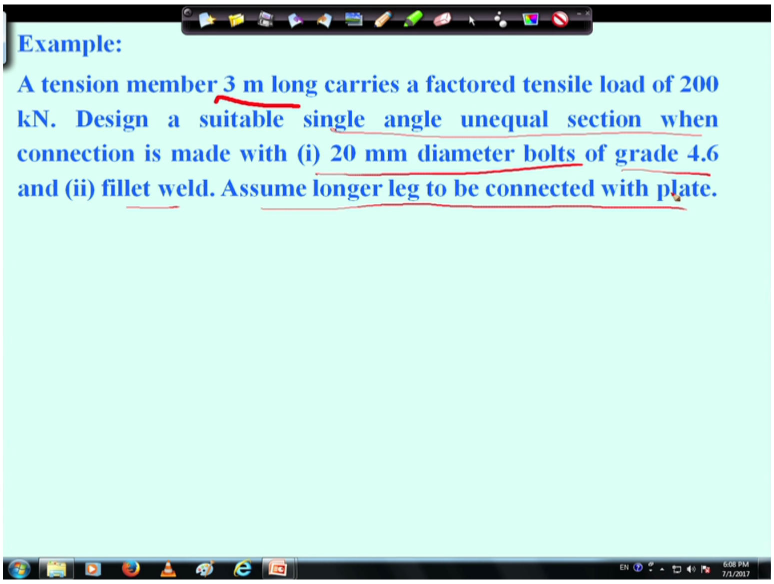
Course on Design of Steel Structures
Professor Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Lecture 25
Module 5
Design Calculation of Tension Members

Hello today I am going to solve a design example manually, in last class we have discussed about the steps followed for design of tension member what are the steps we should follow for designing a tension member that has been discussed in earlier lecture and also computer algorithm has been shown means how to develop a flow chart and how to make a computer program that has been discussed in last lecture. Now in today following all the theories, the steps, the flow chart today we will be solving a example, ok.

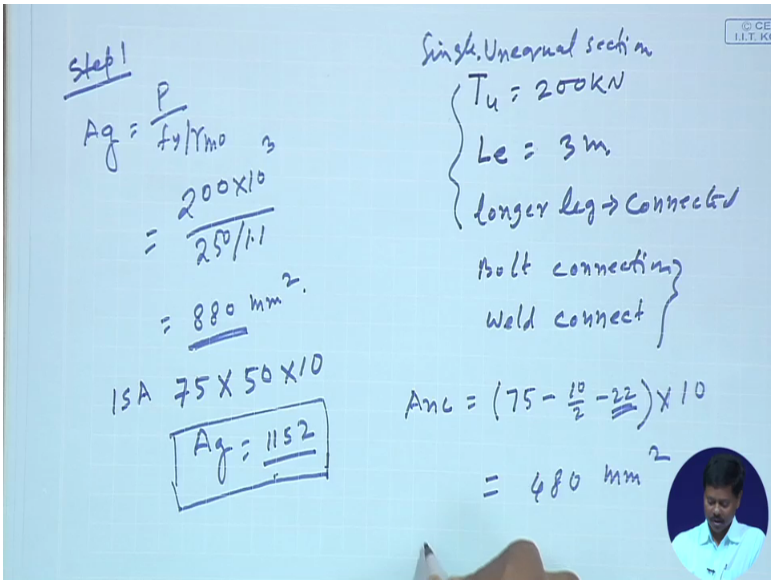
And if we want to write a program step by step whatever we are going to solve today if we do a program and check those then it will be clear to us also means the programmer will be get confidence that ok this program is running fine and accordingly he can develop a program also.

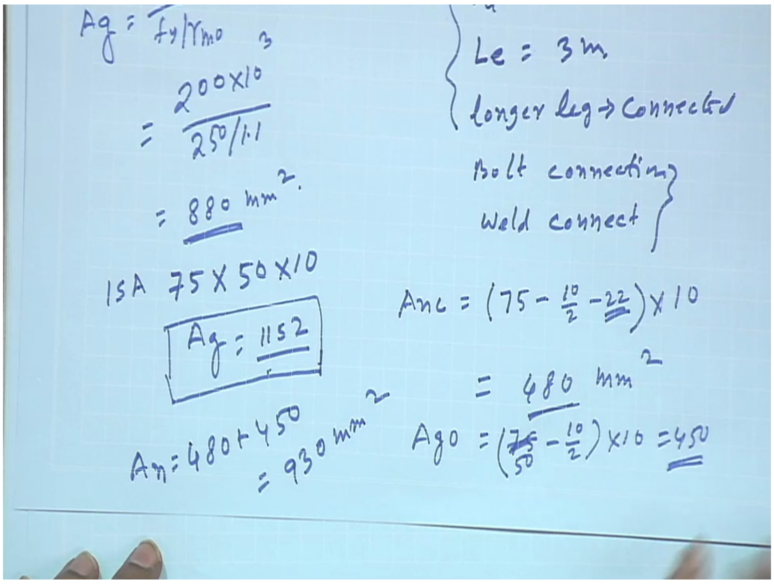
(Refer Slide Time: 1:33)



So problem is like this a tension member 3 meter long carries a factor load of 200 kilonewton 200 kilonewton load is the Tu value, 3 meter long effective length is 3 meter and design a suitable single angle unequal section, so it has been told you have to use single angle not double angle and unequal section, right when connection is made with 20 mm diameter bolt of grade 4.6 and fillet weld. Assume longer leg to be connected with plate, right.

(Refer Slide Time: 2:16)





So these are the things has been told one is the Tu is equal to 200 kilonewton, right. Next is length effective length is 3 meter, next is longer leg is connected longer leg connected, right. Next is bolt connection ok of course once we will do bolt connection then weld connection two we will do and we will see how it is varying in the calculation, ok. So these three things we have to keep in mind these are the things and also unequal section we have to check it is told that unequal section we have to choose and single single unequal section, we cannot choose double unequal section.

