Course on Design of Steel Structures
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Lecture 32
Module 7
Compressive strength of angle struts

In this lecture we will be focused on compressive strength calculation of strut angles, we know struts are called when a member is subjected to compressive force and used in a bracing system or in a roof truss. Then such type of compressive member is called strut and this strut basically takes light load means the load miniature is not heavy and so for lighter load and the length effective length will be comparatively less. So for such cases we generally use angle section to take care the compressive load.

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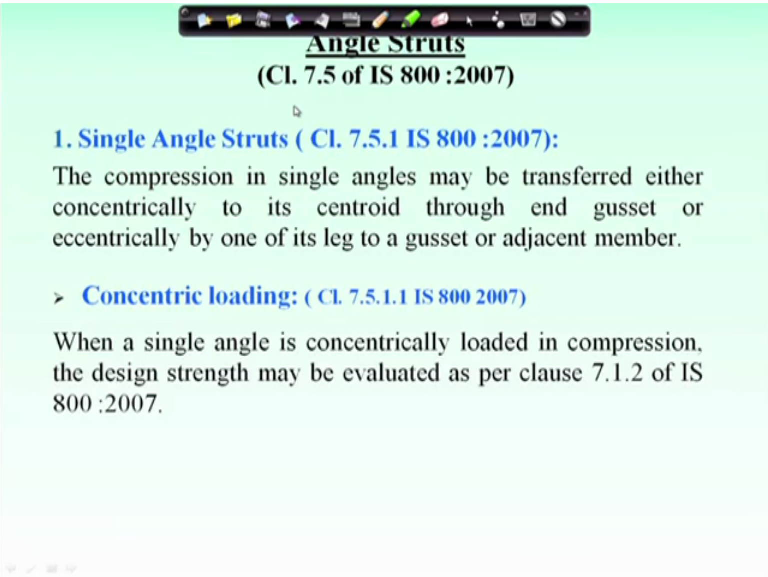

Now this compressive load may act concentrically on the angle section or may act through its one leg which will be eccentric and this angle section calculation means the strength calculation of such type of angle sections are given in code in clause 7.5 of IS 800:2007. Now in clause 7.5.1 of IS 2007 it is told that the compression in single angles may be transferred either concentrically to its centroid through end gusset or eccentrically by one of its leg to a gusset or adjacent member.

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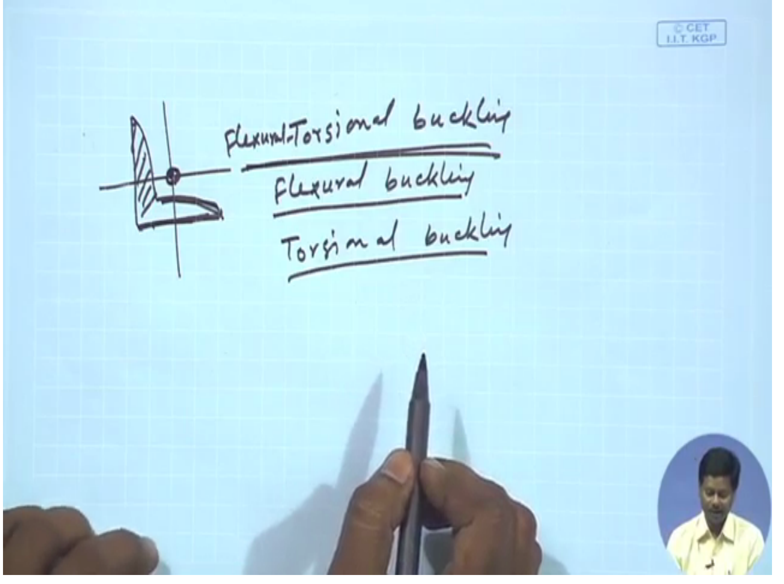

That means a angle sections is loaded with the axial compression member either the equivalent load the compressive load will be transferred through this Cg of this angle section by the use of gusset plate by end gusset the load will be transferred or it may be transferred through one of its leg may be in this through this leg or through this leg it may transfer the things through this leg.

So when the angle section is transferring the load through its one leg, then the eccentricity will come into picture and because of this eccentricity three types of things will happen one is torsional buckling will come into picture torsional buckling means basically flexural torsional buckling flexural torsional buckling will come into picture, another is flexural buckling which comes for all the members which is common, right and another is torsional buckling.

So three type of buckling will come into picture, one is flexural buckling, another is torsional buckling, another is flexural torsional buckling. So the combination of flexural torsional buckling can be calculated means from some formula which is given in the clause 7.5.

