Course on Design of Steel Structures
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Lecture 20
Module 4
Calculation of Net Area in Tension Member

Hello so today we will go through some work out example. In last lecture we have discussed how to calculate the net area of a member along critical section. So the use of the formula we will today try to find out the net area of the section for a given product.

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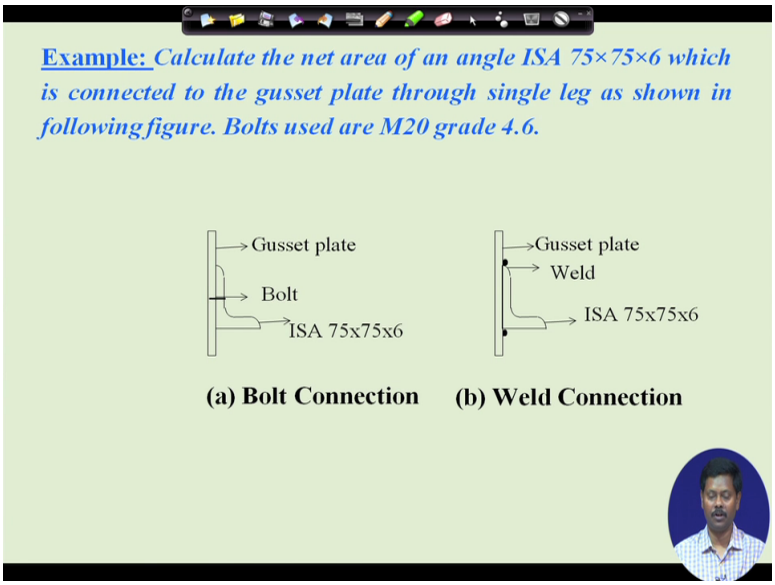

So first problem is this one that is calculate the net area of an angle ISA 75 by 75 by 6 which is connected to the gusset plate through single leg as shown in the following figure and bolts are used of M20 grade of 4.6.

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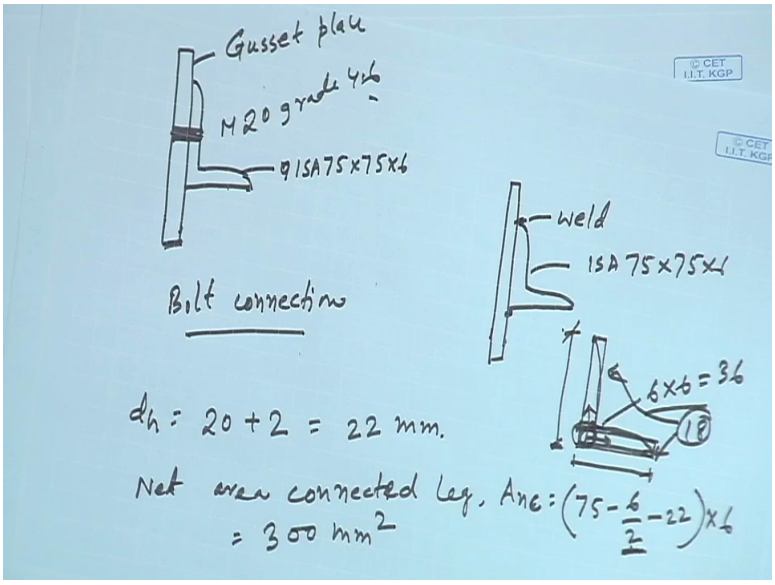

So to start with we can see that first case we can consider that a gusset plate is connected with an angle section of ISA 75 by 75 by 6 with a bolt, right. So this member size is (7) ISA 75 by 75 by 6 and this this is gusset plate and this bolt is M20 grade of bolt with 4.6 grade, so this is one case.

And again this is bolt connection again same angle if it is connected by weld so in this case how the net area is going to be effected that we will try to find out. So this is weld connection in this area, right. So this angle section is also ISA 75 by 75 by 6.