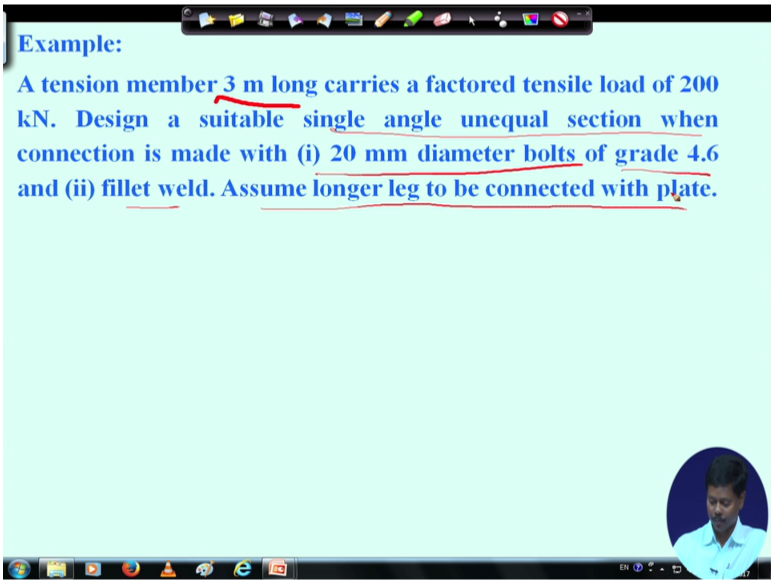
So these are the constants which has been told, so keeping this in mind we can go through one by one that step one if we see in step one what we did means what has been told in step 1 to do that is to find out Ag Ag we can find out P by fy by gamma m0. So if we put those value

P is 200 kilonewton and fy is 250 and gamma m0 is 1.1, so that is coming 880 millimeter square.

Now we can use a suitable section and that is single angle section unequal section, so we can look into the SP 6 and we can find out the suitable section say for example we are choosing 75 by 50 by 10, who gross area Ag is 1152. Here if you see if you compare the required area is 880 but we are giving much higher means little higher 1152 not marginally right but in programming if you do we can start with just just marginally means just after (())(4:49) whatever section is coming that we will consider but in this case just to avoid iteration we have taken a larger section just to avoid iteration because if we take lesser section then it may not be safe in different criteria. Therefore it is always suggested that it take little higher section, right.

So here again we can find out Anc area of the longer leg which is connected to the plate Anc will be 75 minus 10 by 2 minus 22, ok.

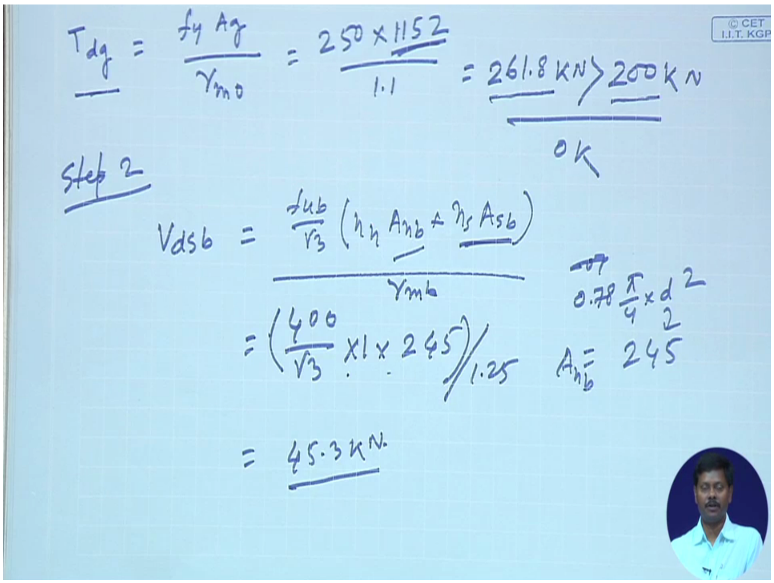
(Refer Slide Time: 5:36)



Here we have consider 20 mm diameter bolt ok when bolt connections we are doing it is told that 20 mm diameter bolt 20 mm diameter bolt means the area of hole will be means diameter of hole will be 22, right so into 10 thickness was 10. Therefore it will be 480 millimeter square. Similarly Ago that is the gross area of the outstanding leg that will become 75 minus 10 by 2 into 10, not 75 this is 50 because shorter length was 50, so 50 minus 10 by 2 into 10 so it is coming 450, right.

So Anc value we can find out, Ago value we can find out, also I can find out An value An will be Anc plus Ago, that means this will become 930 millimeter square. So these are the few properties of the angle sections which we have to keep in mind for calculation of the strength.

(Refer Slide Time: 6:59)