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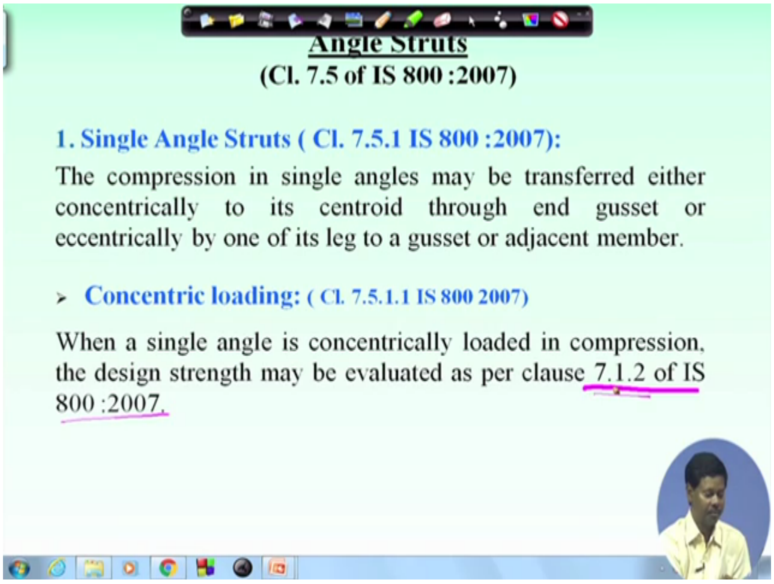

Now for concentric loading when the angle is concentric loaded this can be calculated through the clause 7.1.2 mean in case of concentrically loaded in compression the design strength may be evaluated as per clause 7.1.2 of IS 800:2007. This clause 7.1.2 we have discussed already that means it is a concentric loading what we have designed earlier in case of compression member may be that member it may be channel section, maybe I section, maybe other type of section when it is concentrically loaded then the design formula which I have already already discussed that formula will be used which is given in clause 7.1.2.

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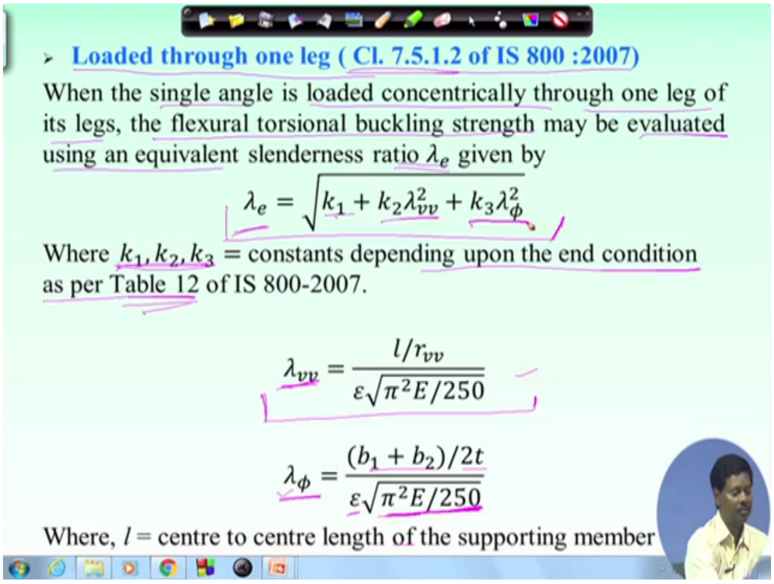

However if this is not concentric then we have to go for another clause which is given as a clause 7.5.1.2 when loaded through one leg, if the angle section is loaded by the axial compressive load through its one leg. So in clause 7.5.1.2 it is told that when the single angle is loaded concentrically through through one of the its leg the flexural torsional buckling strength may be evaluated using an equivalent slenderness ratio lambda E, where lambda E is expressed by these expression which is lambda E is equal to square root of k1 plus k2 lambda vv square plus k3 lambda phi square. So this expression you can find out in IS 800:2007 clause 7.5.1.2.

Now here constants k1, k2, k3 are given in table 12, these are the constant depending upon the end condition these constants are defined, depending upon end condition means whether it is fixed or it is hinged, whether it is one bot, two bolt welded depending on the end condition end fixity condition the value of k1, k2, k3 is defined in table 12 which I will come in next slide.

And lambda vv and lambda phi are also given in the (ex) in the code which are expressed by this, where lambda vv is equal to l by rvv by epsilon into square root of pi sqaure E by 250. So lambda vv the non-dimensional slenderness ratio lambda vv can be calculated from this. Another lambda phi another term can be calculated as b1 plus b2 by 2t by epsilon into square root of pi square E by 250.

Now for a particular grade of steel this pi square E by 250 is constant, so that can be calculated because E is constant for a particular grade of steel so we can find out pi square E by 250, epsilon is also constant I will come. Now l is the centre to centre length of the supporting member l is the centre to centre length of the supporting member. So if we can calculate lambda vv and lambda phi and if we find out the value of k1, k2, k3 from table 12 then I can find out the equivalent slenderness ratio lambda E and which is given as lambda E is equal to square root of k1 plus k2 into lambda vv square plus k3 into lambda phi square.

