Course on Design of Steel Structures
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Lecture 22
Module 5
Strength Calculation of Tension Member

Hello so in today's lecture we will discuss how to calculate the design strength of a member. So I will go through one work out example through which we will try to see how to find out the design strength due to gross yielding of the section, due to rapture of the critical section and due to block shear. So these three aspects will be seen in the workout example.

And in the workout example we will go through one angle section which in which one leg is connected to the gusset plate that means the shear leg effect will be taken into picture. So with that we will see how to calculate the shear leg width and how to calculate the effective of shear leg on design strength calculation of the due to rapture those things we will see.

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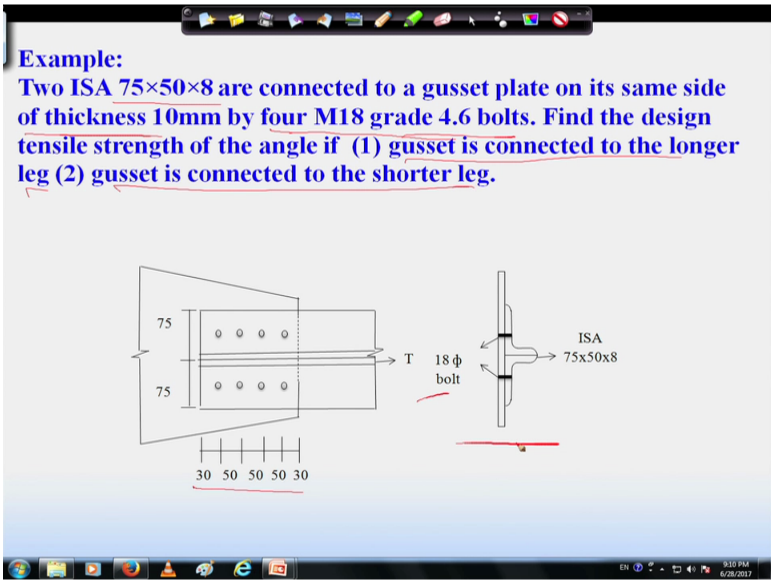

So coming to the problem we can see that here two ISA 75 by 80 sorry 75 by 50 by 8 angles are connected to a gusset plate on its same side of thickness 10 mm so gusset plate thickness is 10 mm by four numbers of M18 grade 4.6 bolts. So grade of bolt is 4.6 and diameter is 18 mm, find the design tensile strength of the angle if gusset is connected to the longer leg and if gusset is connected to the shorter leg.

So the arrangement is shown here in fact this arrangement will see means we will find out the edge distance and pitch distance from the calculation because of the presence of 18 mm diameter bolt but the thing is that here the connections is done like this that longer legs are connected that longer legs are connected with 75 mm leg has been connected.

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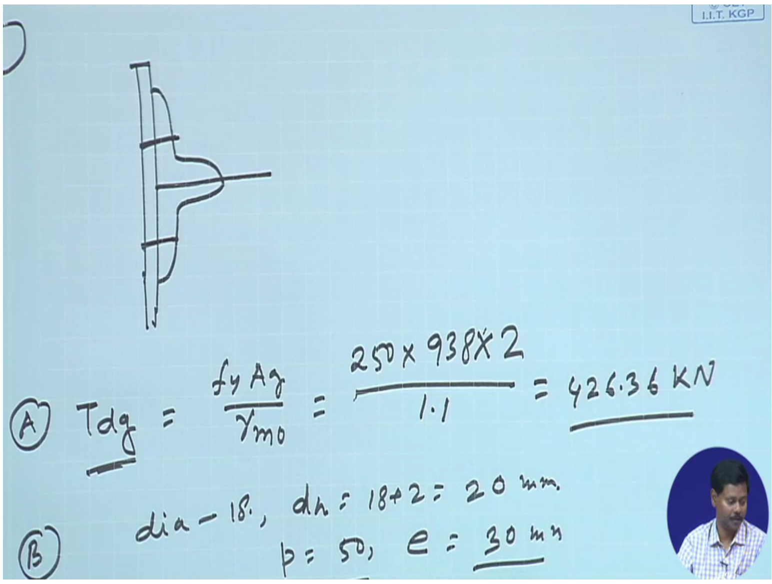

So if we see the picture this is the gusset plate which is connected to two angle section with longer leg connected the first case and second case if shorter leg is connected. So for both the cases we will see and it is connected here. So first we will calculate the strength due to yielding of gross section.

So Tdg strength due to yielding of gross section, so Tdg we can find out fyAg by gamma m0. So fy will be 250 and Ag the gross area of ISA 75 by 50 by 8 is 938 and two angles are there so into 2 by gamma m0 that is 1.1, so if we calculate we can find out 426.36 kilonewton, right. So strength due to yielding of gross sections we can find out Tdg as this.

Then we will go to calculation of the strength due to rapture of the critical section. So as diameter is 18, so hole diameter will be dh diameter of hole become 18 plus 2 that is 20 mm and we can assume pitch distance as say 2.5d that is 50 mm and edge distance e as 1.5d that is 30 mm, so we can use this, ok.

