Course on Design of Steel Structures

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Module 10, Lecture 50

Laterally Unsupported Beams

This lecture we will focus on laterally unsupported beam. So design strength of laterally unsupported beam will be calculated based on the codal permissions, which is given in clause 8.2.2 of IS 800-2007. Now in case of laterally unsupported beam, the lateral torsional buckling will play an important role and because of lateral torsional buckling, the full plasticity of the section will not be developed that means the member will fail before at any it's (())(0:59) full bending stress of the section, the it will fail due to laterally torsional buckling and this lateral torsional buckling happens.

In case of steel rolled section, unlike RCC section or the stocky section, their lateral torsional buckling does not come into picture, but in case of such type of section where we have made economic of the in terms of the material, we face this type of lateral torsional buckling and if we do not provide support laterally then such type of buckling will come into picture.

So this buckling comes, because of the cross sectional shape then support conditions and the length effective length. So what is the effective length? What is the support conditions and what is the type shape depending on that the lateral buckling moment will be calculated and, because of that how it is going to fail that you means how we are going to calculate the lateral buckling strength and then how we are finally going to find out the design bending strength of the section when the section is laterally unsupported will be discussed.

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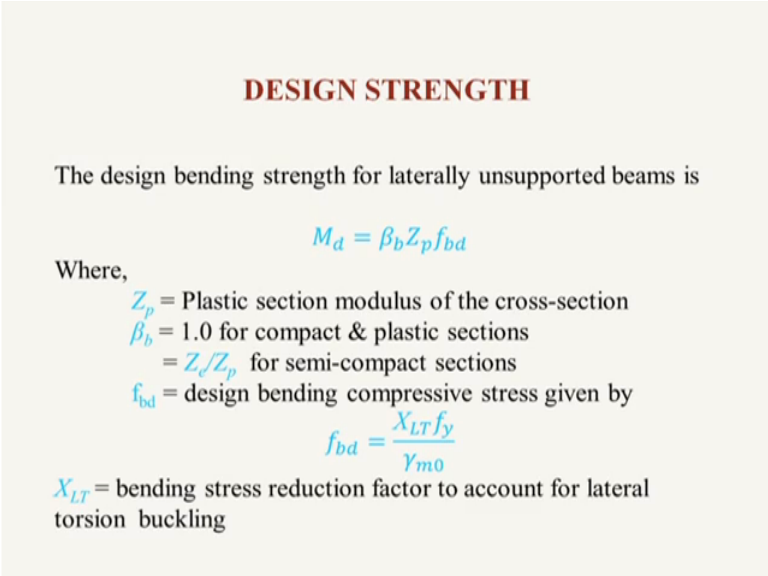

So if we see the design bending strength, which we can write as Md is equal to beta b Zp into.

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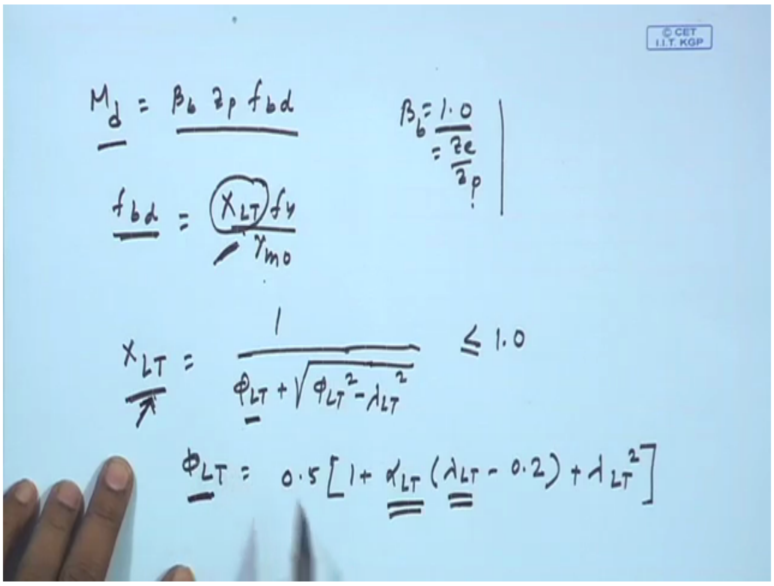