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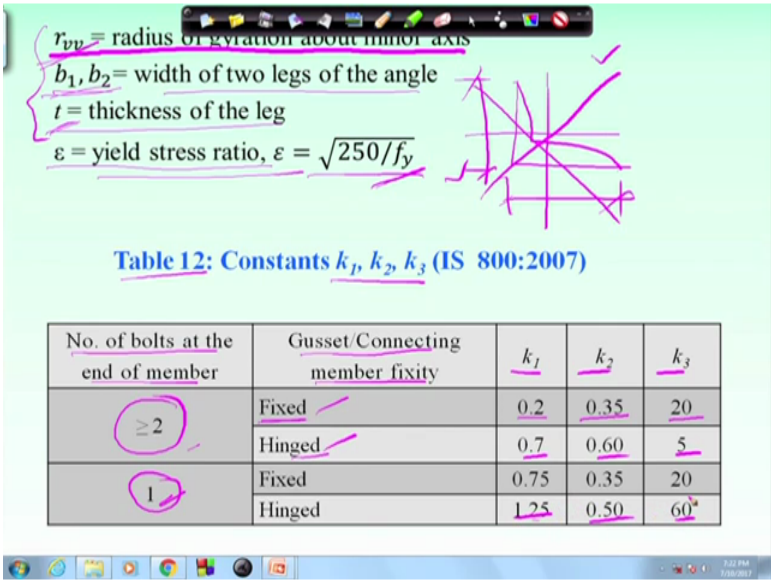

Now here rvv in the previous expression one term we have used that is rvv, rvv is the radius of gyration about minor axis, that means we have a angle section so when we are going to find out rxx, ryy, ruu, rvvv. So this will the minimum radius of gyration will be about the minor axis that is rvv, this is vv axis and b1, b2 is the width of two legs of the angle means b1 if this is b1 then b2 will be this one. So if one leg length is b1 then length of other leg will be b2 and t is the thickness of the leg thickness of the leg of the angle and epsilon is the yield stress ratio which is square root of 250 by fy.

So for a particular angle section we can find out the properties of this means from the geometry, from SP: 6 we can find out the value of rvv for a particular angle section then we know what is the width of the legs of the angle b1, b2 and thickness of the leg and also if if we know the grade of steel then we can find out the yield stress ratio epsilon that also we can find out.

And this constant k1, k2, k3 that can be found in table 12 of IS 800:2007 in table 12 of IS 800:2007 the value of k1, k2, k3 is defined k1, k2, and k3. Now this value of k1, k2, k3 depends on number of bolts at the end of the member as well as the connecting member fixity that means gusset or connecting member fixity means what type of fixity is there whether it is fixed, or hinged depending on that and whether number of bolts are more than 2 more than or equal to 2 or 1. So depending on that I can find out k1, k2, k3.

Say for example if I have a fixed connection, if fixity is there and if the number of bolts are 2 or more than 2 then I can take the value of k1 as 0.2, value of k2 as 0.35 and value of k3 as

20. So similarly I can consider different type of member fixity, if it is hinged then k1, k2, k3 value can be found, similarly if number of bolts are 1 at the end then depending upon the fixity I can find out the value of k1, k2, k3.

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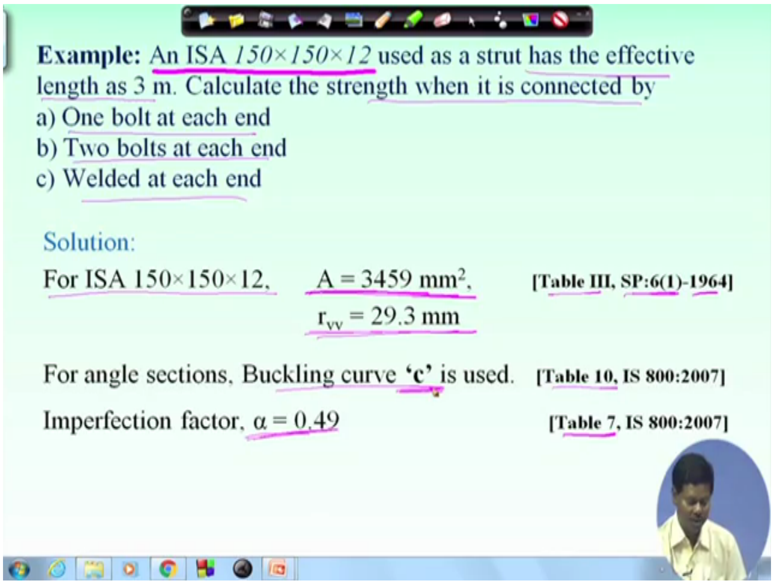

Now the theory whatever we have discussed theory means the expression for finding out lambda E value has been discussed, so for such type of members how to find out the design strength that can be understood if I go through this example

So let us take an example where an ISA 150 by 150 by 12 angle is used as a strut and has the effective length as 3 meter. Calculate the strength when it is connected by one bolt at each end, two bolts at each end and welded at each end. So for these three cases we would like to find out the strength of the member, right. So for three cases the three type of fixity will come and number of bolts if it is one bolt then its condition will be different, if it is two bolts its condition will be different. So through this example we will try to understand how to calculate the design strength of the compressive member of an angle section when it is eccentrically loaded through its one leg.