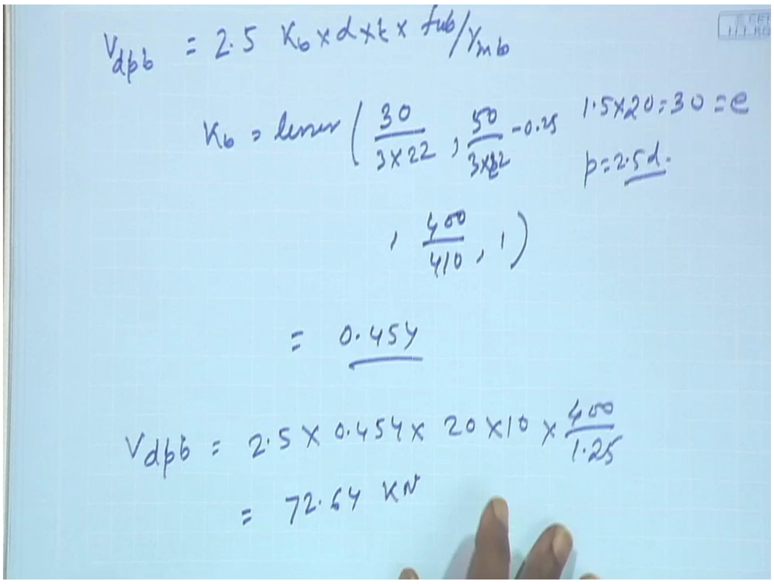


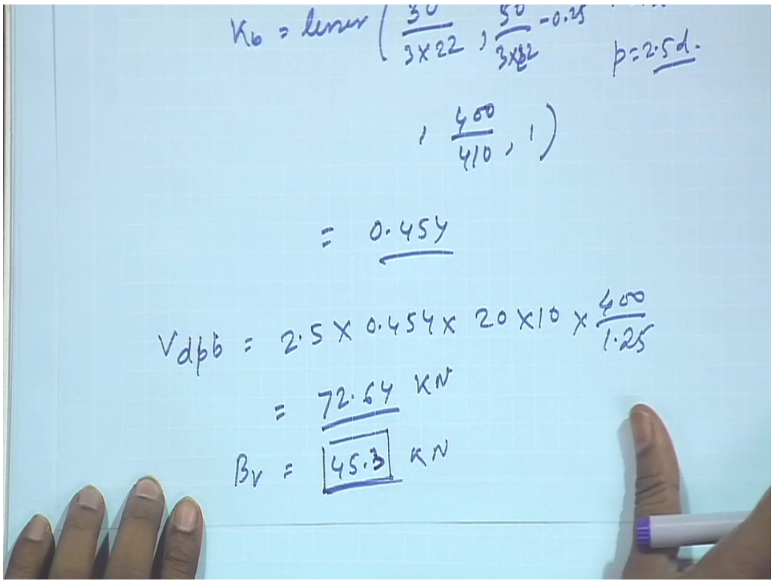
Now we can go for Tdg calculation of Tdg Tdg we know fy into Ag by gamma m0, so if we put this value we can find out 250 into 1152 by 1.1, because Ag is 1152, so this is coming 261.8 kilonewton which is coming more than 200, so it is ok that means it is safe from the gross yielding point of view. So design strength of the section due to gross yielding mean yielding of gross section is coming 261.8 kilonewton, whereas the axial load is 200 kilonewton, so this is safe.

Now we will check for other criteria that is for we will calculate for net section rapture of the net section. So for that now in step 2 we have to find out for bolt connection Vdsb the design shear strength of bolt we have to calculate that we know that is fub by root 3 into Ann Anb plus nsAsb. Now if we assume that shear plane to pass along the thread then this will be 0 along (())(8:51) it will be 0. So net area will be 0.78 0.78 pi by 4 into d square, ok so net area will become An Anb will become 245 if I put the value of d as 20, right.

So Vdsb value can be calculated it will be 400 by root 3 then ok by gamma mb, right into it is single shear into Anb is 245 by gamma mb is 1.25, so this is coming 45.3 kilonewton, ok. Now I have to find out the number of bolts and arrangements of bolt for finding out the net means strength due to yielding of the net section that means rapture strength, to find out rapture strength we need to know the Anc value as well as the beta value. So beta value if we want to know we have to know the shear leg width and the length Lc, right therefore we need to know the distribution of the bolt number of bolts all details.

(Refer Slide Time: 10:38)



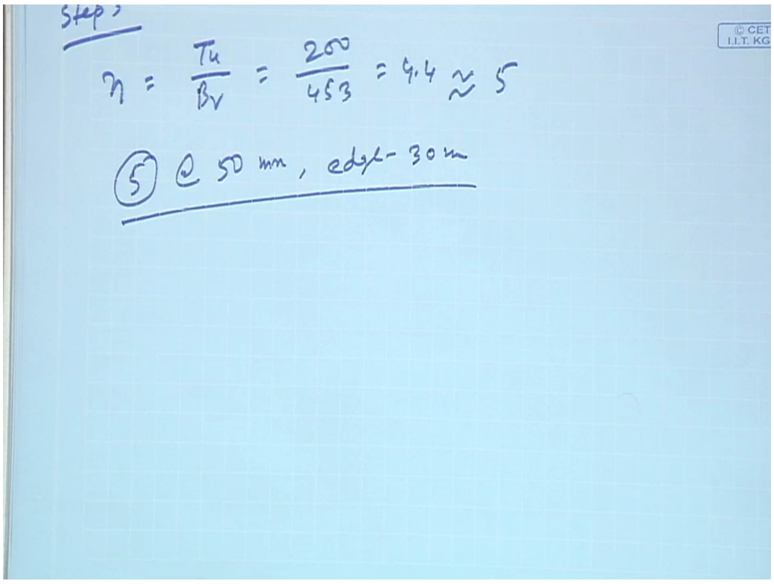


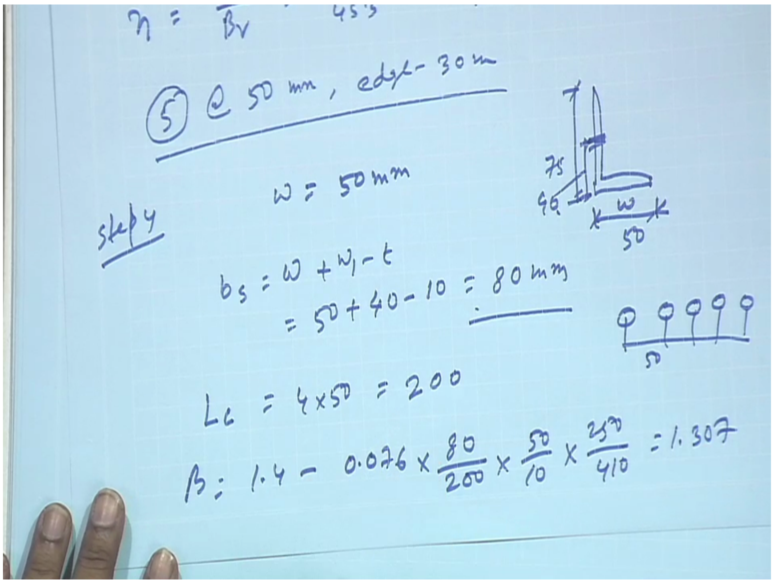
Again bearing strength of bolt Vdpb if I say it will be 2.5 Kb into d into t into fub by gamma mb, right. Now we have to find out the Kb value Kb will be we know lesser of e by 3d0, e we can consider 1.5 into d so 30 so e by 3d0, d0 is 22 and P by P I can consider this is e, P we can consider 2.5d that means 2.5 into 20, right so it will be 50, so 50 by 3 into (32) 22 minus 0.25, like this then (fu by) fub by fu then 1, so lesser of this is coming as 0.454, right.

So bearing strength we can find out as 2.5 Kb is 0.454 into d into t into fub is 400 by gamma mb, right. So this value are coming as 72.64 kilonewton, so bolt value I can write bolt value

Bv as 45.3 kilonewton because it is lesser of the shearing and bearing, right shearing value was coming 45.3, so and bearing was coming 72.64, so bolt value we can find out as 45.3.

