Course on Design of Steel Structures
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Lecture 23
Module 5
Strength of Tension Members and Weld Connection

Hello today we are going to start the design calculation of tension member where it is connected with weld joint. So in last classes we have gone through one workout example where the strength of the tension member has been calculated using bolt connections. Now same thing we will be doing for weld connections in case of weld connection how the net effective area is going to change with respect to bolt connections, how the shear lag distance is going to change those things will be we will come across and we will see also we will see that block shear how to calculate, how to calculate that Atn, Atg, Avn, Avg.

So those parameters will be calculated in todays lecture and we will see how what is the difference between bolt connection and weld connection with respect to strength calculation of tension member.

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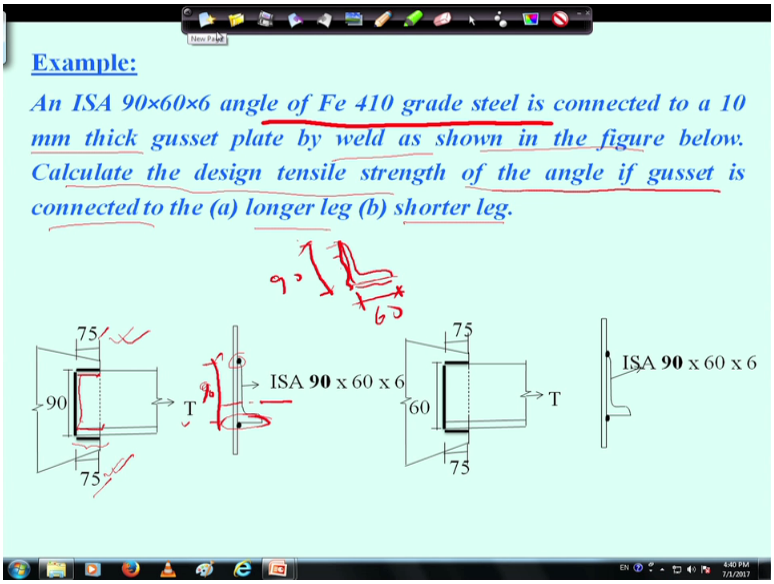

So we will go through this example that is an ISA 90 by 60 by 6 angle of Fe 410 grade steel is connected to a 10 mm thick gusset plate by weld as shown in the figure below. We need to calculate the design tensile strength of angle if gusset is connected to the longer leg and to shorter leg. So both the cases we will see that if the here we have consider this angle, this is

60 and this is 90. So this angle once we will connect the weld connection by this this angle this leg and again if we connect with this leg then how the strength is going to vary that we will see, means similar to the bolt connections, right.

So one by one we will see how the load means strength of the member is going to change if the longer leg is connected and if the shorter leg is connected. So here if you see that weld length distribution has been given in this way, if longer length is connected this is this will be 90, so if 90 mm longer length is connected then the weld length is 90 plus in this direction, let as assume 75 mm distance have been given, so what will be the tensile strength. And practically generally the length of the bottom one will be more compare to length of the top one because if Cg distance goes like this then more load will be carried by this portion compare to this portion.

Therefore generally the weld length will be larger here and it will be lesser here but in this case we have assume that distribution of length is same that is 75 and 75, just to have a calculation just to see the calculation that what are the parameters going to vary and how to calculate this, right.

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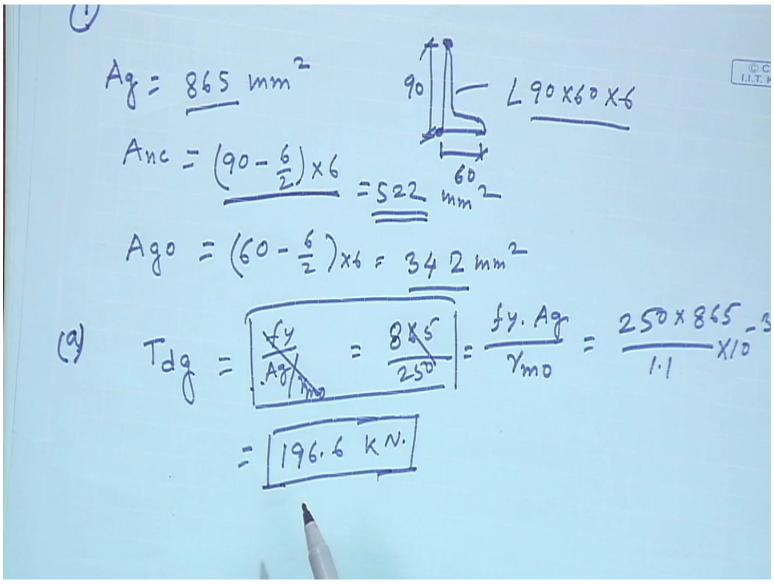