Basically what changes we will find out for different cases that is the equivalent lambda which is lambda E. So lambda E depend on k1, k2, k3 so that k1, k2, k3 can be found from table 12 and depending on the type of fixity and number of bolts the k1, k2, k3 value will change and accordingly the strength will be going to change. So through this example we will try to understand.

Now say for example that for ISA 150 by 150 by 12 from SP: 6 I can find out the cross sectional area of the member which I can find as 3459 millimetre square. Similarly I need the radius of gyration about minor axis, that is given as 29.3 millimetre, this is available in table 3 of SP: 6 by (1) in 1964 and for angle sections we know the buckling curve will be c, for angle section buckling curve is will be consider as c which is given in table 10.

And for buckling class c alpha value will be 0.49 which can be found from table 7 of IS 800:2007. So these are the few things which we can found we can find from the table 10 and table 7, that is the buckling curve is c and with respect to buckling curve the imperfection factor alpha is 0.49 and also the cross sectional area and radius of gyration about minor axis are also can be found from table 3 of SP: 6(1) 1964, right. So from this data I can now find out the design strength of the compressive member as defined here.

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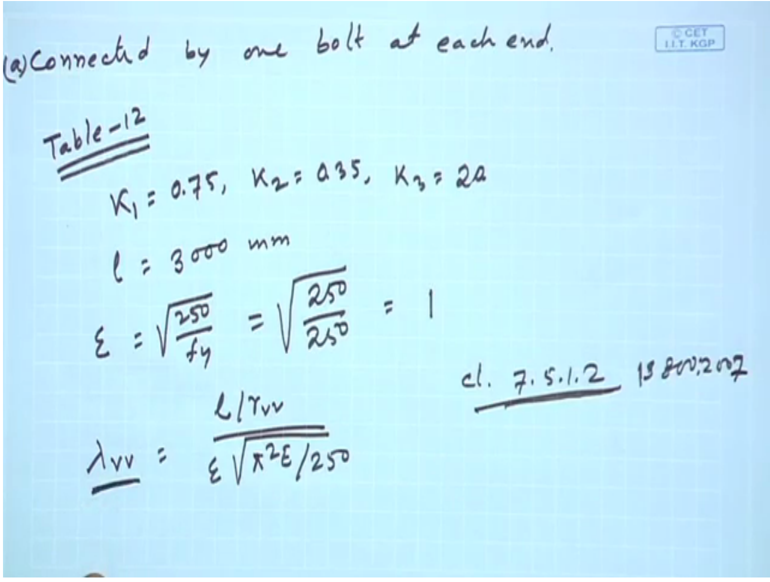

Now for first case if I consider the first case that is connected by one bolt at each end. So first case if I see then I can I can see that from table 12, I can find out the value of k1 as 0.75, k2 as 0.35 and k3 as 20. So this I can find from table 12. Now here length l is the centre to centre distance length that is 3 meter that means 3000 millimetre.

Now yield stress ratio in this case will be we know 250 by fy square root of that, now in this case we are using steel grade where yield stress will be 250, so 250 by 250 is equal to 1, right. Now I can find out the value of lambda vv which is expressed as l by rvv by epsilon into square root of pi square E by 250, this I can find from clause 7.5.1.2 of IS 800:2007 IS

800:2007, right. So from IS 800:2007 the expression given in clause 7.5.1.2, I can find out the value of lambda vv.

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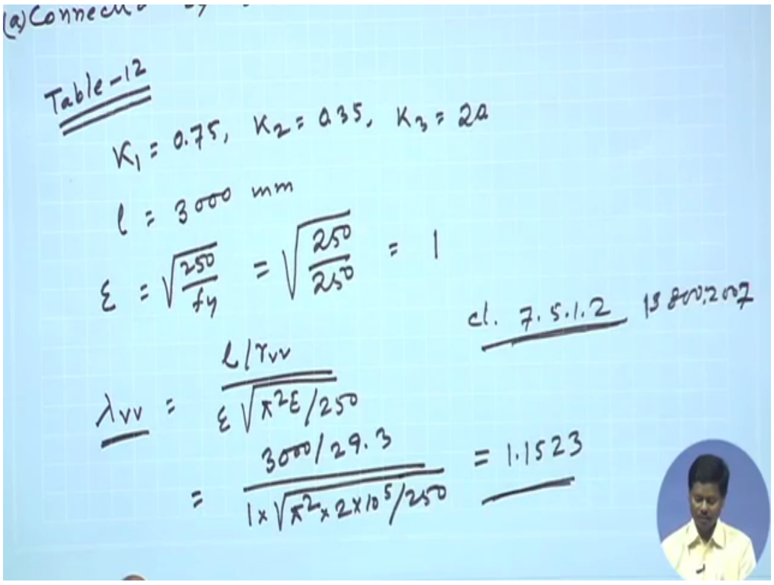