(Refer Slide Time: 12:45)



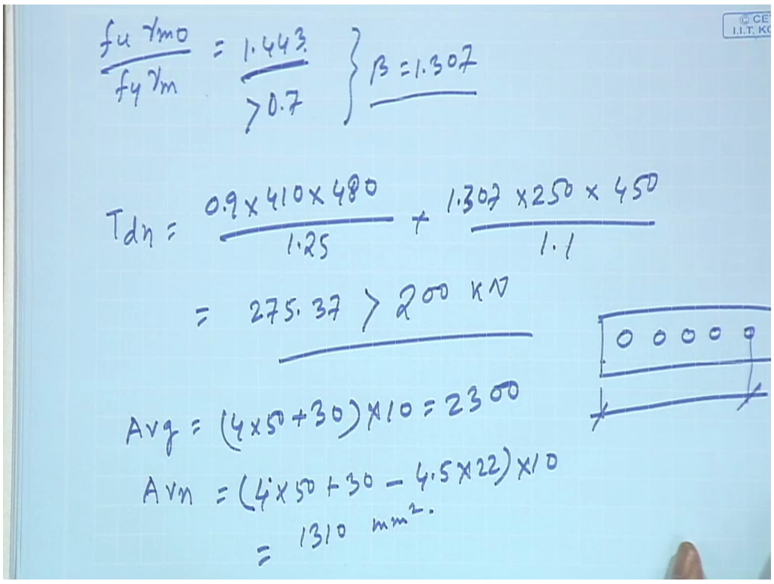


So from this I can find out if we go to step 3 that number of bolt n will be Tu by bolt value that is 200 by 45.3, 4.4 that means 5 number of bolt, ok. So let us use 5 number of bolts at a distance of 50 mm pitch and edge as 30 mm, so this is the bolt arrangement, ok. So according to those bolt arrangement we can find out the rapture strength.

So step 4 if I go to step 4, I can find out rapture strength so here I can see that w the outstanding length if I draw the section this is the section we have consider where this is 50, right and this is 75, right. So w is this the outstanding length so w is equal to 50 mm and bolt is provided at a distance of 40, right. So bs will be we know the shear leg width will become w plus w1 minus t, so 50 plus w1 will be 40 and thickness is 10, so 80 mm.

So once bolt distribution is known we can find out shear leg width as well as the distance between L bolt Lc distance between L bolt we have 5 bolts, right. So distance between L L bolts will be these are 50 pitch distance, so 4 into 50 this will be 200 mm. So from this I can find out beta as 1.4 minus 0.076 into bs is 80 by 200 Lc into w by t that is 50 by 10 into fy by fu 250 by 410, so I can find out 1.307, right. So beta value I can find out 1.307.

(Refer Slide Time: 15:42)



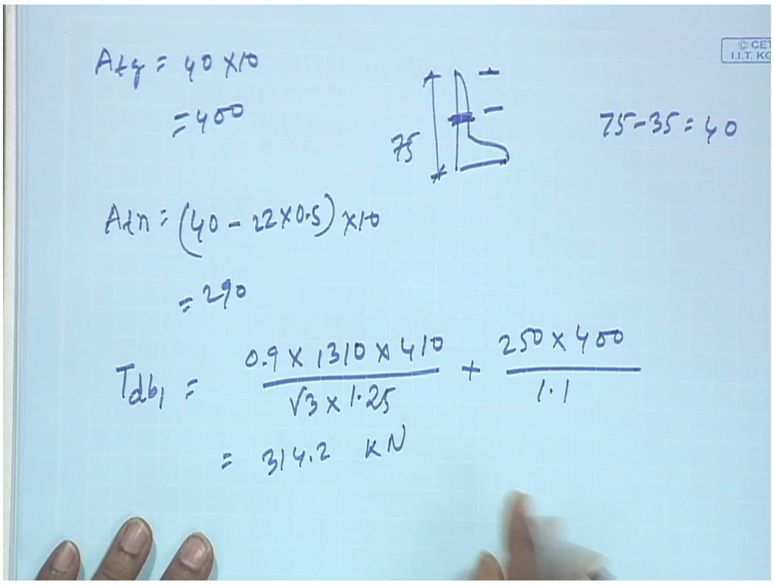
Again fu by fu gamma m0 by fy gamma m1 will be the limiting value of beta beta should be less than this and this value we are getting 1.443 and beta we get 1.307 and it should be greater than 0.7, so we can see that beta value is in between these two so it is ok, right. So satisfying above criteria we can consider beta as 1.307.

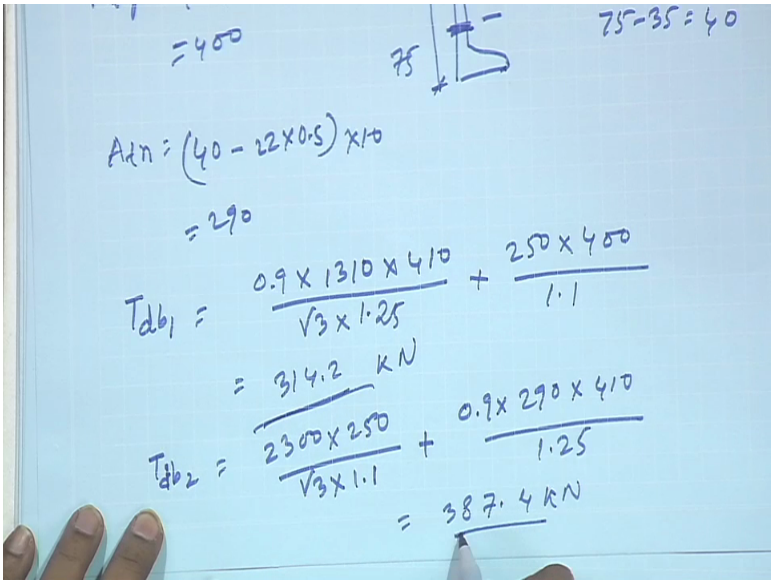
So Tdn value I can find out if I put in the formula that is 0.9 into fu into Anc we calculated as 480 by gamma m1 that is 1.25 plus beta is 1.307 into fy into Ago Ago is 450 by gamma m0. So putting this value we could find 275.37 kilonewton which is greater than the Tu value that is 200 kilonewton. So from rapture strength point of view also the section whatever we have consider is ok, right.

Now we will go for design strength of the member due to block shear failure, ok. So for block shear failure we have to calculate the value of Avg and here Avg will be so if we see this 5 bolts are there, right so Avg value we can find out 5 bolts then if I see it is like this so the distance will be end distance to the center of the end bolt that is 4 into 50 plus 30 into thickness 10, so the area is becoming 2300 millimeter square.