So for first case if we try to find out then diameter of bolt hole dh I can find out nominal diameter of bolt plus clearance 2 mm, so this is 22 mm. So net area of the connected leg net area of connected leg we can find out and the unconnected leg we can find out and then we can edit. So net area of the connected leg Anc will become this will be Anc will be 75 minus 6 by 2 minus 22 why 6 by 2 into t.

Because when we are going to calculate the net area of a leg we can calculate that means assuming that this is one part if I consider this is one part this 75 by 75 and this is another part. So area will be 75 into 6 again for this leg area will be 75 into 6 but if you see that as 75 is from root to toe that means we are adding twice this part. So to take it actual value we are going to reduce half of the things in this part and half of the area in this part. Therefore we have reduced 6 by 2 not 6 into 6, 6 by 2 into 6.

So the area will become because this area will become 6 into 6 and that means 36 that means 18 will be going to here and 18 will be going to here. Therefore the Anc value will become after calculation it will be 300 millimeter square right 300 millimeter square.

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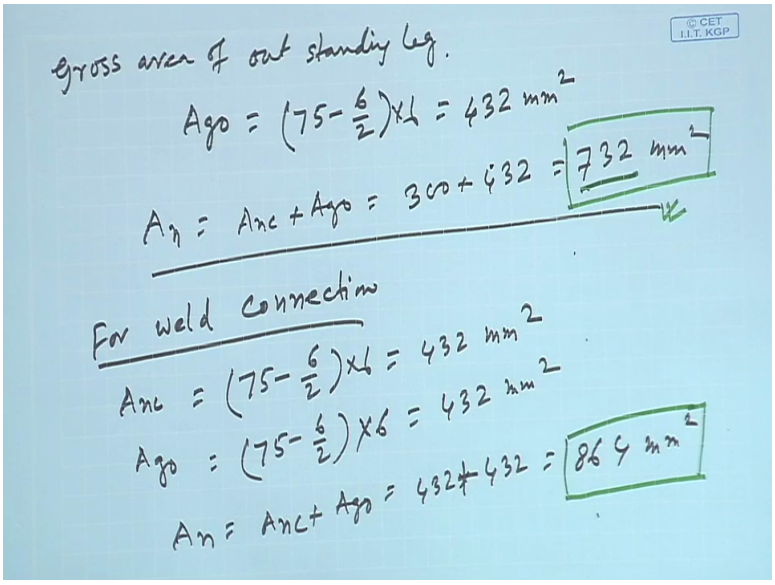

Similarly the gross area of the outstanding leg I can find out gross area of the outstanding leg that will be Ago gross area of the outstanding leg that will be simply 75 minus 6 by 2 into 6, so this will be 432 millimeter square. So net area An net area of the angle will be Anc plus Ago is equal to 300 plus 432 is equal to 732 millimeter square. So this is how I can find out the net area of the angle section, right.

That means when I am going to find out the net area of the angle section I am going to reduce the hole area hole area due to presence of bolt. Now in this case one bolt was present so in one leg so we have (cal) reduced the hole area of one bolt, right. So now in case of weld connection there is no reduction.

So I can find out simply the area that is for weld connection I can find out the net area of the connected leg that will be simply 75 minus 6 by 2 into 6 that will be 432 millimeter square and Ago the gross area of the outstanding leg will also be same because due to weld connection there is there will not be no hole in the angle section therefore there will be no reduction. So this will become also 432 millimeter square, so net area of the angle in this case will be Anc plus Ago is equal to 432 (into) plus 432 that means 864 millimeter square.

So here what we could see that net area of the weld connection is becoming 864 millimeter square. So if we compare that for weld connection the net area is 864 and (weld) net area for

bolt connection is 732, that means the strength of the member or the angle is going to be reduced if we use bolt connection compare to the weld connection because because of the insertion of the hole the reduction in strength will happen as the hole cannot take tension means that area cannot take tension that is what the effective area for taking the tension will be less that is 732 millimeter square, right.