So if I put the value I can find lambda vv as 3000 because l is 3000, rvv we found 29.3, epsilon is 1 and pi square into E is 2 into 10 to the power 5 by 250. So after calculation we can find lambda vv value as 1.1523, right. So we can find out the value as 1.1523.

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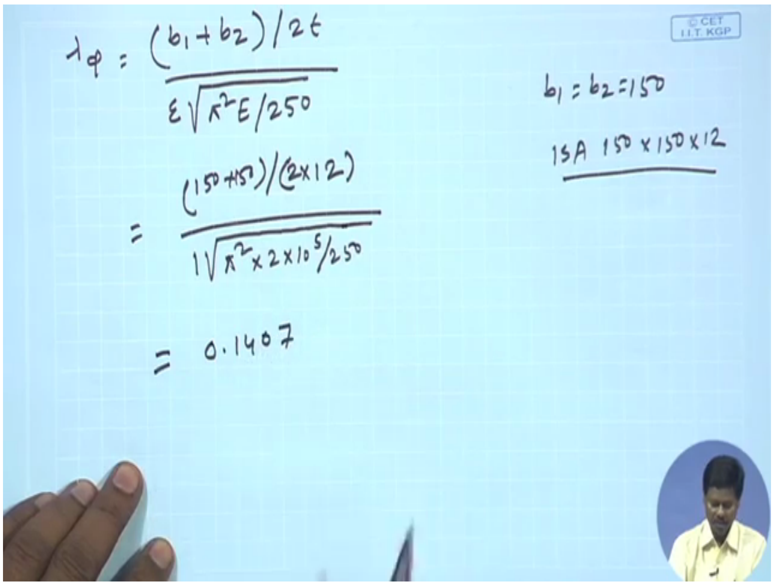

Next I will find out the value of lambda phi, so lambda phi we know this is given as b1 plus b2 by 2t by epsilon into pi square E by 250. So here b1 is equal to b2 is equal to 150 because ISA we have used ISA 150 by 150 by 12, right. So I can put this value b1 plus b2 that means

150 plus 150 by 2t by 2t means 2 into t is 12, right. Then epsilon is 1 and pi square E by 250 is same that will be pi square E will be 2 into 10 to the power 5 and by 250. So after calculation of this expression I can find out lambda phi as 0.1407.

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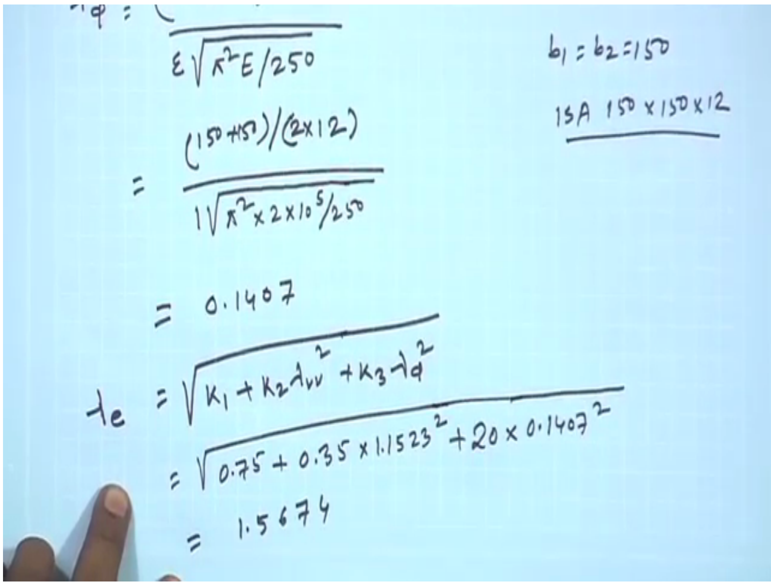

Now the equivalent lambda can be found that will be that will be calculated from this expression that is k1 plus k2 into lambda vv square plus k3 into lambda phi square. So if we put the value k1, k2, k3 that is k1 was 0.75, k2 was 0.35 and lambda vv we have calculated as 1.1523 square plus lambda 3 was 20 into lambda phi is 0.1407 square. So finally I can found I can find lambda e as 1.5674, right. So lambda e the equivalent slenderness ratio lambda e can be found as 1.5674.