So we come to first case that if longer length is connected that means if the shorter length is this one 60 mm and this is 90, so this length is going to be connected, right. So we have to find out the properties of the angle section geometrical properties like the gross area of the angle Ag we can find out or 90 by 60 by 60 this size of the angle section is 90 by 60 by 6.

So from IS handbook SP 61 1964 we can find out the Ag value as 865 millimeter square this we can find out from SP 6 and we have to calculate Anc and Ago, Anc means the net area of the connected leg net area of the connected leg will become 90 minus 6 by 2 into 6, here you can observe with respect to bolt connection that as there is no bolt hole, so net area is just this one the area of the connected leg that is 90 minus 6 by 2 into 6 which will be 522. So we are not reducing any area, right.

Similarly the outstanding area gross area of the outstanding length that will become outstanding length was 60, so 60 minus 6 by 2 into 6, so this is becoming 342 millimeter square. So this will be required for strength calculation, so this property we have to remember that is Ago is 342, Anc is 522 and Ag is 865.

Now we will come to strength calculation, first is tensile strength governed by yielding so tensile strength governed by yielding that we can find out as Tdg Tdg we know that will be fy by Ag by gamma m0, so that I can find out that is 865 by 250 sorry Tdg oh sorry sorry I am just giving wrong equation. Tdg is equal to fy into Ag by (gamma) fy by gamma m0, this will be the equation, right.

So fyAg by gamma m0, fy is 250 and Ag is 865 and gamma m0 is 1.1 and to make it kilonewton we can multiply with 10 to the power minus 3, then we can find out Tdg value as 196.6 kilonewton, right. So the tensile strength governed by yielding of gross section is coming 196.6 kilonewton, so this is one and next we will calculate the tensile strength governed by rapture of net section, ok.

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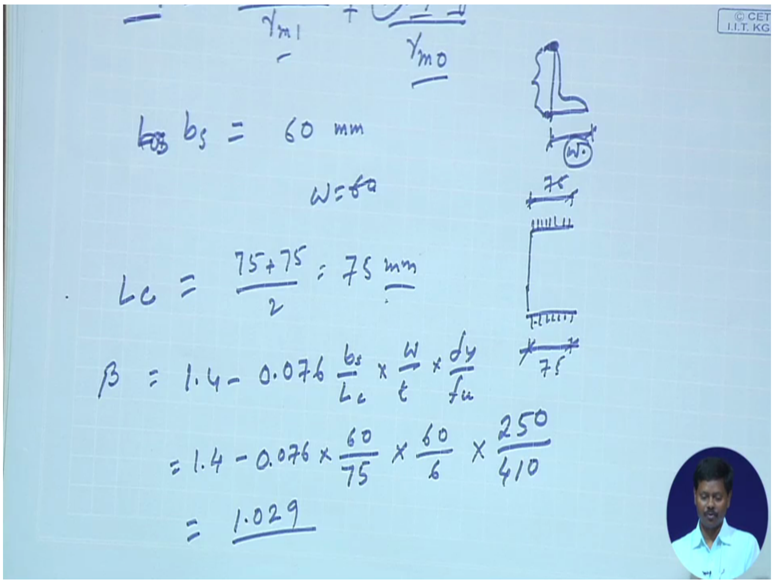

So second case we will try to find out the net tensile strength governed by the rapture of net section that is Tdn. So for finding out Tdn we need to know that because Tdn we know the value will be 0.9fuAnc by gamma m1 plus beta into fyAgo by gamma m0. Now we know all the parameters like fuAnc, gamma m1, fyAg, gamma m0 we know except this parameter beta, right.

To find out beta we have to know what is the shear leg width shear leg distance sorry bs we use to call bs shear leg width that shear leg width will be here 60 mm, because if you refer to the code you will see here it is connected like this, it is connected here and it is connected here. So the outstanding length is this one that is w and that will be the shear leg distance because this portion is connected, right.