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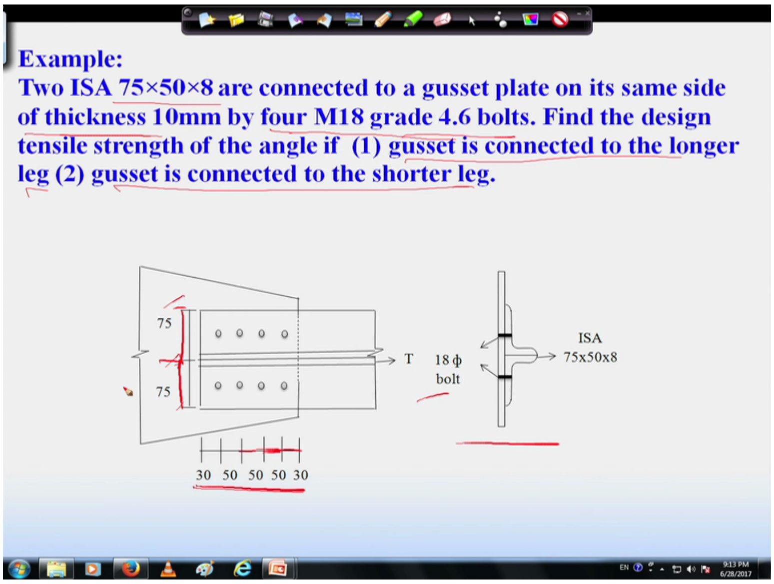

So using this the detail will be like this that is pitch distance will be 50 and edge will be 30 and this distance is 75 because longer leg is connected, right.

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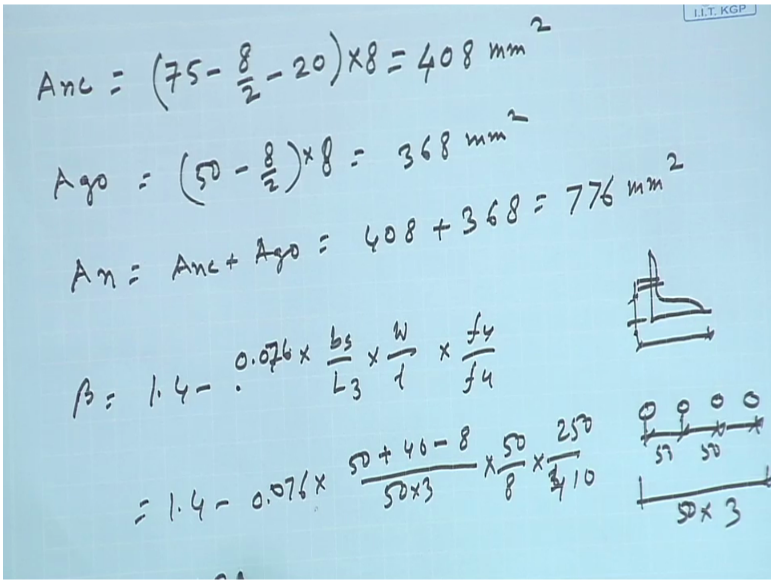

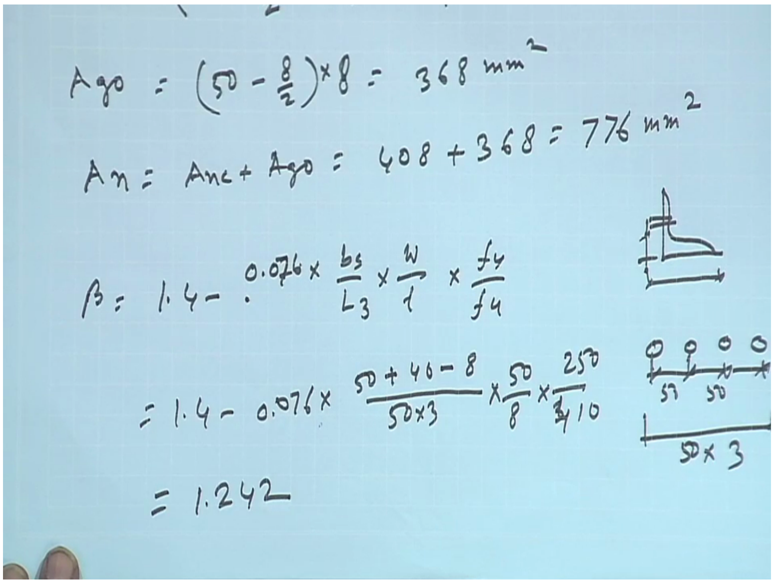

Now we have to calculate the value of Anc, Ago so Anc the net area of the connected leg that will be 75 minus 8 by 2 minus 20, this is hole diameter into thickness if we will consider that will be 408 millimeter square. Similarly area of the outstanding gross area of the outstanding leg Ago that will be 50 was the leg length minus t by 2 into t, so that is coming 368 millimeter square. So An the net area of the angle section will become Anc plus Ago, so if we add these two we will get 776 millimeter square.