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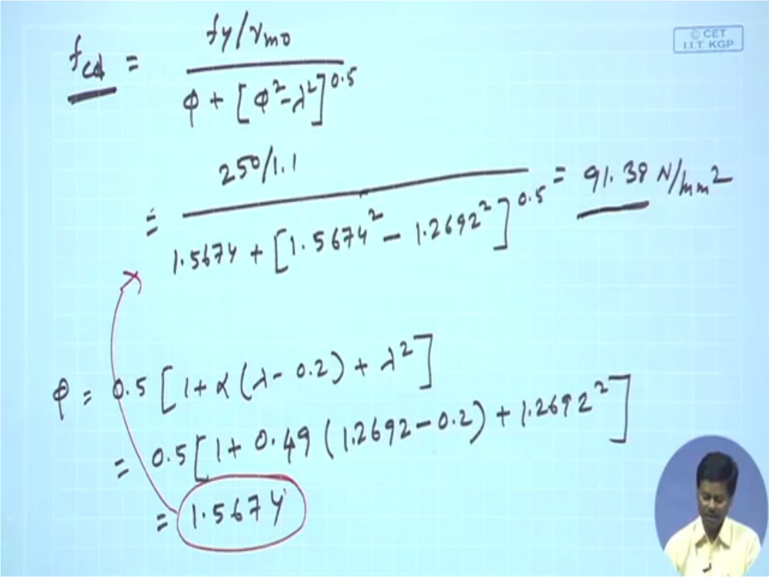

Now from this I can find out the value of fcd design compressive stress, design compressive stress we know the formula is fy by gamma m0 by phi plus phi square minus lambda square to the power 0.5.

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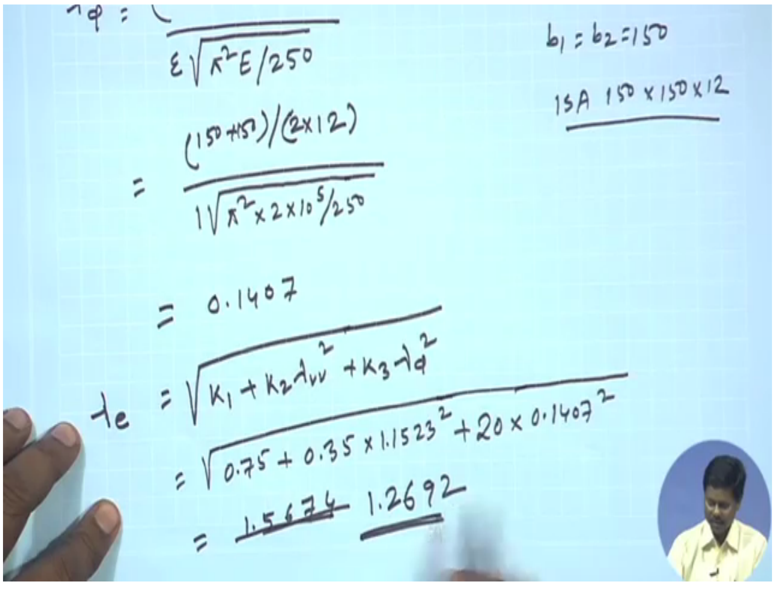

So if I put those value, I will get 250 by 1.1 by phi value we got as (1 point) no phi value we have not calculated, we have calculated this lambda e value this lambda e value will be basically I I did a mistake 1.2692, right lambda e value is 1.2692. Now I have to find out phi value. So phi value before that I have to calculate the phi value so phi value will be we know 0.5 into 1 plus alpha, lambda minus 0.2 plus lambda square. So this value if I put, I can find out the value of phi as like this 0.5 this alpha value is the imperfection factor that is 0.49 and lambda we got 1.2692 minus 0.2 plus 1.2692 square. So this will be 1.5674.

Now this value will be used this phi value will be used here phi, right. So phi can be written as (1.57) 1.5674 plus phi square that means 1.5674 square minus lambda square lambda value we got 1.2692 square whole to the power 0.5. So after calculation we can find out fcd value as 91.38 newton per millimetre square, right. So design compressive stress of such type of angle can be calculated as we have shown and for this particular case we are getting 91.38 newton per millimetre square.