So there is the difference between calculation of shear leg distance of member using bolt and member using weld, right. So here bs will be the outstanding leg distance that is 60 mm, right because here w is equal to 60 and also we have to find out the average length of weld length of weld that is Lc average length of weld. Now it is connected if you see in the question that it was connected like this means it was connected 75 millimeter length of this this portion and 75 millimeter of this portion. So average length will be 75 plus 75 by 2 that means 75 mm. So here average length we can use as 75 mm.

So I can find out beta the factor beta will be 1.4 minus 0.076 into bs by Lc w by t and fy by fu. So from this we can calculate we know all the values of the variables like 0.76 into bs we know that is 60 and Lc we have calculated as 75, outstanding length was 60 and thickness was 6 mm and yield stress we can consider 250 and ultimate stress we can consider 410. So if we put this value we can find out the value of beta as 1.029, right. So beta value is coming 1.029.

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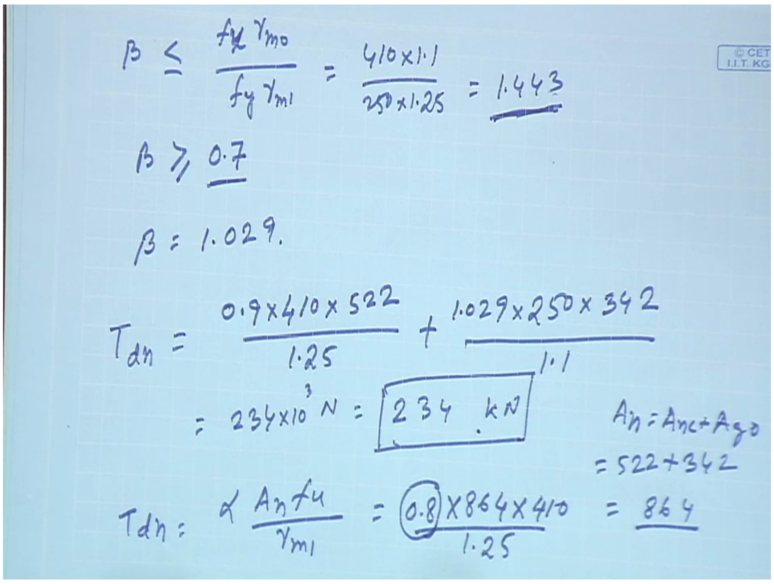

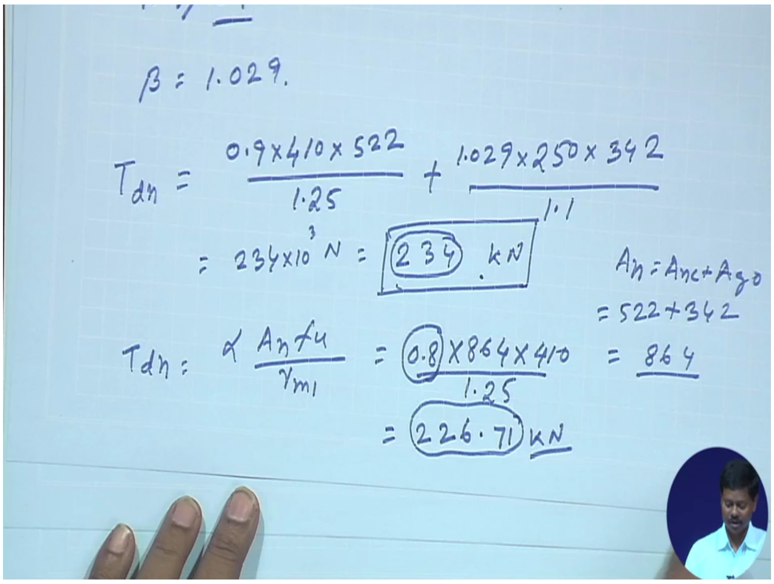

Again this beta value has to be less than equal to (fy) fu gamma m0 by fy gamma m1. So this value if we calculate that will be 410 into 1.1 by 250 into 1.25 this is coming 1.443, so beta value is should be less than 1.443 and also beta should be greater than or equal to 0.7.