Now I have to calculate beta value beta value will be we know 1.4 minus 0.076 by 0.076 into bs by Lc w by t into fy by fu. So if I put this value then I can get this as now bs bs will be if this is connected like this it is connected so bs will be this plus this, right. So that will be 50 plus this is 40 this is 40 and minus 8 thickness, bs by L3 L3 will be if we see the bolts are four bolts are there with a pitch of 50 50 mm pitch. So Lc distance will be 50 into 3, so this will be 50 into 3 into w w is the outstanding length that is 50 by thickness is 8 into fy by fu. So after calculation we can find out the beta value as 1.242, right beta value as 1.242.

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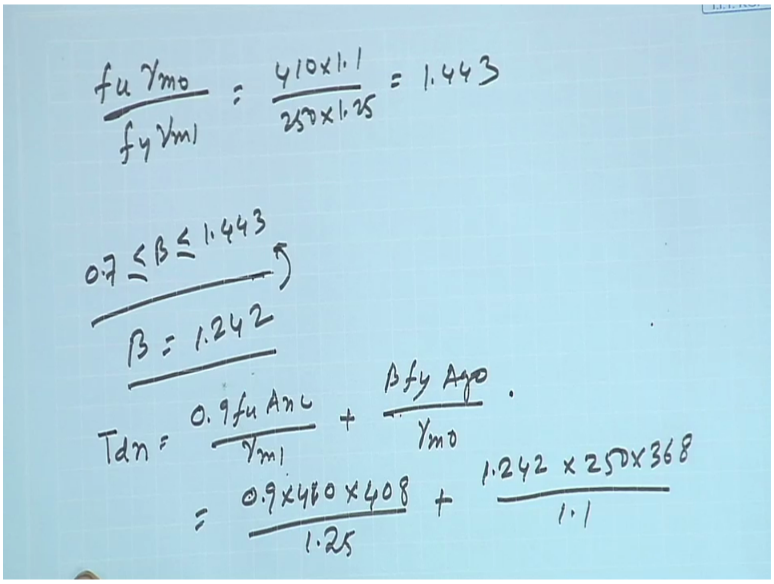

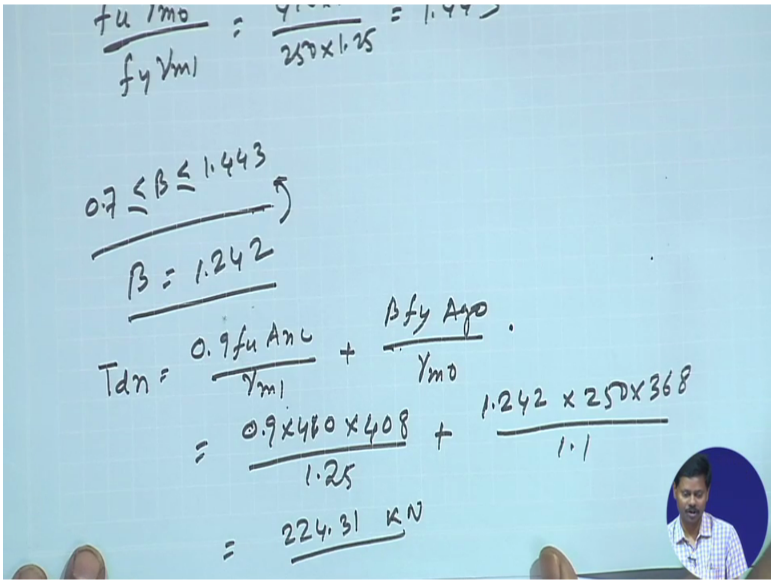

Now it has to satisfy between 0.7 and fy by fy by fu by fy into gamma m0 by gamma m1, that is fu by gamma m0 by fy by fy gamma m1 this value are coming as this 1.443, that means beta has to be less than or equal to 1.443 and greater than 0.7 and our calculated beta has 1.242, so it is means it is under this condition so beta value we can consider as 1.242.

So now I can find out the Tdn value Tdn we know 0.9 fu Anc by gamma m1 plus beta fy Ago by gamma m0. So if I put this value we can get 0.9 into 410 into Anc was 408 by 1.25 plus beta value we have calculated as 1.242 into fy into Ago is 368 by 1.1, so this value this is coming as 224.31 kilonewton, right.