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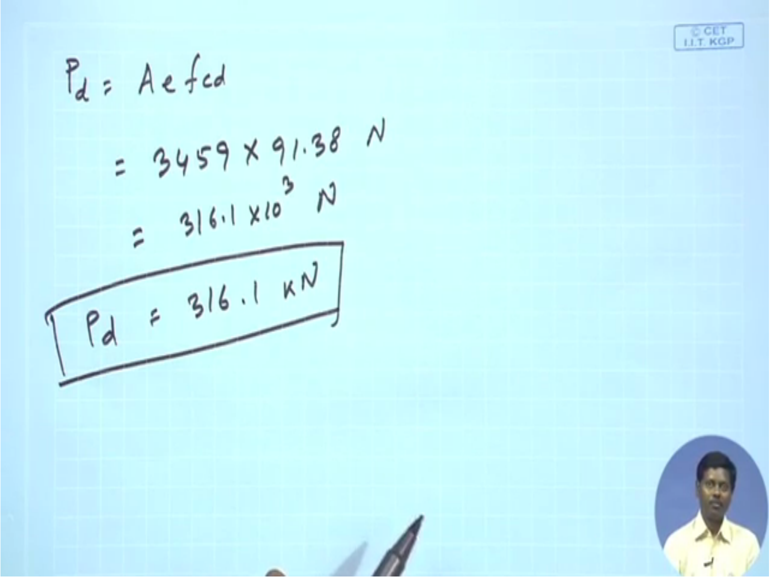

Now from this I can find out the design compressive strength Pd as Ae into fcd, right. So Ae the effective area is the gross area for this case, so this will be 3459 which we have found earlier and fcd have been calculated as 91.38 newton per millimetre square. So this will be in newton, so this will be 316.1 into 10 cube newton or I can say 316.1 kilonewton. So Pd the design compressive strength of the angle strut when it is eccentrically loaded can be found as 316.1 kilonewton. This is the first case, when two sides are connected by one bolt.

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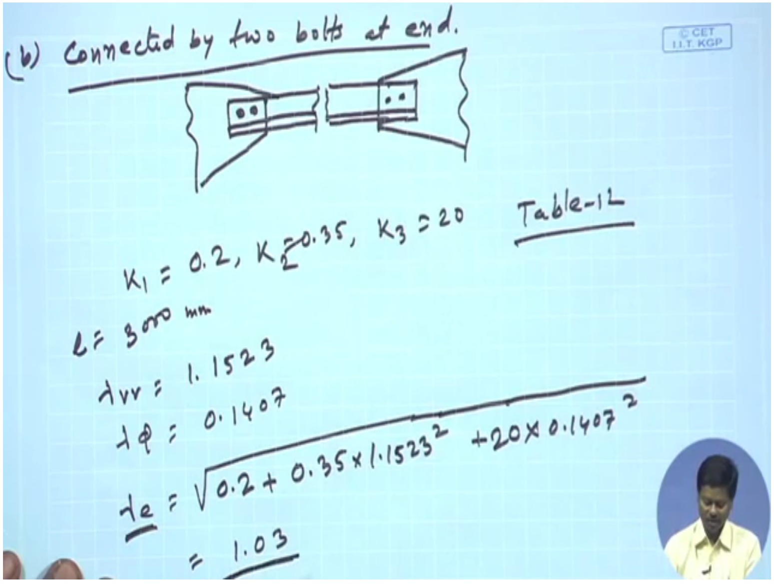

Now the same calculations will be done when the two sides are calculated by two bolt for the same case and let us see how the strength is going to vary from earlier case. So two bolts means if I see this member if two members are connected if these members are connected with a gusset plate say for example like this then two bolts are connected, so similarly in this end also we can find that the member is connected to its gusset plate by two bolt. So for this case how we can find out the design strength of the member. So this is case (b) which is connected by two bolts at each end.

So for this case I can find out the value of k1 because here k1, k2, k3 will be different k1 will be 0.2, k2 will be 0.35 and k3 will be 20 from table 12 from table 12, I can find out the value of k1, k2, k3, right. Now other things will be same because l is consider as 3000 millimetre and we are considering that both end are fixed like earlier case. So lambda vv will be same like previous case what we have calculated because here nothing is going to be changed, lambda phi will also be same as calculated earlier.

Now lambda e will be different because it depends on the value of k1, k2, k3 okay. So if I put the value of k1, k2, k3 in the expression of lambda e then I can find out the value of lambda e as like this 0.2 plus 0.35 into lambda vv square that is 1.1523 square plus k3 k3 is 20 into lambda phi square 0.1407 square. So after calculation we can find out as this. So if you remember that lambda e value was different for earlier case as compared to the present case.