So this is fulfilling the criteria of this lower limit of 0.7 and upper limit of this, so we can consider beta as a calculate value what we obtained earlier that is 1.029, right. Now I can find out the strength Tdn right due to rapture of critical section, Tdn so that I can put the value that will be 0.9 into fu is 410 into Anc 522 we found by 1.25 is gamma m1 plus beta we have calculated as 1.029 into fy into Ago that we calculated as 342 by gamma m0 that is 1.1. So this is becoming 234 into 10 cube newton or 234 kilonewton. So Tdn value is becoming 234 kilonewton, right.

Now now alternatively also we can calculate the Tdn value in an approximate way that is Tdn is equal to alpha into Anfu by gamma m1, that we can calculate now alpha is 0.8 because for weld connection this alpha value as per codal provisions is 0.8 into An An value will be An we can calculate that is Anc plus Ago, that means Anc was we have found earlier 522 and Ago was 342 so that is 864.

So An the net area of the angle section you just 864 and fu we know 410 by gamma m1 1.25, remember this alpha value alpha value for bolt connection it varies it varies as 0.6, 0.8, 0.7 according to the number of bolt. But in case of weld connection we straight take alpha as 0.8 unlike in case of bolt. So this has given in the IS: 800-2007 in the clause so we have to keep in mind that in case of weld connection we should consider alpha value as 0.8.

So if we put this value we can find out this value as 226.71 kilonewton 226.71 kilonewton, right. So actual value we got 234 kilonewton also we can find out approximately as 226 is more or less closer.

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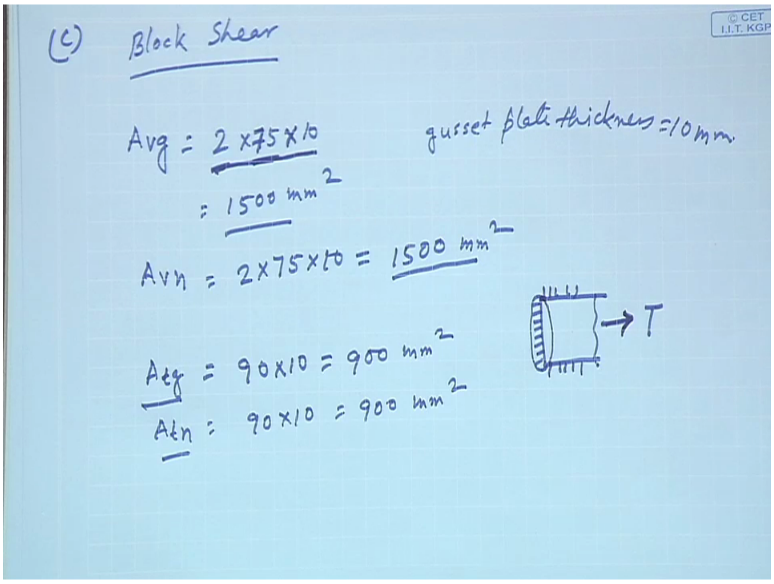

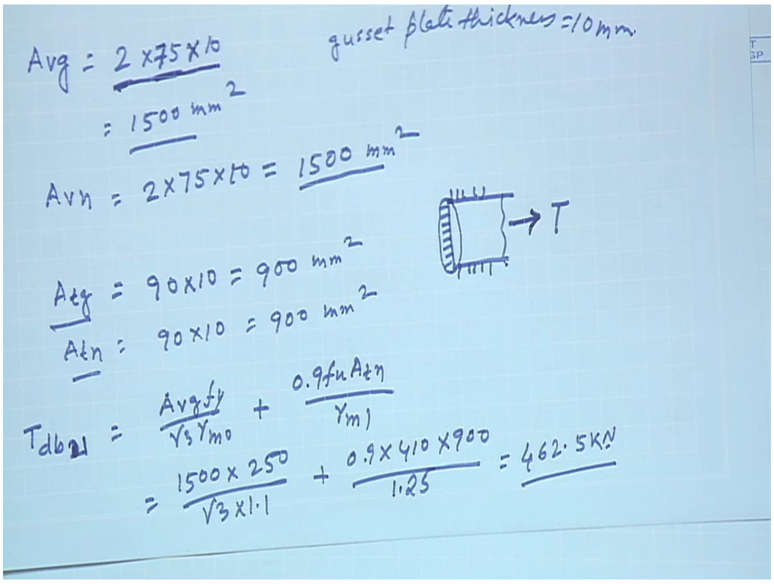

Now we will try to find out the third case that is tensile strength governed by block shear, for block shear how tensile strength is going to governed that we will try to find out in this case, right. So in this case we have to calculate the area of gross area due to shear Avg that will become 2 into 75 into 10 because gusset plate thickness is this is gusset plate thickness that is 10 mm, right gusset plate thickness is 10 mm and also the weld length was 75 in two side, 75 into 2. So Avg will be 2 into 75 into 10, this area is along the force, right the tensile force the axial tensile force working the in a direction in which the Avg value has to be taken. So that is becoming 1500 millimeter square.