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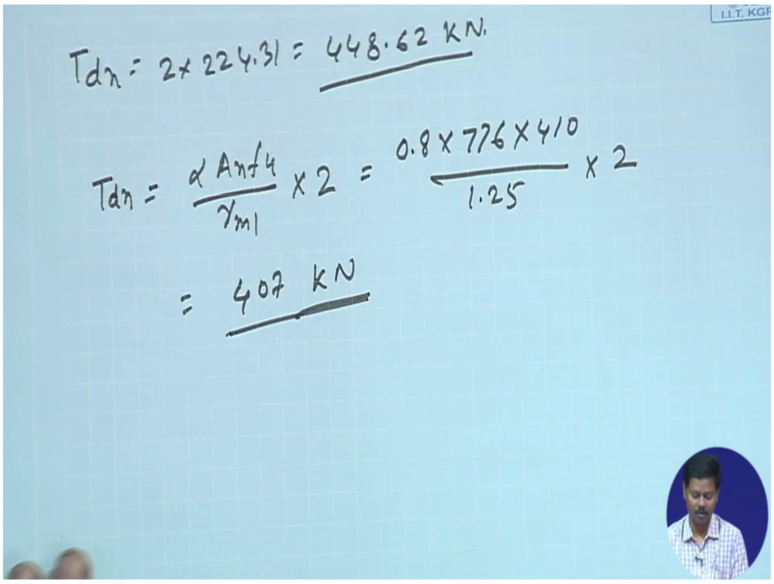

So this is the strength due to rapture of one angle. So for both the angle strength due to rapture for both the angle it will be 2 into 224.31, so 448.62 kilonewton. So strength due to rapture Tdn is this and alternatively we can find out also Tdn as just to check how much deviation is coming from the earlier calculation that is alpha Anfu by gamma m1 into 2, right. So if I consider alpha as because this is four number of bolts so this will be 0.8 An we have calculated 776 fu is 410 by 1.25 into 2, so this is coming 407 kilonewton. So approximately also we can calculate Tdn as 407 kilonewton.

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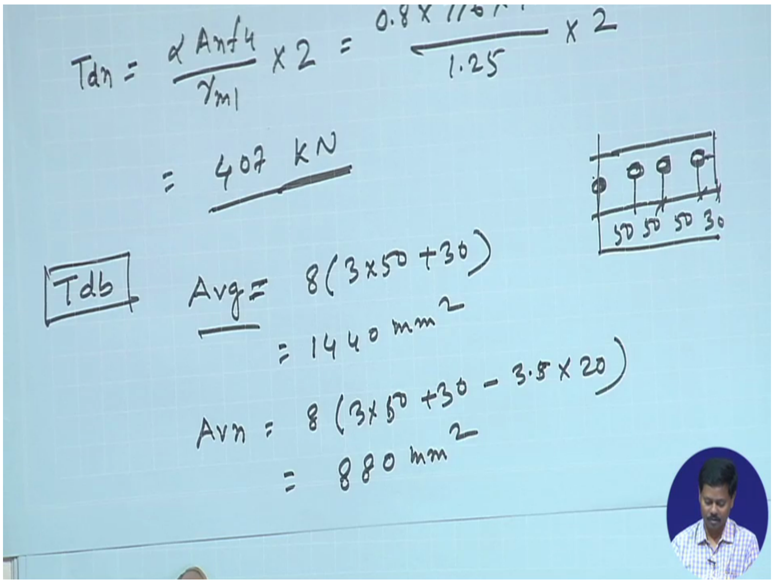

Now we have to calculate Tdb the block shear strength due to block shear. So for that we have to calculate first Avg Avg will be thickness 3 into 50 plus 30 and thickness was 8 because if we see Avg value so this is 30, then 50, 50 and 50 four number of bolts are there. So this is 30, 50, 50, 50 so I can find out the area area will be 8 into 3 into 50 plus 30. So this will become 1440 millimeter square.

Similarly Avn the net area we can find out, this is the gross area, net area will be 8 into 3 into 50 plus 30 minus 3.5 into 20 because here we will find out from here to this, right. So three hole will be directed and half of this hole will be directed, so it will be 3.5 not 4. So if we calculate this we can find out Avn value as 880 millimeter square, right. So the shear area area due to shear the gross area and the net area we could find out.

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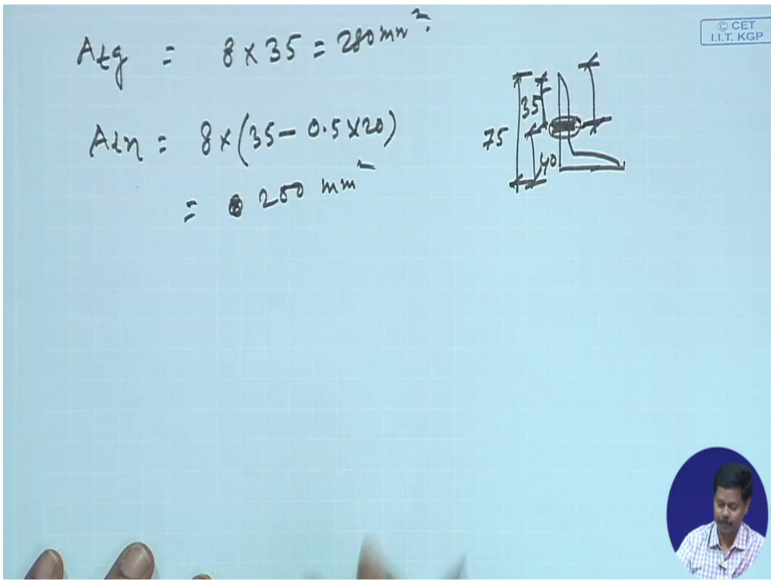

Then Atg due to tension failure we can calculate Atg will be 8 into 35 this is because if we see the angle this is connected and this longer length is connected whose length is 75 mm. so the gauge distance is this is this is 40, so this will be 35. So the Avg value will be 35 into 8, so I can find out 280. And Atn will be 8 into 35 minus 0.5 into 20 because in this direction this will be the net area so 50 percent of the hole area will come into this. So I can consider the net area as as 200 millimeter square, right.