Similarly Avn value is coming 4 into 50 plus 30 minus the bolt hole area that is 4.5 into 22 into 10, so this is becoming 1310 millimeter square, right. So Avg and Avn value can be calculated in this way.

(Refer Slide Time: 18:48)

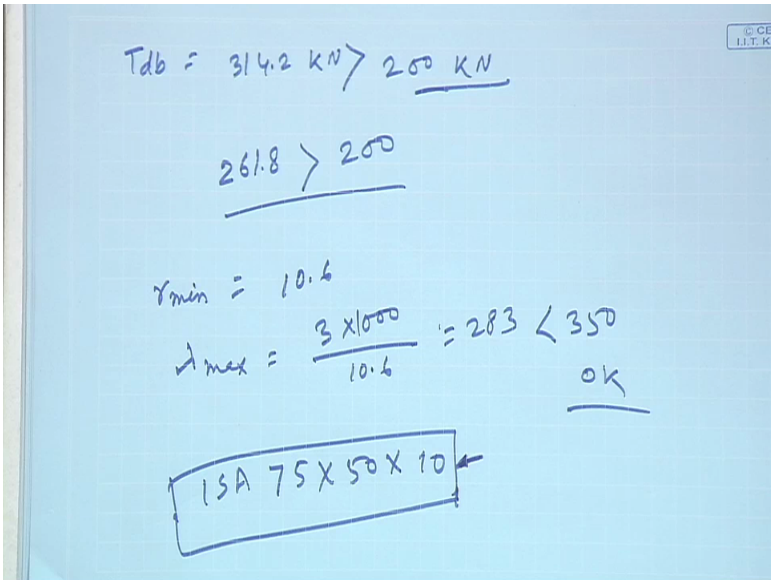




Now coming to Atg value Atg value will be if we see that bolt means if the section is like this and bolt is provided in this way then Atg value will be this is 75, this 75 and this is 35, right. So we can find out Atg as 40 into 10 because 75 minus 35 will be the value, so this is 400 and similarly Atn will be 40 minus 22 into 0.5 into 10, 290, right. So once we found this value I can find out the value of Tdb1 as 0.9 Avn Avn is 1310, fu by root 3, gamma m1 is 1.25 plus fy is 250 into Atg 400 by gamma m0 is 1.1, so this value is coming 314.2 kilonewton.

Similarly Tdb2 value I can find out as Avg into fy by root 3 gamma m0 plus 0.9 into Atn into fu by gamma m1, so these values are coming 387.4 kilonewton. So Tdb value will be lesser of these two Tdb1 and Tdb2, ok.

(Refer Slide Time: 21:23)



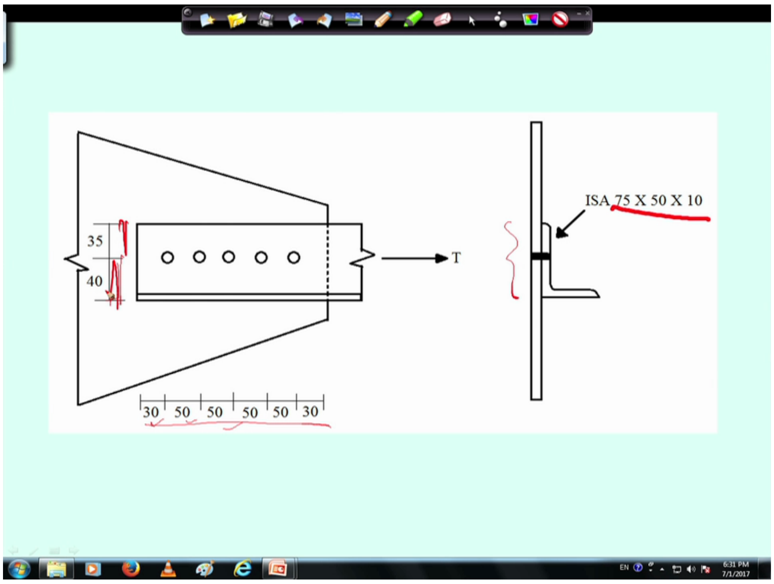
That means the Tdb value is will become 314.2 kilonewton and that is greater than 200 kilonewton, ok. So here the design tensile strength of angle we are getting lesser of these three Tdg, Tdb and Tdn that is 261.8 kilonewton and the external load is coming 200 kilonewton, so this is absolutely ok so we can go ahead with this section. Now I have to go for slenderness ratio check.

So for ISA 75 by 50 by 10 the slenderness ratio we have to find out before that we have to find out r minimum is 10.6 from SP 6, I can find out so maximum slenderness ratio I can find out yield effective is 3 meter by 10.6 minimum slenderness ratio this is coming 283 which is less than 350, ok so the angle is safe that means the angle whatever we have considering 75 by 50 by 10 this ISA is safe to carry 200 kilonewton load, ok.

So here we can see that lesser size of this angle lesser size one step lesser size of angle may be safe however we have to check because our required load was 200 kilonewton, external load was 200 kilonewton and the design strength we are getting 262 kilonewton which is little higher than the load coming into the member. Therefore there is a scope of making another iteration to get lesser size means less size the small size of the angle section, right.

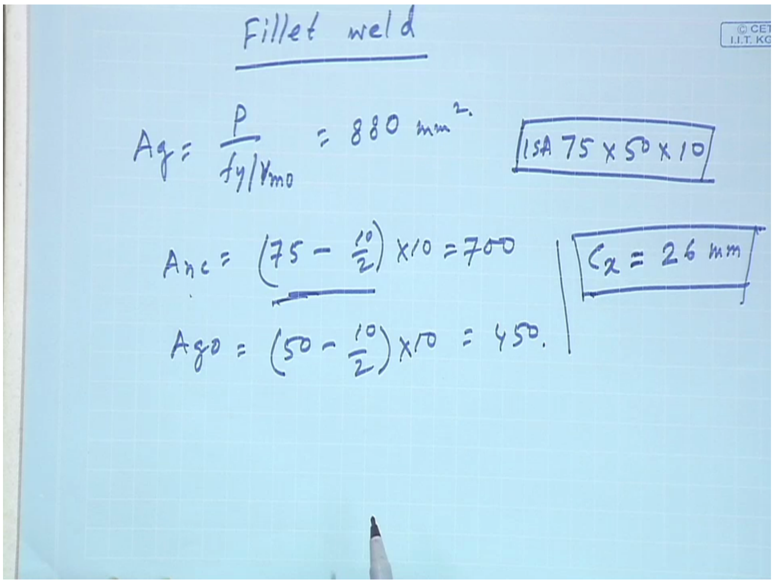
However as this is ok we can go ahead with this section as well, though it may not be economic but it is safe.