Similarly Avn Avn is the net area of the shear shear due to shear that will also become 2 into 75 into 10, so this is also 1500 millimeter square. Here you notice that Avn value and Avg value are same because in case of bolt connection the Avg value and Avn value were different because of the presence of hole. So net area and gross area will be different but in case of weld connection net area and gross area will be same.

Therefore it will be unlike bolt connection design, right and we will see that for the same angle section we can find out that the strength will be more in case of weld joint with respect to bolt joint.

So similarly I can find out Atg that is the gross area due to tension so that will be 90 into 10 because if you remember the weld distribution was like this, so this is the tensile force acting. So the area perpendicular to the direction of the force that is 90 into 10. So it will be 900 millimeter square and similarly Atn also will be same as calculated as Atg that will be 900 millimeter square. So Atg value and Atn value we can calculate.

Now we will find out the Tdb value, so Tdb1 or Tdb2 we have to find out and the least of these two will be the value of tensile strength due to block shear. So Tdb1 Tdb1 will become we know Avgfy by root 3 gamma m0 plus 0.9fu Atn by gamma m1, so if I put this value I can find out as 1500 into 250 by root 3 into 1.1 plus 0.9 into 410 Atn value was 900 and gamma m1 we know as 1.25. So if we calculate we can find out this as 462.5 kilonewton, right 462.5 kilonewton.

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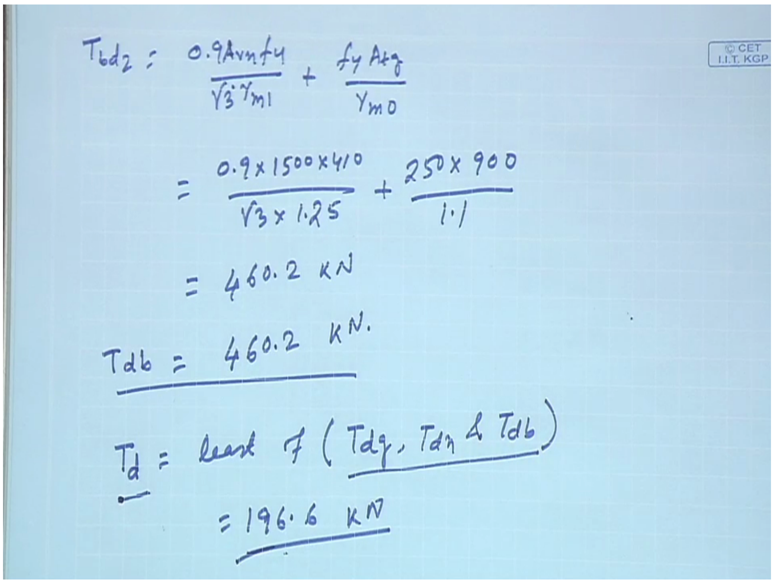

Similarly I will find out Tdb2 Tdb2 will be 0.9 (Av1) Avnfu by root 3 gamma m1 plus fyAtg by gamma m0. So if I put this value I can get the value of Tdb2, here fu value is 410 root 3 into gamma m1 is 1.25 plus fy is 250 Atg we calculated earlier 900 by 1.1, so this will become 460.2 kilonewton and we know Tdb value will be the least of Tdb1 and Tdb2. So least of Tdb1 and Tdb2 is becoming 460.2 kilonewton, right.

Now the value of design tensile strength will be least of Tdg due to gross yielding, Tdn due to rapture of net section and Tdb due to block shear. So if we see these three value we can find out that this is coming least value is coming 196.6 kilonewton and this is coming due to gross yielding, right. So the design strength of the weld connection will be 196.6 kilonewton, right when the longer length is connected by the weld.

