shear.

Now bearing Vdpb will be again 2.5 kbdt, so here we have kbdt into fu by gamma mb, here kb value will be different because here e is equal to 25 mm and p is equal to 40 mm, right. So we can consider the kb value as from this formula that is e by 3d0 that means 25 by 3 into 18, then p by 3d0 minus 0.25, then 400 by 410, then 1. So smaller of this so smaller of this value is coming 0.46, so kb value we can calculate as 0.46.

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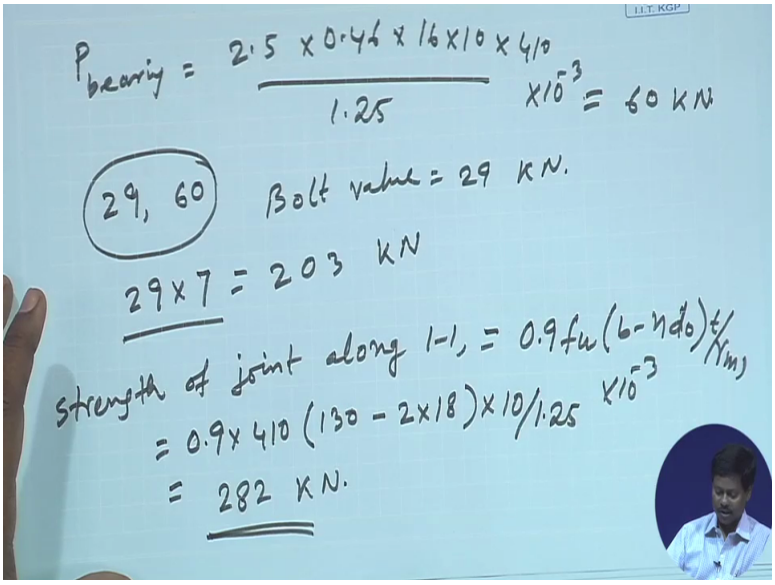

So p bearing we can find out will be how much 2.5 into 0.46 into 16 into 10 into 410 by 1.25 into 10 to the power minus 3 for making it kilonewton, so this is coming 60 kilonewton, right. So bolt value due to shear it is coming 29 and due to bearing it is coming 60. So smaller of this two will be the bolt value, so we can consider the bolt value as 29 kilonewton, right.

So the strength of joint based on bolt value will become how much strength of joint because 7 number of bolts are there so this will be 203 kilonewtons strength of joint from bolt value based on bolt value that means if 7 bolts are felt at a time if 7 bolts are felt at a time then the strength of bolt will become 203 kilonewton. Again now we will see if it fails along section 1, 1 then what will be the strength of that joint.

So section 1, 1 if we calculate strength of joint along 1, 1 then this will be 0.9fu into (b minus n) d0 into t by gamma m1, right gamma m1. So I can calculate this value that will be 0.9 into fu into the thickness was total 130 and 2 numbers of bolts along 1, 1 so 2 into 18 then t is 10 mm by 1.25 into 10 to power minus 3 for making it kilonewton, so this is becoming 282 kilonewton, right. So strength of joint along with 1, 1 is becoming 282 kilonewton.

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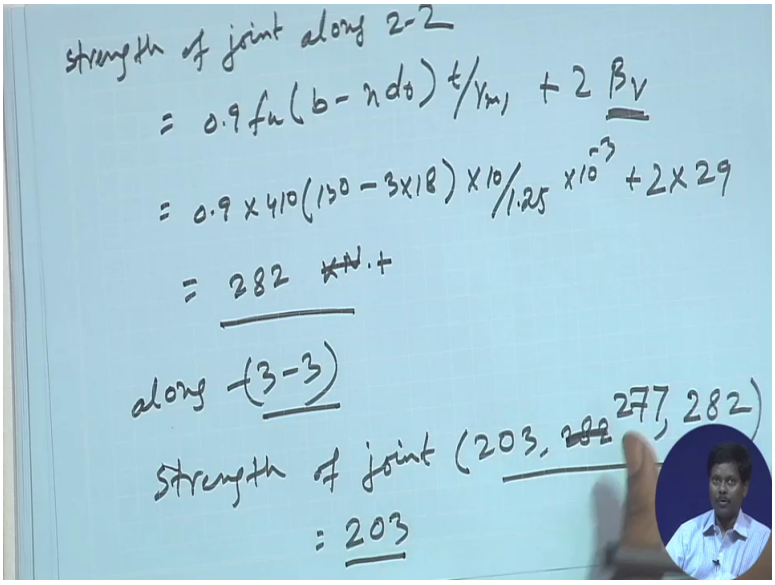