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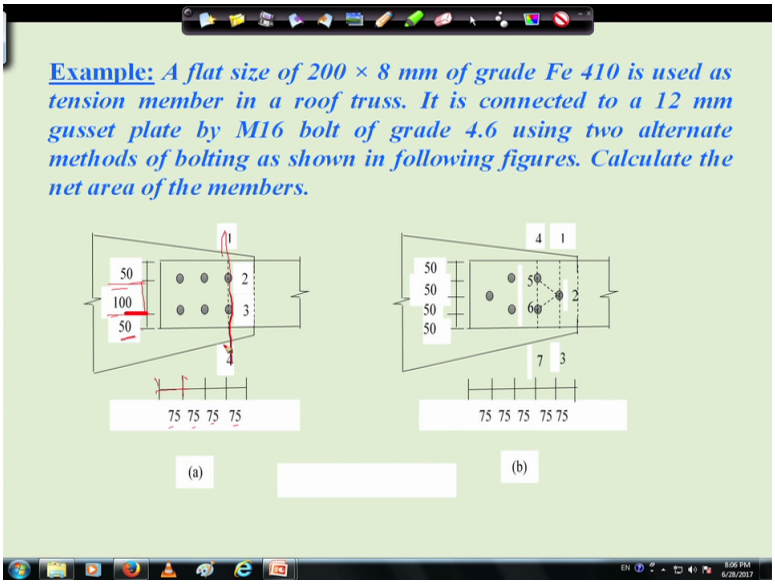

Now another problem we will go through that is a comparison between chain bolting and zig-zag bolting, this is the problem. Say a flat size of 200 by 8 mm of grade Fe 410 is used as tension member in a roof truss. It is connected to a 12 mm gusset plate by M16 bolt that means 16 mm diameter bolt of grade 4.6 using two alternate methods of bolting as shown in the following figure. Calculate the net area of the member.

So what we could say that in case of chain bolting say first we will consider the chain bolting, this connections are given here if we see here that the edge distance is 50 and pitch is means this distance is 100 and again 50, right and this pitch distance along horizontal is 75, 75, 75, 75 right and in case of plane bolting or chain bolting it will be means the failure may happen in this direction means 1-2-3-4 this is simple way the failure will happen. So we have to calculate the net area along this line.

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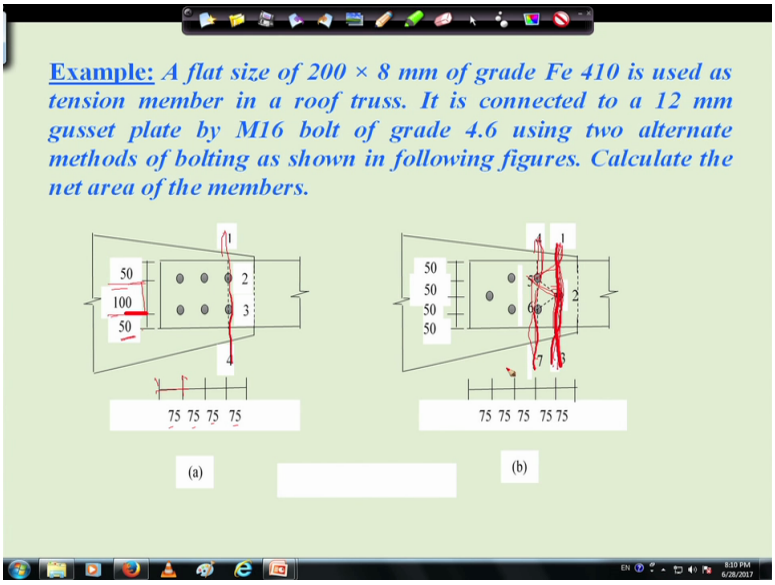