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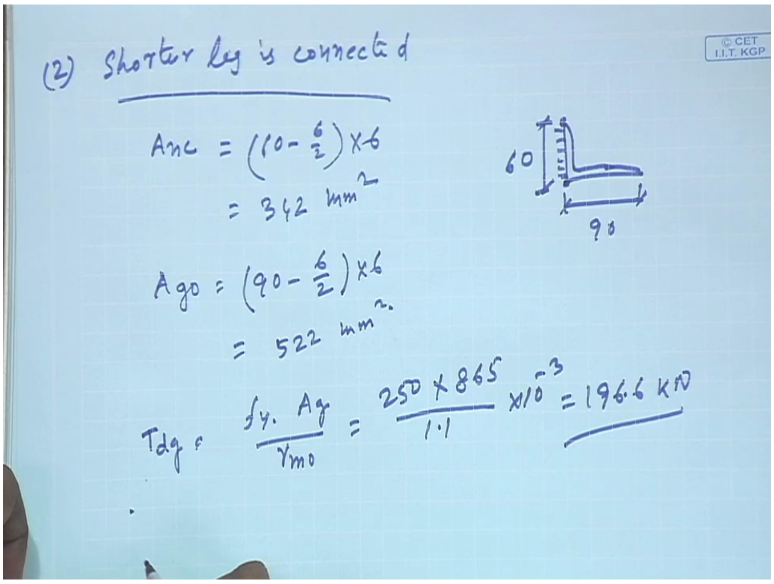

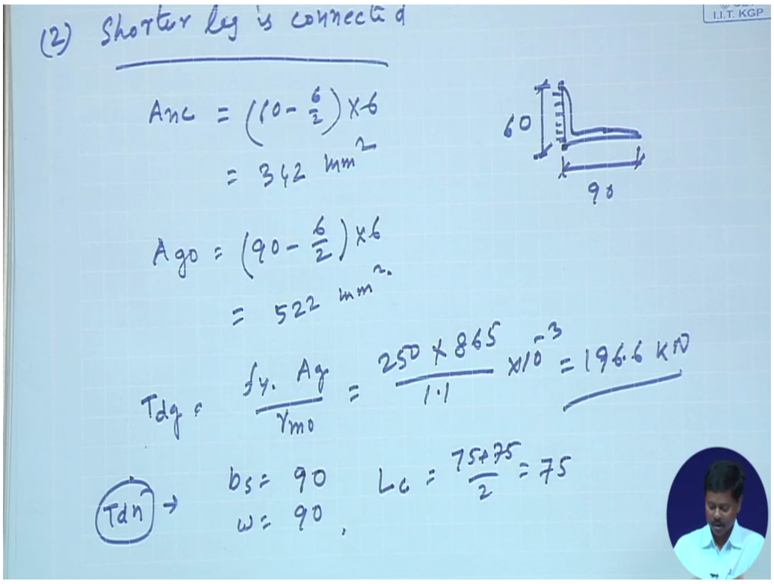

Now we will see the same thing in case of shorter length connection means if shorter length is connected. So second case that shorter leg is connected, right if the shorter leg is connected so here I can find out Anc value as in this case the outstanding leg will be the longer leg right. Say for example this is 90 and this is 60, so this leg is connected connected here, here and this leg is connected, right.

So Anc the net area I can find out 60 minus 6 by 2 into 6, this will be 342 millimeter square. Similarly the gross area of the outstanding leg Ago I can find out 90 minus 6 by 2 this will be into 6, this will be 522 millimeter square, right. So now here I can find out Tdg value Tdg value will be fy into Ag by gamma m0, so if I put this value that will be 865 by 1.1 into 10 to the power minus 3, so 196.6 kilonewton.

So if we remember here the earlier calculation that the Tdg value of the angle section when its longer (leg is) length is connected, the Tdg value was same, right. So irrespective of the connected leg the gross yielding means strength due to gross yielding of the section will be same that is 196.6, but the strength due to rapture of the net section or strength due to block shear failure that will be different. In fact in case of strength due to rapture the shear leg will be different shear leg effect will be there.

So we will see here it will be reduced, the strength is going to be reduced because longer leg is the outstanding length so the shear leg effect will be quite more compared to the earlier case, therefore we have to means the reduction of strength will be there so we have to see in that way, right.

So now let us come to the second one that is for calculation of Tdn, ok Tdn now for Tdn now here we can see that bs will be simply bs means the shear leg width that will be simply 90 mm and w that is outstanding leg that will be also 90 mm, right. So Lc here LC also same that is 75 plus 75 by 2 that is 75.