Next we will see what will be the value of bolt value if it fails along 2, 2 that means strength of joint along 2, 2 this will be how much this will be 0.9fu into b minus nd0 t by gamma m1 plus 2Bv bolt value means individual bolt value of 2 that means when section 2, 2 will fail it has to fail fast 2 value along means along 1, 1 then the fail failure at along 2, 2.

So we will calculate 0.9 into 410 into 130 means similar process minus 3 into 18 in this case number of bolts are 3 into 10 by 1.25 10 to the power minus 3 plus bolt value of 2 bolts along 1, 1. So this is coming 282 kilonewton, right. So strength of joint along 2, 2 we are getting 282 kilonewton.

So now again if it has to fail along 3, 3 it has to fail section means the bolt along 1, 1 and bolt along 2, 2, right. So failure strength will be much higher then 1, 1 or 2, 2. So the strength of the joint we can calculate strength of joint will be lesser of all that means 203, then 282 or this is sorry this is 282 plus ok. So actually strength of joint along 1, 1 was 277 calculation I have done some mistake so 277 and then strength of joint along 2, 2 will be 282, so lesser of this three, this three will be that means 203. So this is the strength of joint of the arrangement of bolt as shown in the figure earlier.

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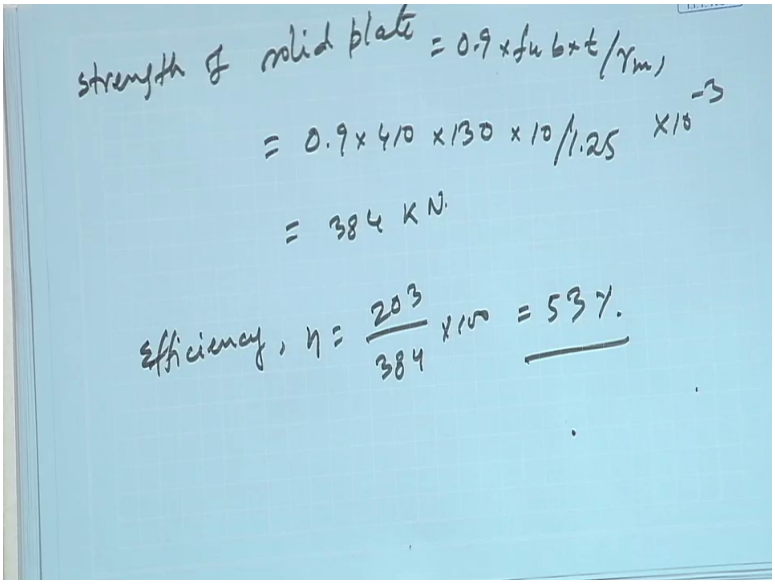

Now we have to find out the efficiency of the joint, so efficiency of the joint means the strength of joint divide by the strength of the solid plate that means if bolting connection is not done the hole not be inserted then what will be the strength of the plate. So strength of solid plate we have to calculate first that will be 0.9 into fu b into t by gamma m1. So if I put those value I can find out the strength of the solid plate, this is coming 384 kilonewton, right.

So efficiency I can find out, this will be 203 by 384 into 100 that means 53 percent, right. So this is how we can find out the efficiency of the joint. So in this lecture what we have seen we have gone through two examples, one was based on the lap joint and butt joint and we found what will be the strength of the joint for different type of lap joint and butt joint that we have calculated in first example and in second example we have calculated the efficiency of the joint and how the joint fails means joint can fail as a hole due to shear of the bolt or it can fail along a particular section.

So we have found the strength of joint along different section and as a hole and we try to find out the joint strength and then efficiency, thank you very much.