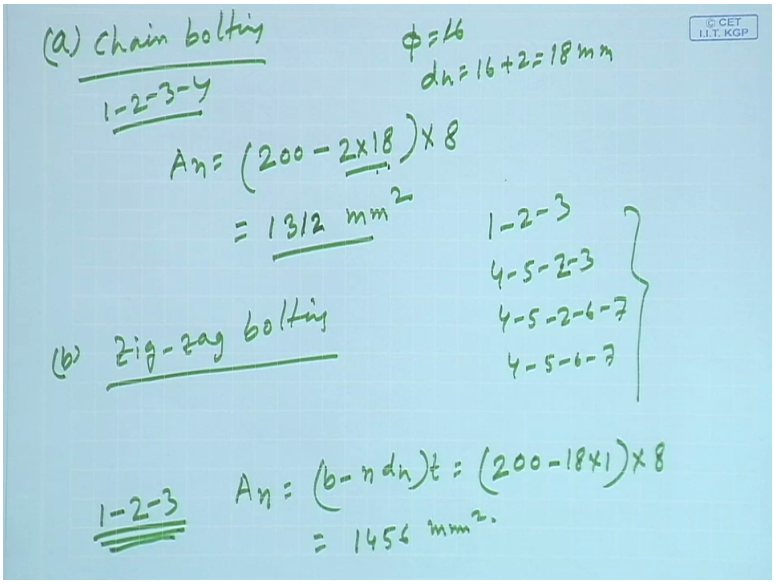

So for chain bolting we can find out the net area along line 1-2-3-4 that will be simply An is equal to 200 minus 2 into 18. Here nominal diameter of the bolt is 16 so bolt hole will become dh will become 16 plus 2 that is 18 mm, right. So the along this line 1-2-3-4 two bolts are there therefore the reduction will be 200 minus 2 into bolt hole bolt diameter into the thickness thickness was given as 8 mm. So after calculating we can find out this is 1312 millimeter square.

So for chain bolting the net area will be this so from this net area I can finally find out the rapture strength means what will be the strength of the means strength of the plate that can be found right Agfy sorry not Agfy 0.9 Anfu by gamma (())(12:00), so from that I can find out so that formula I will come later, how to find out the strength due to rapture that I will come

later I have to find out. So when we are going to find out the strength we need to know the what is the net area so that net area we have to calculate.

So now second case I will come that is zig-zag bolting, in case of zig-zag bolting there are several options in which it may fail so we have to be careful. One is you see that in line 1-2-3 it may fail line 1-2-3 it may fail then it may fail 4-5-6-7 but if it has to fail 4-5-6-7 also bolt 2 has to fail this is one case.

Another case is it can fail the 4-5-2-3 again 4-5 sorry 1-5-2-3 and again 1-5-6-7 so there are several options are there. So if we write down one by one option one will be 1-2-3 another will be 4-5-2-3, 4-5-2-6-7 and 4-5-6-7. So I have to calculate the net area along this four direction four path, right and the minimum one will be the net area of the plate.

So first we will consider 1-2-3 say along 1-2-3, so along 1-2-3 means this one 1-2-3. So here what we could see it is a simple one that only one bolt is coming into picture. So net area we can find out that will be b minus n into dh into t, that will be 200 minus 18 into 1 into 8 thickness is 8. So I can find out that is 1456 millimeter square. So net area along 1-2-3 we can find out in this way, right.

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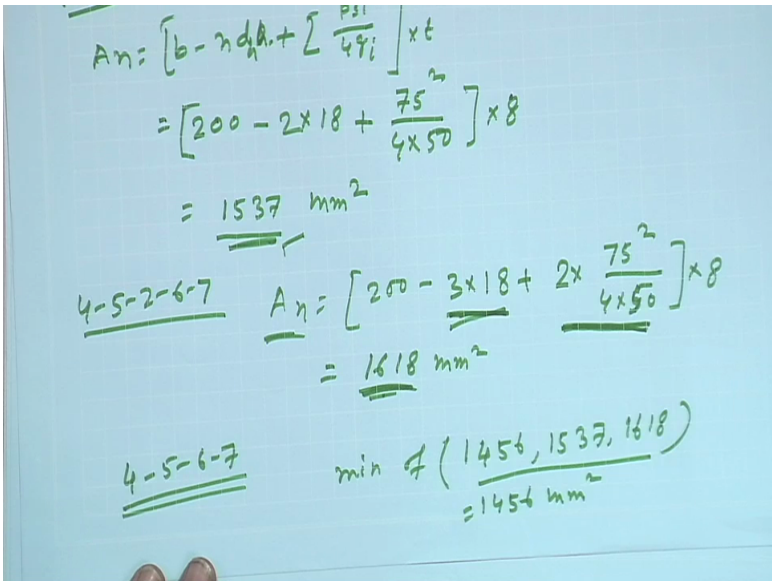