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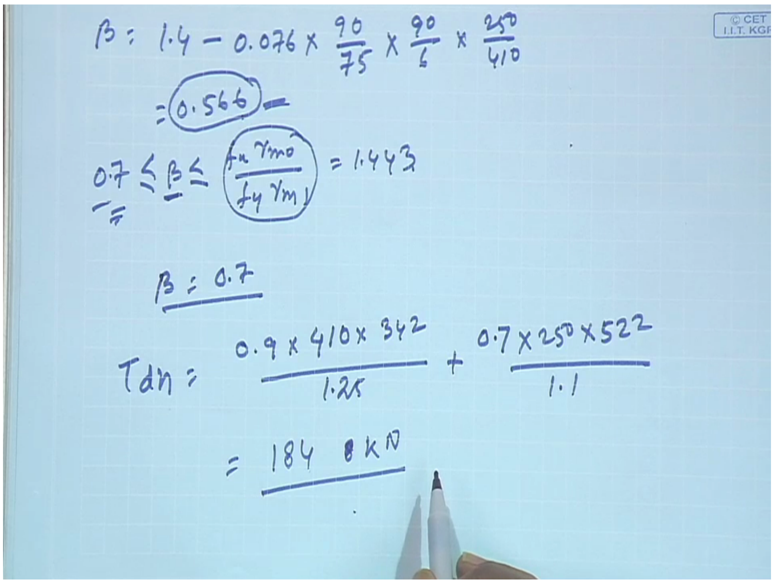

Now let us see the reduction factor beta, here beta will be 1.4 minus 0.076 into bs by Lc, bs means the shear leg width that is 90 by Lc is 75 and w by t that is also 90 by 6 and fy by fu 250 by 410, that is coming 0.566 and this beta value has to be less than or equal to fu gamma m0 by fy gamma m1 and it has to be greater than or equal to 0.7, right. And this value earlier we have calculated that is 1.443.

So what we could see beta value atleast it has to be 0.77 and we have calculated as 0.566 and if you remember earlier this beta value was quite high, right. So in case of the member if it is connected with its shorter length then because of its outstanding length as longer one the shear lag effect will be more and because of this shear lag effect we could see here beta become 0.566 and as we have to take atleast 0.7, so we are going to take 0.7.

So Tdn value we could see if we put this value that 0.9 into fu fu means 410 into 342 that is Anc by gamma m1 is 1.25 plus beta is 0.7 we are considering fy into Ago is 522 by gamma m0 is 1.1, so here we are considering 184 kilonewton. Now you could see if you compare with the earlier case here you can see that Tdn value is going to be much less compared to the earlier one, right.

Therefore we have to keep in mind that which leg we should try to connect, right as I told earlier also that we have to try to connect the longer length with its means longer length we should connect with the gusset plate or other members to get the maximum efficiency of the member, right.

And automatically here we could see that because of the connections of its shorter length the shear lag effect is predominant and because of shear lag effect we could see the reduction of the strength is quite high and the net rapture strength is becoming quite less compared to the connection when its longer length is connected, right.

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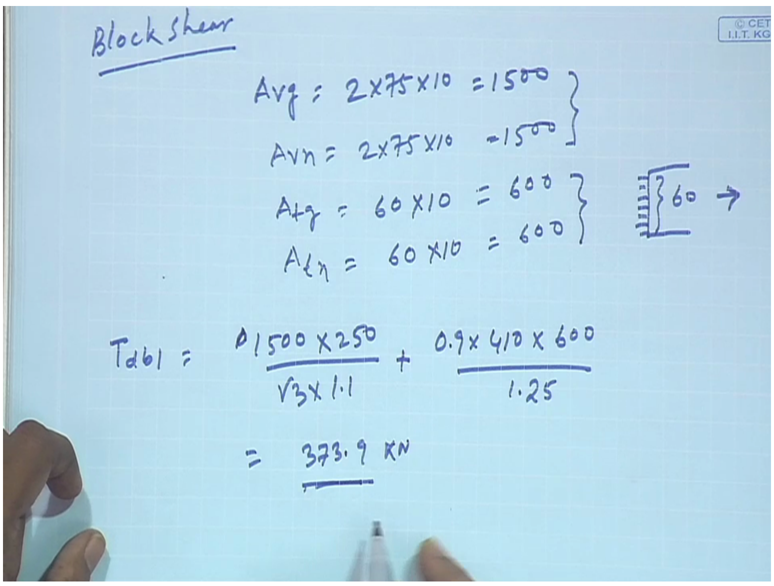