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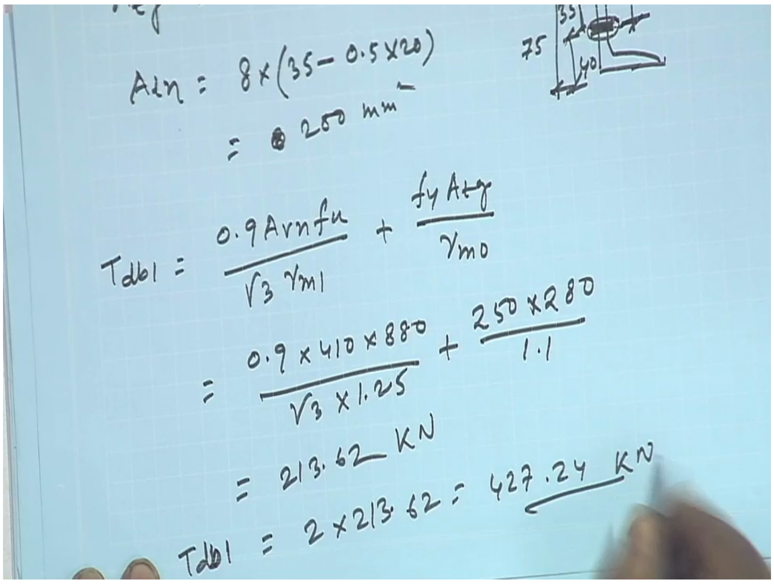

So now I can find out the Tdb1 value which is calculated from this formula that is 0.9Avnfu by root 3 gamma m1 plus fyAtg by gamma m0. So if I put the value of the parameters then I can find out the Tdb1 value, here Atg value is 280 and gamma m0 is 1.1, so this value is coming 213.62 kilonewton, right 213.62 kilonewton. Now so Tdb1 will become for two members as two members are connected so Tdb1 will be 2 into 213.62, so 427.24 kilonewton, right.

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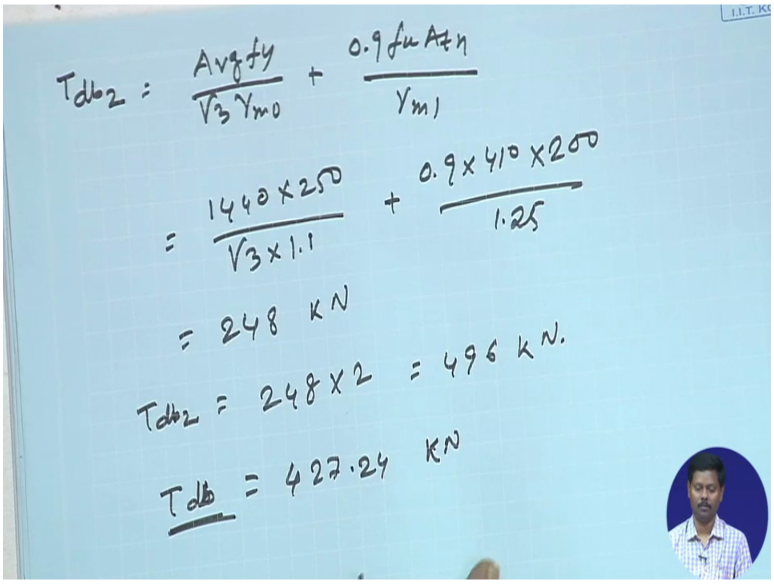

Again I can find out Tdb2 Tdb2 will be Avgfy by root 3 gamma m0 plus 0.9fuAtn by gamma m1. So if I put the value of Avg as 1440 into 250 by root 3 gamma m0 is 1.1 plus 0.9 into 410 into Atn is 200 by 1.25, so this is coming 248 kilonewton, that means the block shear Tdb2 for two angle it will be 248 into 2, 496 kilonewton. So the Tdb the strength due to block shear failure will be minimum of Tdb1 and Tdb2, that is coming 427.24 kilonewton minimum of Tdb1 and Tdb2 will be the Tdb value.