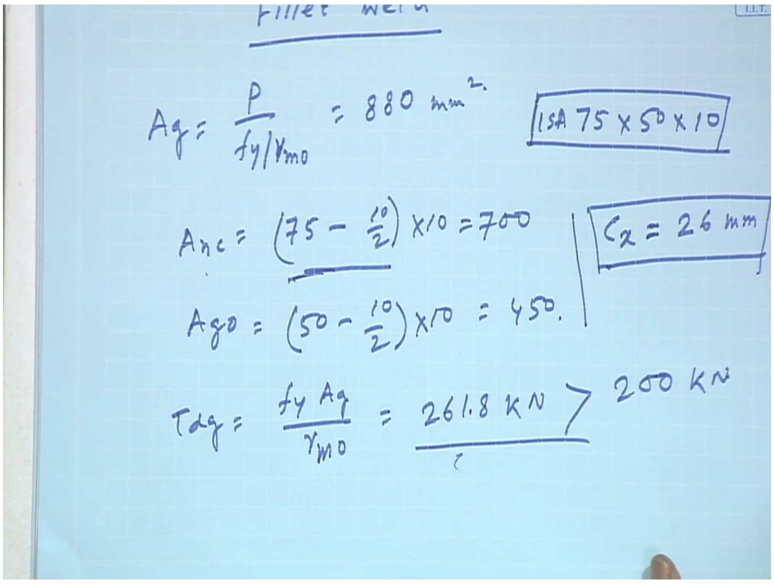
(Refer Slide Time: 24:19)



So in fact we should remember that when we are going to design we have to give a diagram that means unless we make a diagram it will not complete. So I can show the diagram this so here you see that this is a 75 by 50 by 10 angle section and its longer length is connected to the gusset plate and the distribution will be like this that edge distance is 30 and pitch distance is 50, ok and this distance is 40 and this is 35, right so this is how that means bolts placed in the angle section to connect the gusset plate.

(Refer Slide Time: 25:04)



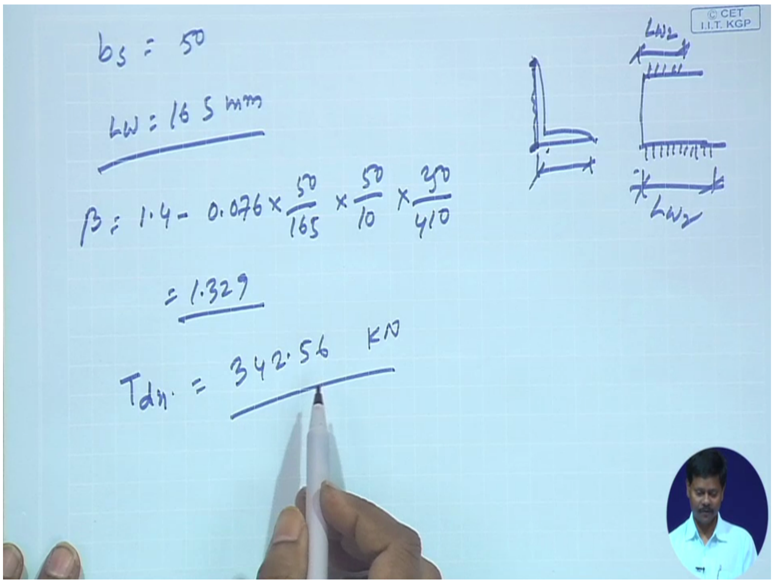


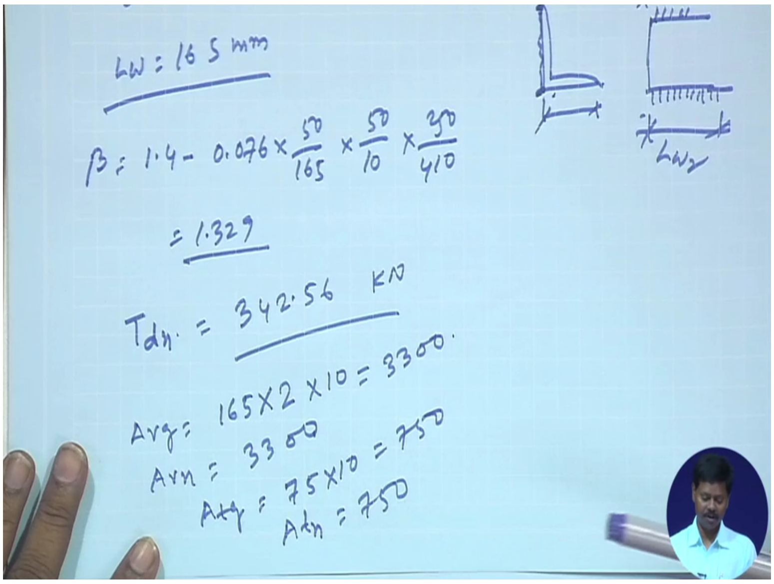
Now if it is connected with fillet weld the same member if it is connected with fillet weld then how to find out the strength that we will see. So here we can see that Ag will be same because that is P by fy by gamma m0, so that is 880, right. Now here Anc and Ago we have to find out, Anc will be as there will be means if we consider the same angle section 75 by 50 by 10 we are using same angle section to check whether in weld connection also it is safe or not.

So for same angle section we can find out the Anc as 75 minus 10 by 2 into 10, so here you can observe that we are not reducing any bolt hole because it is weld connection in case of bolt connection net area is deducted from the bolt hole, ok. So Ago also we can find out 50 minus 10 by 2 into 10, 450, right. So these two will be required calculation of Tdn and also we should know the Cx the center of gravity from the base that is 26 mm because this will be required for weld distribution means how weld is distributed to know that we need to know the value of Cx, right.

Now Tdg value we can find out same as we calculated earlier that will become 261.8 kilonewton and that is more than 200 kilonewton, which is ok. So Tdg value will be same for bolt connection as well as weld connection.