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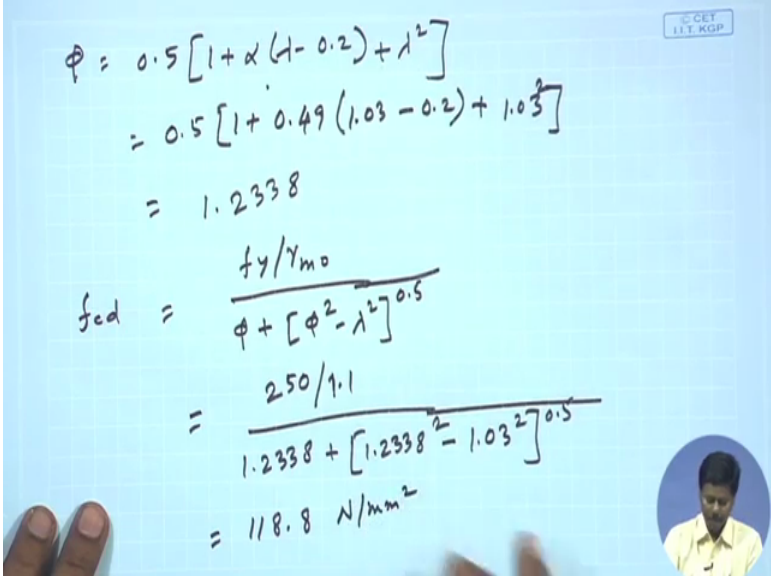

So as lambda e value has been changed the phi value will be changed because phi value depends on the lambda e, so phi value I can find out that is we know 0.5 1 plus alpha into lambda minus 0.2 plus lambda square. So putting the value of alpha and lambda in this equation, alpha is 0.49 and lambda is 1.03 if I put this value then the value of phi I can found I can find as 1.2338.

So fcd value can be found from this formula fy by gamma m0 by phi plus phi square minus lambda square whole to the power 0.5, right. So if I put the value of different parameters as fy as 250, gamma m0 as 1.1, phi as 1.2338 which has been calculated in the earlier step then 1.2338 square minus lambda has been calculated as 1.03 whole to the power 0.5. So from this I can find the value of fcd as 118.8, right newton per millimetre square.

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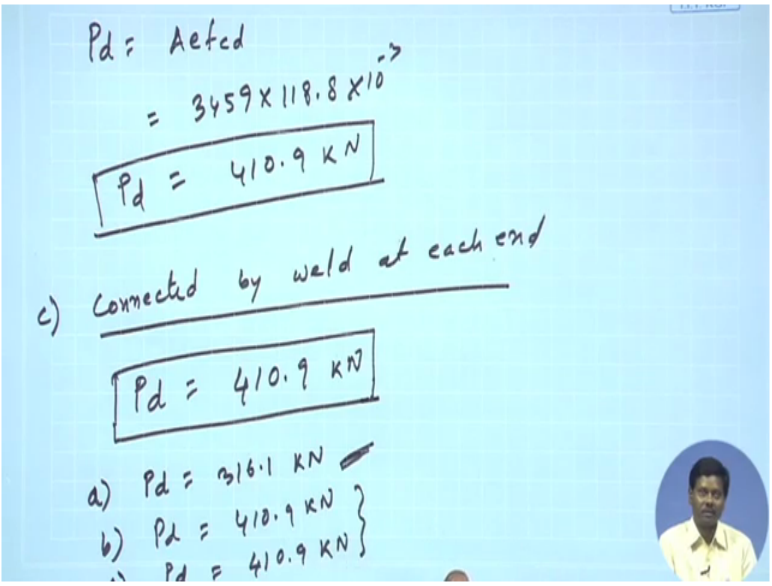

So the Pd value I can find as Pd is equal to Aefcd that will be 3459 into 118.8 into 10 to the power minus 3 to make it kilonewton. So this will become 410.9 kilonewton. So for second case the design strength of the compressive member will become 410.9 kilonewton.

Now coming to third case when it is connected by weld at each end, so for this case what we can consider that this will be similar to the earlier case earlier case means when the angle is connected by two bolts in both the end. So in case of weld connection we can assume means it will be also similar that it will be fixed at both the end and as we have calculated the k1, k2, k3 value considering two bolts for this case also will become same.

So the Pd value will become simply same as we have considered earlier, that means the weld connection and connections made by two bolts or more is same, right similar behaviour we will get when it is in fixity condition, right.

So what we have seen here that Pd value for first case we got 316.1 kilonewton and for second case we got Pd is equal to 410.9 kilonewton and in third case Pd value we got 410.9 kilonewton, that means when two bolts or weld connections are used the design strength is becoming higher compared to the one bolt connections, right. So if we want to increase the strength of the member we should choose for higher number of bolts means where one bolt is sufficient we will choose two bolt with smaller diameter, so that we can use two bolt as well as we can increase the strength of the member this is how we can by the means we can utilize the this advantages things and we can we can make more load means we can allow more load for such type of connections.

Again in summary what I wanted to tell is that that if member has to take more strength then always we should go for two bolt at the end means connection should be two or more bolt, if one bolt is there means is required then also we should try to make two bolt with lower diameter. So that we can accommodate more strength on the member with same member size member size will be same but strength will be more because lambda e is going to change, right.

So this is what we wanted to discuss about todays lecture regarding the design strength calculation of angle strut when it is eccentrically loaded through its one leg, thank you.