Now strength due to block shear for block shear we will try to find out the strength, here we could see that Avg will become 2 into 75 into 10 that is same as earlier. Avn is equal to also 2 into 75 into 10 that is also same only Atg will be different earlier it was (60 into 10) 90 into 10 here it is 60 into 10, 600 and Atn also will be 60 into 10 that is 600, that means Avg and Avn are becoming same with respect to earlier one. But Atg and Atn is going to reduce because in this case the shorter leg is connected.

So its length is 60, therefore the weld length perpendicular to the direction of the load is coming 60. So Atg value will be 60 into 10, Atn value will be 60 into 10. So I can find out Tdb1 Tdb1 is equal to Avg Avg means 1500 Avg fy by root 3 gamma m0 plus 0.9 fu into Atn Atn is 600 by 1.25 that is becoming 373.9 kilonewton, right 373.9 kilonewton we are getting. And this is obviously less than the earlier one slight reduction is there because of this connection of the shorter length.

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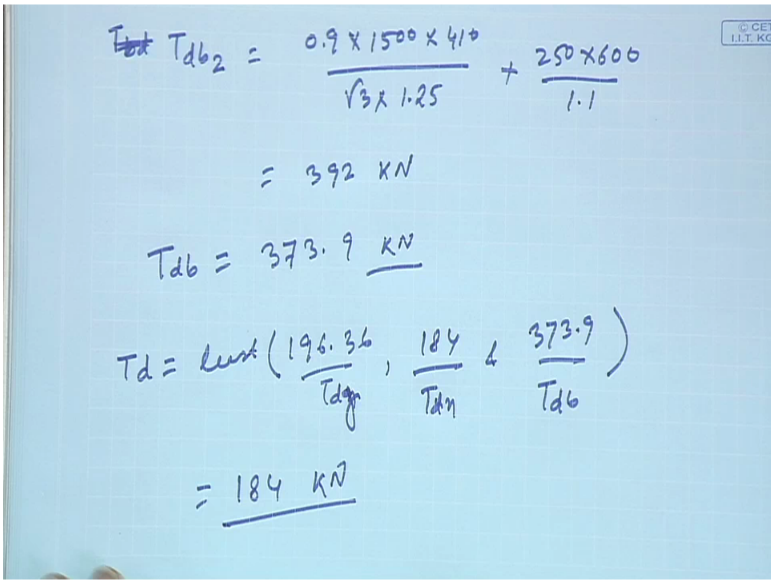

So now again Tbd2 Tdb2 I can find out as 0.9 Avn 0.9 Avn was 1500 into fu by root 3 gamma m1 is 1.25 plus fy 250 into 600 by 1.1, so this is becoming 392 kilonewton. So Tdb will be the least of these two that is Tdb1 and Tdb2, so from this I can see that 373.9 kilonewton is the block shear strength.

So now we can find out the design tensile strength Td and this will be least of these three load that is 196.36 that is Tdn then sorry Tdg, then 184 which has come from Tdn and 373.9 that is Tdb, right. So least of these three that means 184 kilonewton, that means here the critical strength is governing due to rapture of the net section. In earlier case we have seen critical strength was governed due to yielding of the gross section, this is what generally happens.

But in this case we could see that the critical strength are coming due to rapture of the net section that is 184 kilonewton, right. And we could see that this critical strength is less in this case means when shorter length is connected with the gusset plate with respect to the earlier one where longer leg is was connected to the gusset plate.

So in this example means through this workout example we could see that efficiency of the same angle can be increased if the connection is done properly connection can be done properly in in a sense that when the longer leg of the angle section is connected with the gusset plate then we could increase the efficiency of the section. Also from earlier lecture means if we compare with the earlier calculation where bolt joint was there if we see that weld connections is taking little higher load then the bolt connection.

So from these two examples means examples from the bolt connection and examples from the weld connection and the connecting leg, connection with longer leg, connection with shorter leg. So for this four permutation combination we could see the best option is connection should be done with longer leg and if possible with the weld connection, in that case maximum efficiency can be obtained, ok with this I would like to conclude todays lecture, thank you.