(Refer Slide Time: 27:42)





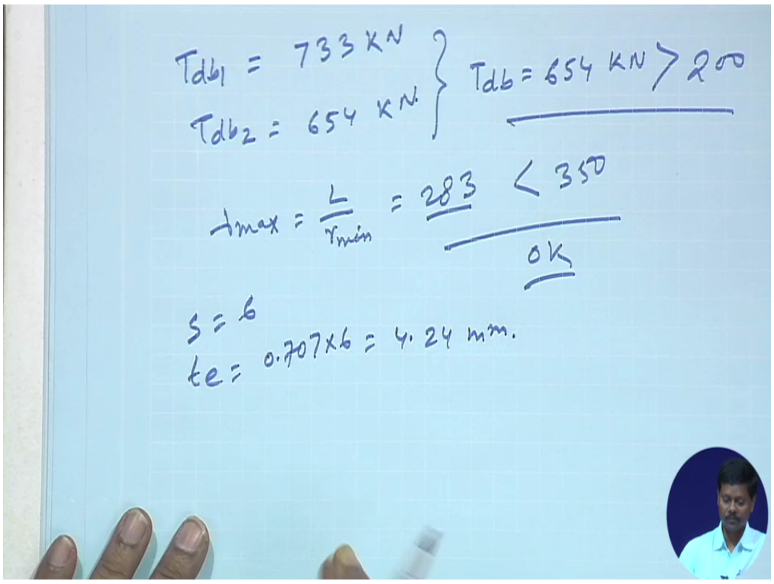
Now we will find out the strength governed by rapture of net section, so in this case shear leg width will be different from bolt connection because here it is connected by weld in this two direction as well as it may be connected here, so shear leg distance will be this much, right. That means the shear leg width will be here 50 mm and we do not know the distribution we do not know the distribution means if we see in this direction certain amount of distribution will be in this and certain amount of length will be on the upper side, right.

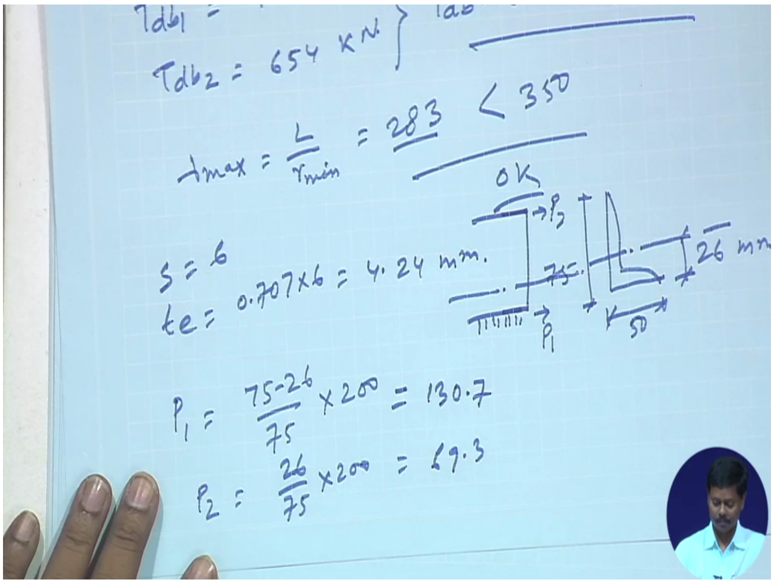
So we do not know what is the Lw1 and Lw2, if I consider this is as Lw2 we do not know what is the Lw1 and Lw2, right. So as per codal provisions we can assume average length Lw as 165 mm if we look back to the code we can see that Lw the average length of the weld can be consider as 165 millimeter for the purpose of calculation of beta. So beta we can calculate now as 1.4 minus 0.076 into 50 by 165 into 50 by 10 into 250 by 410 and that is coming 1.329, right.

So I can find out the Tdn value Tdn value will become if I put those value I can find Tdn value as 342.56 kilonewton, I am not going into details because all the parameters are known if we put those value I can find out Tdn value as 342.56 kilonewton, right.

Next I will go to strength due to block shear, ok so for block shear failure I have to find out Avg Avg will be average length we have consider 165 so 165 into 2 into 10, right this is what and Avn also will be because there is no hole so Avn also will be equal to Avg that will be same. Similarly Atg Atg will be 75 into 10 and this is 750 and Atn value also will be same, Atg and Atn will be same, Avg and Avn will be same.

(Refer Slide Time: 30:53)





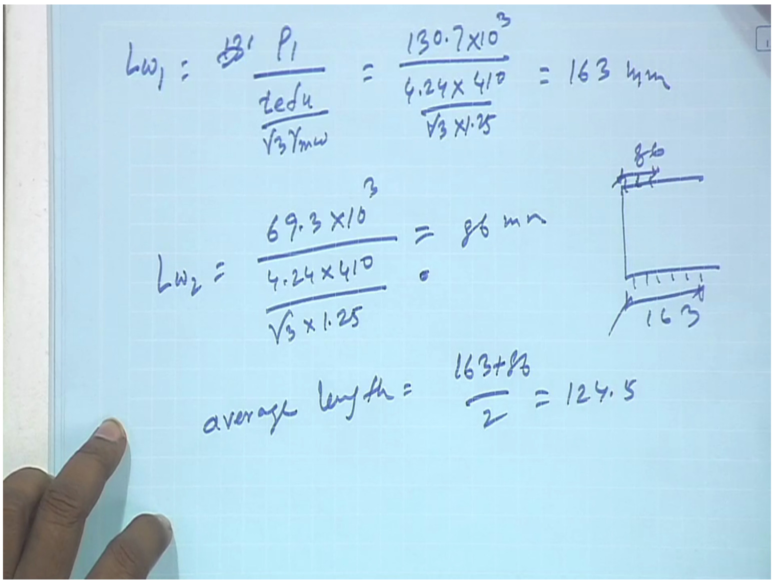
Now I can calculate the value of Tdb1 and Tdb2, so if I put those value I am not going into details because of shortage of time, I can find out Tdb1 as 733 kilonewton and Tdb2 value I can get 654 kilonewton. So I can say that Tdb value is coming 654 kilonewton which is much more than 200 kilonewton, so it is ok. So the section whatever we have choosen for weld connection is absolutely fine and also I can find out the lambda max lambda max will be L by r minimum that will become same as earlier 283 which is less than 350 so it is ok.