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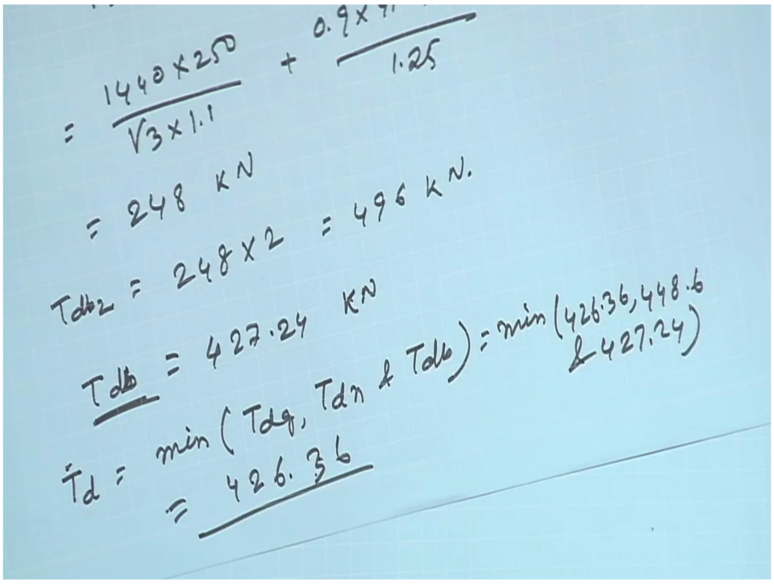

Now Tde the design strength of the member Tde will be minimum of Tdg, Tdn and Tdb. So if we see those values are minimum of 426.36, 448.6 and 427.24, that means 426.36 will be the design strength of the member, right. So this is how we can calculate the design strength of a member when the member is connected with a gusset plate means angle member, right.

Now we will see the another one if the shorter leg is connected with the gusset plate, here we have calculated the strength of the connection where the longer leg is connected. Now we can see what happens in case of shorter length, this is one thing another thing is that which one is efficient that means which one is stronger, whether shorter length if we consider means if we connect or longer length we can connect that also we will see.

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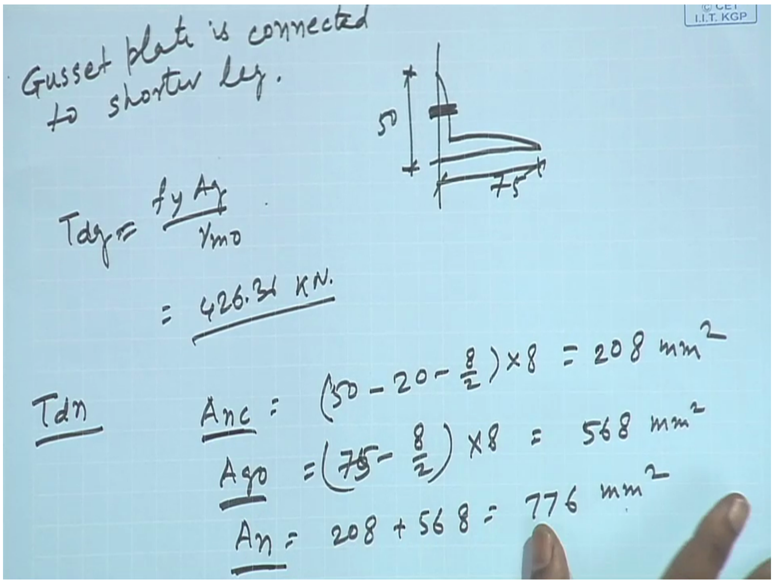

So in this case the connections will be like this that is this is 75 and this is 50, right and this is connected with the bolt. Now in this case means here gusset plate is connected to shorter leg, right. So here Tdg will be same because Ag in any case it is same, so this will be 426.36 kilonewton Tdg will be same but when we are going to calculate the Tdn value the design strength due to rapture there the difference will come because there Anc will be different, here Anc will be 50 minus 20 minus 8 by 2 into 8, unlike earlier case the value of Anc will be changed. Ago also will be 75 minus 8 by 2, so this is coming 208, this is coming 568 millimeter square.

Similarly I can find out An value the net area that is becoming different with the earlier one, here it is coming 776 millimeter square, right. So An value we have calculated Anc value we know, Ago value we know, now we can find out the Tdn value provided the beta is known.

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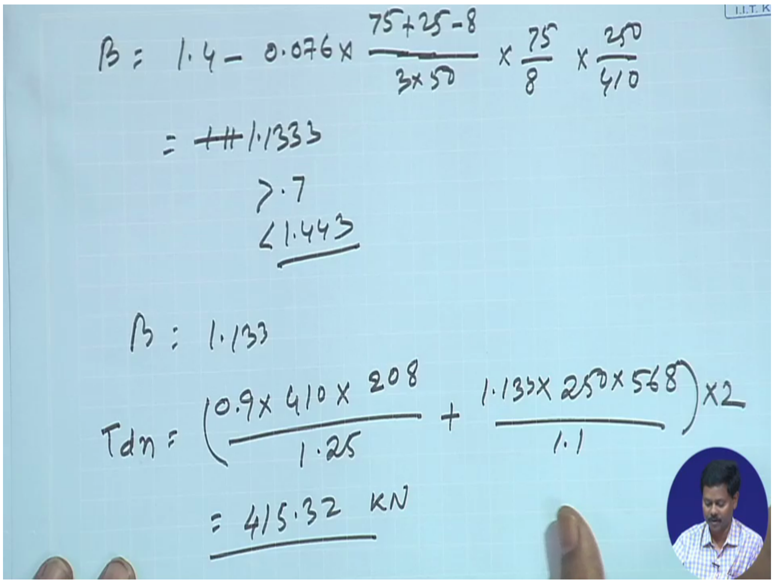