Now we will find out the net area along 4-5-2-3 along 4-5-2-3 right. So net area along 4-5-2-3 I can find out, so 4-5-2-3 means this 4-5-2-3 that means one staggered pitch is there so if I calculate An this will be b minus ndh plus n into dh into dh plus psi square by 4gi, here i is equal to 1 into t.

So if I calculate this if I put the value b is 200 minus n n will be 2 because it crosses two bolt 5 and 2, right. So 2 into 18 plus only one inclined length is there, so that I have to find out. So psi will be here 75 and g will be (4) g will be 50, so g is given here this is 50, right so this is 50 and this value is 75. So this is how I can find out the value t is 8. So after calculation we can find out 1537 millimeter square, so net area along 4-5-2-3 is coming 1537.

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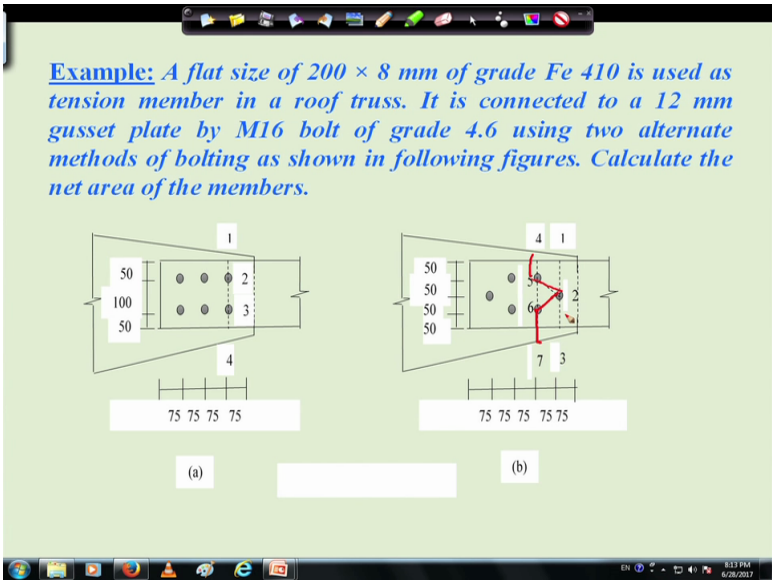

Again net area along 4-5-2-6-7 4-5-2-6-7 4-5-2-6-7 means this will be 4-5-2-6-7 that means three bolts are there. So here I can find out net area will be b is 200 minus n will be 3 into dh is 18 plus here two numbers of inclined length is there so 2 into psi psi value is this 75 and 4g 50 into t. So I can find out the value as 1618 millimeter square that means here you see though the number of bolts are increasing but due to staggered pitch some area is going to be added, so though we are deducting 3 into 18 but we are adding this.

Therefore the net area you see if you compare with this 4-5-2-3 net area is becoming more, that means failure along this direction chances is less chances of failure along 4-5-2-6-7 is less compare to this however we have to see the least one.