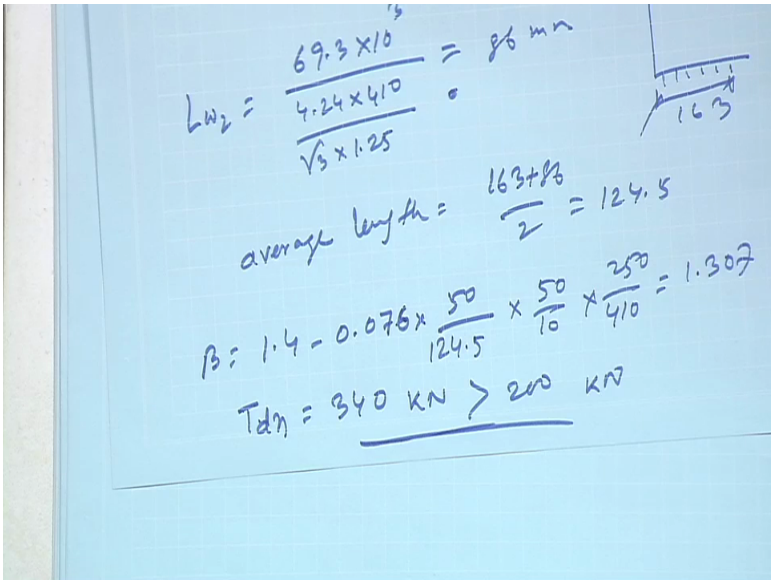
That means the section which we have consider that is 75 by 50 by 10 in case of bolt connection as well as in case of weld connection it is safe, ok so this is how we can design a section under tensile load, right. Now this is not the end of the design because in case of weld connection we have to calculate the weld length and we have to distribute the weld length properly, right. We know that this section is ok but should be the weld distribution, what should be the weld length total length so that we have to find out.

So we have to now we have to means we have to assume certain size of the weld the size of the weld how do I assume I can find out size of the weld from the thickness of the member because size of the weld depends on the minimum thickness of the member sorry minimum size of the weld depends on the thickness of the weld member, right. So here member thickness was 10 mm, so we can assume the size of thickness as 6 mm because 3 mm will be minimum, so we can assume 6 mm so if size is 6 mm then te will be 0.707 into 6 is 4.24 mm, right.

Now if a member is like this that is 75 and this is 50, then the load will be along its Cg distance, right and this distance is we have calculated earlier that is (26) this is 20 it was 26 mm, right. So we have to distribute the weld means we have to distribute the weld in such a way in this direction and in this direction in such a way that Cg of the weld group also pass through same line, ok to make it concentric. Therefore the force by the weld to resist on lower side say if this is P1 means if we see this is P1 and this is P2 then P1 should be 75 minus 26 by 75 into 200, ok and P2 should be 26 by 75 into 200, so load distribution should be in this way, right so if we calculate this we will get value 130.7 kilonewton and this is 69.3 kilonewton, right.

(Refer Slide Time: 35:11)





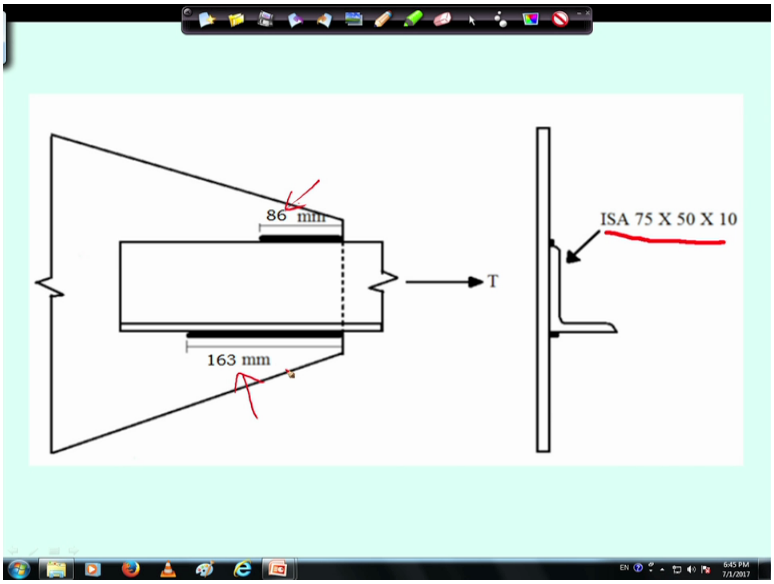
So I can find out the length required at the lower side Lw1 that is (130) that I can make the formula as like this P1 by weld strength weld strength will be tefu by root 3 gamma mw, so I can put the value 130.7 into 10 cube that is newton and t is 4.24, fu is 410 by root 3 into 1.25, so I can get 163 millimeter.

Similarly Lw2 I can find out that will be 69.3 then 4.24 into 410 by root 3 1.25, so this is becoming 86 millimeter, right So distribution of the weld length will be like this it will be 163 and this will be 86, right. So in this way we have to distribute.

Now average length of the weld will be average length will be 163 plus 86 by 2, 124.5 this is required for calculating the actual Tdn value. So beta value we can find out from the average length because we have consider average length as 165, right which is not correct so actual length we can find out from this, so here bs is 50 by Lc in place of 165 we can consider 124.5 into 50 by 10 into 250 by 410, so this value is coming 1.307.

So with this new value Tdn value we can find out as 340 kilonewton which is greater than 200, so this is ok that means I need to calculate the average value whatever we have consider average value was 165 is not correct that was assumptions but actual value was coming as 124.5 millimeter, right. So with the average value again I have to check whether my strength due to rapture of the net section is coming more than the applied load or not. So that check is necessary, right.

(Refer Slide Time: 38:26)



Now if I see the distribution in the diagram I can find out in this way that this section is ISA 75 by 50 by 10 and this length is 86 and this is 163 millimeter, right. So weld distribution has been done in such a way the Cg of the weld group and the Cg of the angle are becoming are coinciding are becoming same, so that there should not be any eccentricity of the member, right.

So this is how we can design a section means design a member tensile member due to axial tensile force, right and when we are going to design I have told that at the end we have to draw a diagram showing the distribution of the bolt or distribution of the weld length and the what will be the total length of the gusset plate, what we are using according to the required pitch and edge distance or according to the weld length required, so depending on that we have to decide finally what should be the gusset length and in terms of diagram if we represent it will be easier to understand by the site engineer, ok. So with this I like to conclude todays lecture thank you.