So in this case beta we can calculate as 1.5 into minus 0.076 into bs by Lc, bs means here it will be 75 this outstanding length plus 25 minus 8 and Lc is 3 into 50 and w by t outstanding length by t into fy by fu. So calculating this we can get (1.11) 1.133 and this value is greater than 0.7 and less than 1.443 which was calculated earlier. So beta we can consider as 0.133, right.

Now we can find out the Tdn value, so Tdn value we can find out 0.9 fu Anc Anc is 208 in this case by gamma m1 plus beta beta is 1.133 into fy is 250 into Ago Ago is 568 in this case by gamma m0 that is 1.1, so this value is coming into 2 if I make then the total strength of the two angles this will be 415.32 kilonewton, right. So Tdn value we can calculate.

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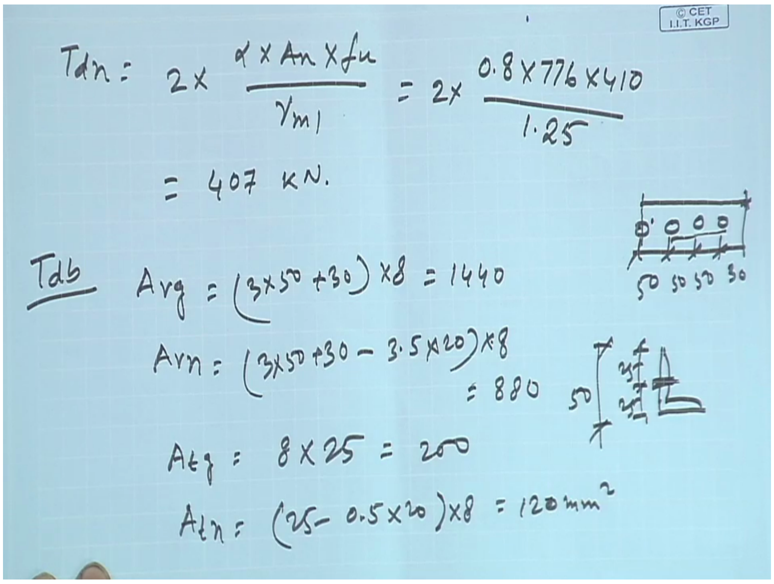

Now alternatively we can also calculate Tdn value from that formula 2 into alpha into An into fu by gamma m1, so if I put this value for four number of bolts it will alpha will be 0.8 An is 776 fu is 410 by gamma m1, so this value will be 407 kilonewton, right. Now so Tdn value we can calculate.

Now block shear Tdb we will calculate, for calculation of Tdb we have to calculate the average sorry the area Avg, Avn means gross area due to shear and net area similarly due to tensile Atg and Atn gross and net, so these four area we have to calculate. So if we calculate Avg that will be 3 into 50 plus 30 into 8, because this we have shown that four bolts are there I have shown earlier. So this will be 3 into 50 plus 30 is the edge distance, so if we do that we can find out the value as Avg as 1440.

Similarly Avn will be 3 into 50 plus 30 minus 3.5 into 20 into 8, this will be 880. As I told when we are going to consider Avn Avn means from this we are going to (()) (26:14) the length. So three holes will be deducted and one hole 50 percent of that will be deducted, so Avn we can calculate.

Similarly Atg we can calculate this will be 8 into 25 because if we see the connections, this is 25 and this is so 8 into 25 that will be this is also 25 sorry because this total is 50, if we consider this then this will be 200. Similarly Atn will be 25 minus 0.5 into 20 into 8 this will be 120 millimeter square. So Avg, Avn, Atg, Atn we can find.

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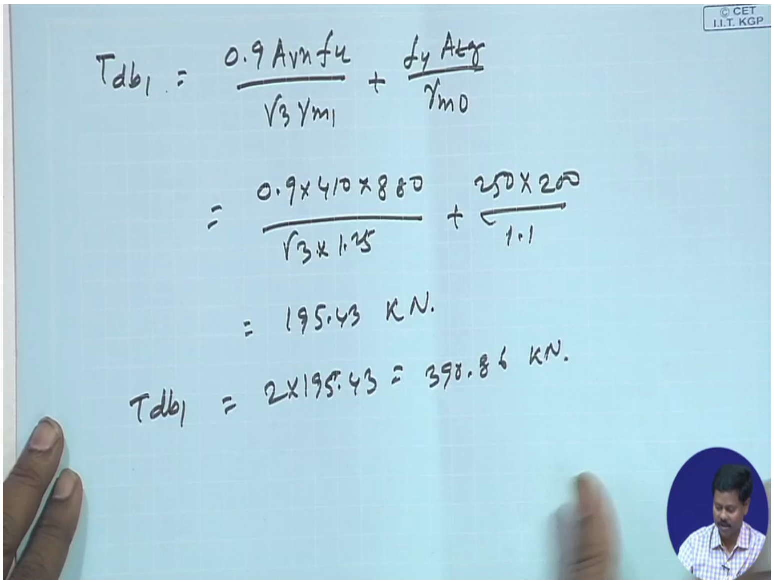