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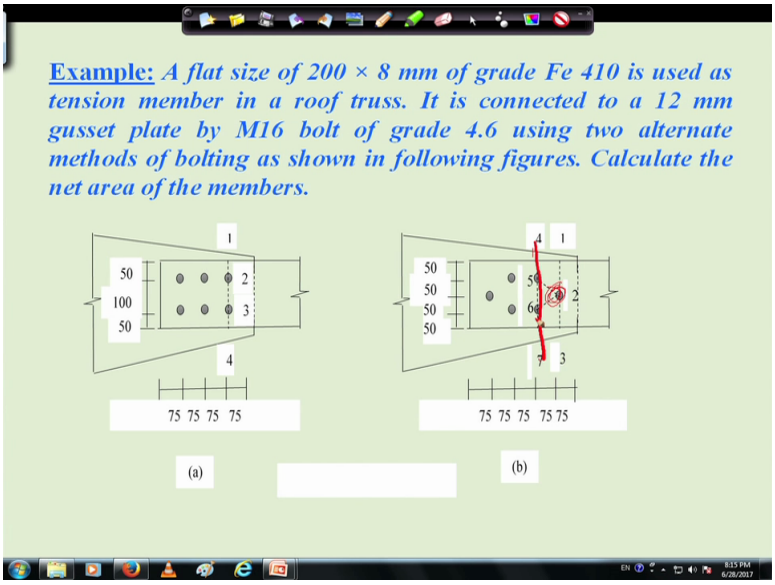

Now another scope is that 4-5-6-7 now 4-5-6-7 means this way now if the plate has to fail along 4-5-6-7 then first it has to fail this due to shear the bolt 2 has to fail, that means when we will be going to calculate the strength along this direction we have to add strength of 2, that means it will be more than the earlier cases therefore we are not going to calculate this because we know it will be more strength will be more so we are not going to calculate.

So what we could see the net sectional area we are getting minimum of one we got 1456, then we get 1537 and then 1618 so minimum of this that means 1456 and 1456 happened in case of failure of 1-2-3.

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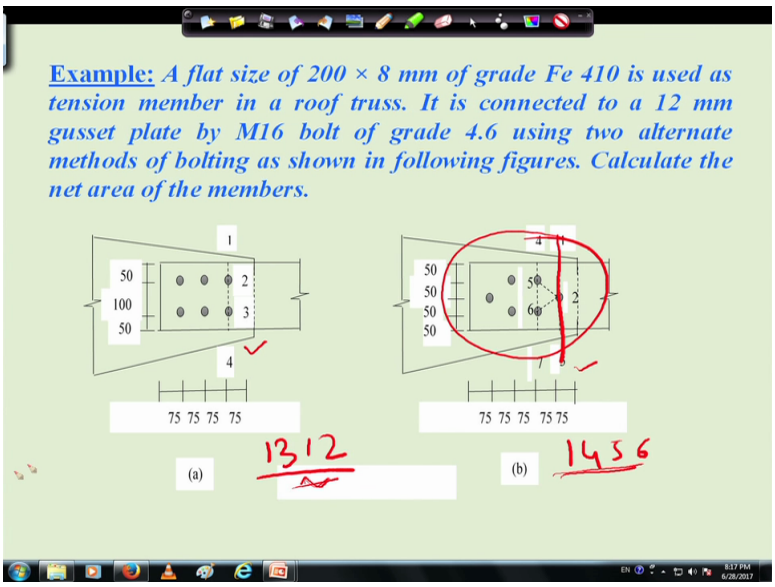

That means when the failure is means we are considering this direction it may fail, right. So along 1-2-3 sorry this one along 1-2-3 it will fail means under this geometrical condition and configuration the critical section will be 1-2-3 along 1-2-3 and this critical section net area we are going to get as 1456, right.

And if you remember that if we consider means here the critical sectional area we are getting 1456 1456 millimeter square and for this we are going to find out the net area as 1312, right. So for plane bolting means 6 number of bolts is given here, here also we have given 6 number of bolts but we are getting less strength in case of plane bolting compare to the zig-zag bolting, that means we should go for zig-zag bolting as much as possible that means the efficiency of the bolting connections will be more in case of zig-zag bolting compare to the chain bolting, right.

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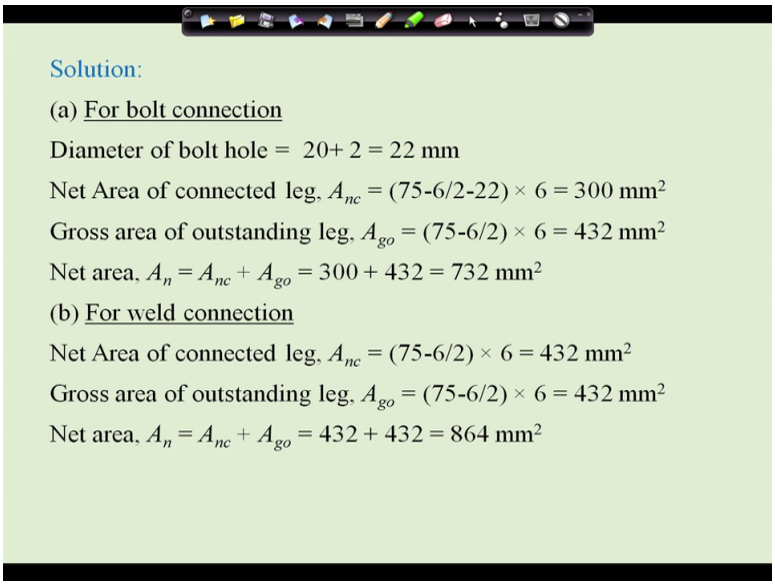

So this is what about the net area calculation so if we see the solution whatever I have discussed I have written here you can have a look that is for plane bolting we have Anc, we can find out sorry not this one after this we have this slide.

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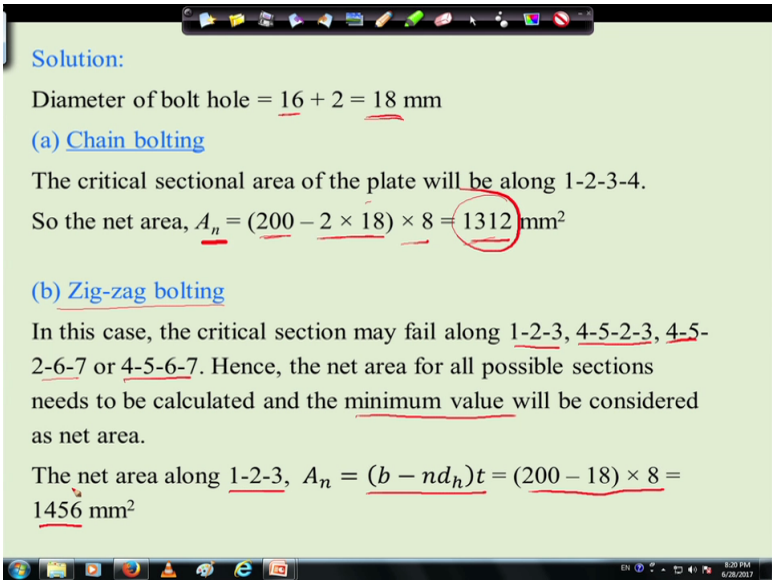

So if we go the solution we will see for chain bolting the net area will be 200 with minus the hole area into thickness so 1312, right.

So for chain bolting the critical sectional area of the plate will become 1312, here we have consider 18 because 16 mm diameter has been consider and so bolt diameter means hole diameter will be 16 plus 2 that is 18 mm.

For zig-zag bolting as we have shown that the chances of failure may happen along 1-2-3 along 4-5-2-3 along 4-5-2-6-7 or along 4-5-6-7. Therefore we have to calculate the all possible cases and we have to find out the minimum value, right. Now if we consider the net area along 1-2-3 there it will be simply b minus ndh into t where n is equal to 1 and there is staggered pitch therefore we got 1456 net area along 1-2-3.