Now we can find out the Tdb1 and Tdb2, so Tdb1 will be 0.9Avnfu by root 3 gamma m1 plus fyAtg by gamma m0. So if I put this value Avn value is 880 by root 3 into 1.25, Atg value is

200. So after calculation we can get 195.43 kilonewton that means Tdb1 of 2 angle section it will be 2 into 195.43 that will be 390.86 kilonewton.

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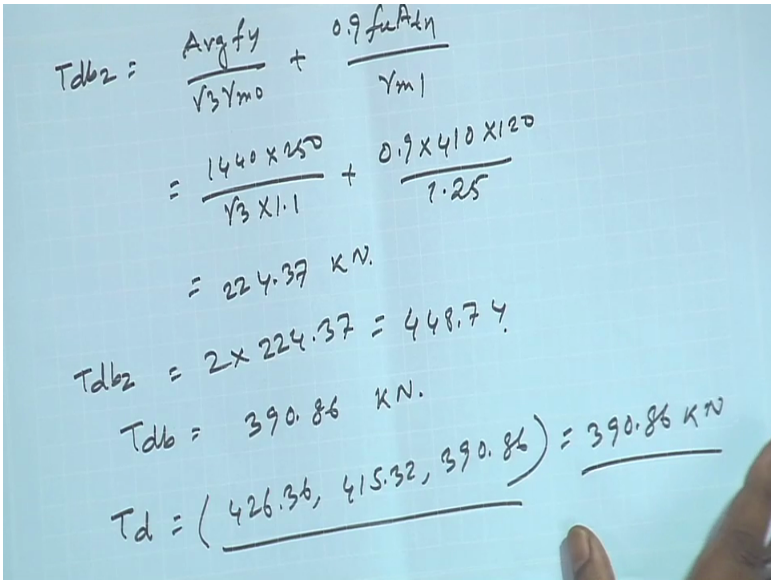

Similarly I can find out Tdb2 value Tdb2 value will be this is earlier formula Avgfy by root 3 gamma m0 plus 0.9 fuAtn by gamma m1, so if I put the value Avg as 1440 and Atn as 120 then I can find out the value as 224.37 kilonewton. So Tdb2 value will become 2 into 224.37 because 2 number of angles are there.

So we can find out the value as 448.74, so Tdb value will be lesser of Tdb1 and Tdb2 that is becoming 390.86 kilonewton, right. So the Td value the design strength will be lesser of these three that is 426.36, 415.32 and 390.86, right. So that means it will be 390.86 kilonewton. So the design strength of the member when the shorter leg is connected to the gusset plate then the design strength of the member will become 390.86.

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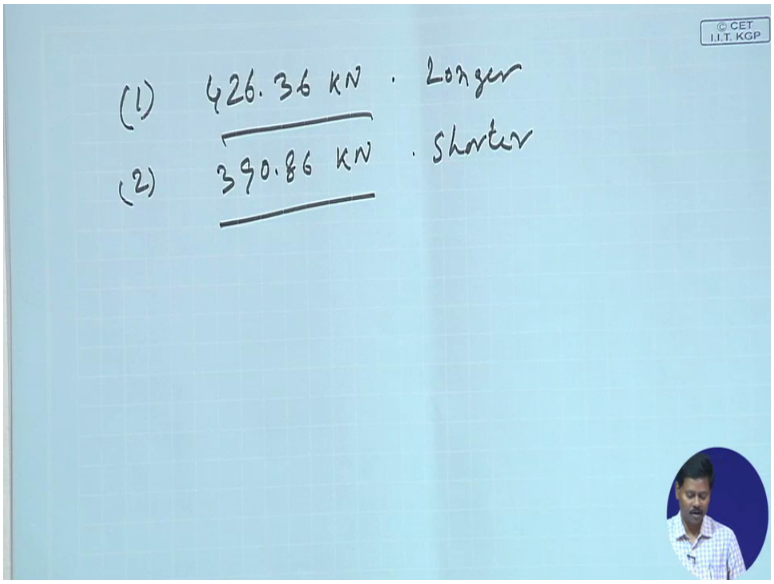

Now if we compare that in case of first one the value is coming 426.36 kilonewton and in case of second one value is coming 390.86 kilonewton, right. Here longer length is connected and here shorter length is connected. And what we see here that if longer length is connected then the strength is more strength of the joint is more or the section is more, right.

So whenever we are using unequal section we will try to join the longer length with the gusset plate to get the strength more with same material, right. So this is how we can calculate the design strength of a member which is subjected to axial tension and the three criteria we will follow and the least of these three will be the design strength of the member, thank you.