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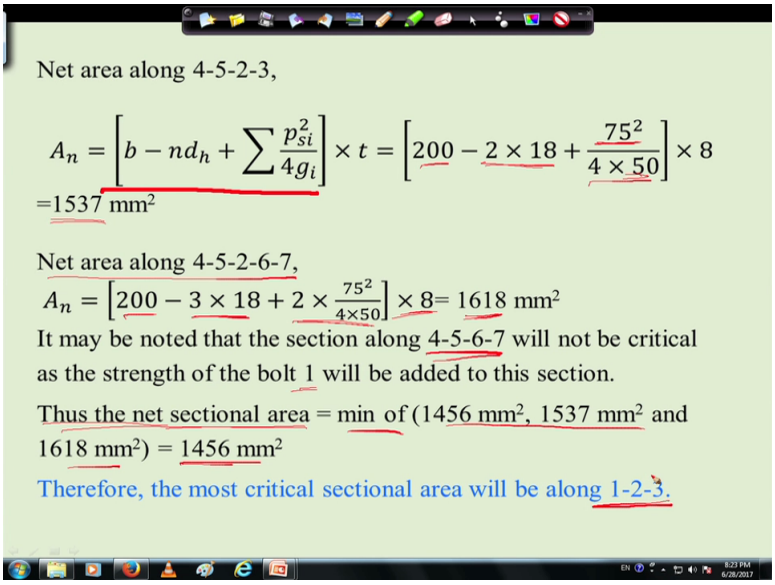

Similarly if I go next 4-5-2-3 we can find out the net area that will be b minus ndh plus psi square by 4gi into t, here along 4-5-2-3 two bolts are coming into picture. So the deducting when we are going to do we are deducting area of the bolt hole of two bolt, so 200 minus 2 into 18 then plus because of staggered pitch some area will be going to added which is the amount of psi square plus by 4gi.

So here psi the staggered pitch we have seen that that is 75 mm and gauge was given 50 mm so we could find the net area is coming 1537 millimeter square. Then again if we come to net area calculation along 4-5-2-6-7 4-5-2-6-7 then we can see that net area will become here 200 minus 3 into 18 because 3 number of bolts coming into picture and 2 number of staggered pitch are coming into picture.

So minus 3 into 18 plus 2 into 75 square by 4 into 50 into 8 thickness so this is coming 1618 mm square and we are not going to calculate along 4-5-6-7 because if it has to fail first the bolt 1 has to fail that means when we will be calculating the failure strength along 4-5-6-7 we have to add the failure strength of the bolt 1. Therefore this will be higher than the earlier one that is why we are not going to calculate.

So the sectional area that means the critical sectional area will become the minimum of these three cases, ok and minimum of these three cases will be coming as 1456 millimeter square which is coming along 1-2-3, so this is how we can find out the most critical sectional area and also we have seen that most critical section area means for different cases we have calculated but one thing we have observed that if we compare the connection using plane

bolting or chain bolting and using zig-zag bolting the efficiency will be higher in case of zig-zag bolting that we have to keep in mind.

So when we are we will be going for design of some connection we will try to prefer chain bolting sorry zig-zag bolting because it will be more efficient then the plane bolting that is what we have to. Now in next class we will discuss about the strength calculation of the tension member. Now tension member may fail due to yielding of the gross area so because of yielding what will be the design strength that we will be calculating.

Next we will calculate the rapture of the critical section that means along critical section how it is going to fail that we will try to calculate and there we will see that shear leg effect will come into picture and I told that shear leg happens when the hole sections are not connected to the member. So if part of the member is connected then the direct axial tension will first come to that portion and the shear leg effect will be there in the outstanding leg means which are not connected.

So because of shear leg effect the strength is going to be reduced little bit. So we have to calculate that shear leg effect and then we have to find out the design strength due to rapture and another scope of failure will be the block shear failure as a hole it may fail due to shear which is called block shear failure.

So for that also we have to calculate how the block shear failure is going to happen and what will be the design strength and then out of this minimum of these three strength will be the design strength of the member because we will calculate the three cases and minimum of that will be the strength of the tension member this is what we will learn in next class, thank you.