Md is equal to beta b Zp into Fbd. So the design bending strength of laterally unsupported beam can be written as Zp into Fbd into beta b, where beta b we can consider as 1.0 for compact and plastic section and we can consider as Ze by Zp for semi-compact section. so depending on the type of section, the beta b value will be calculated either 1 for compact or plastic section or the ratio of Ze by Zp for semi-compact section and this Zp is basically the plastic section modulus of the cross section and Fbd is the design bending compressive stress.

So design bending compressive stress Fbd we can find out from this formula XLT into Fy by gamma m0. This is the bending stress reduction factor to account for lateral torsional buckling. So the design bending compressive stress Fbd can be found from this XLT into Fy by gamma m0, where XLT is the bending stress reduction factor. So what is a bending stress reduction factor that we need to calculated. This has been calculated as 1 by phi LT plus root over phi LT square minus lambda LT square and in any case, it should be less than or equal to 1.

So the reduction factor XLT, we can calculate from this expression, where the phi LT value can be calculated as this, that is 0.5 into 1 plus alpha LT into lambda LT minus 0.2 plus lambda LT square, right. So phi LT value can be calculated from this expression and where we can see that there is a term which is alpha LT and also lambda LT that non-dimensional slenderness ratio that we have to find out. So if we know the value of alpha LT and lambda LT then we can find out phi LT and if we know phi LT then we can find out the value of reduction factor that is XLT. So bending compressive stress reduction factor XLT can be found from this. Now what alpha LT?

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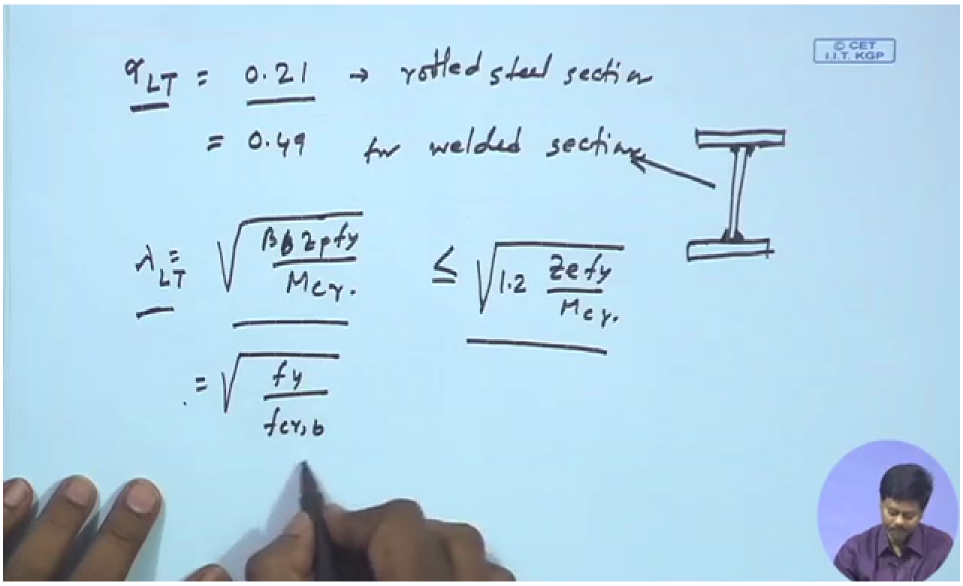

Alpha LT is the imperfection factor for lateral torsion. So alpha LT is the imperfection factor for lateral torsional buckling of beam, we can consider this as 0.21 for steel rolled section, okay. So for all rolled section, the value of alpha LT can be found as 0.21 and it will be 0.49 for welded section that means if we suppose, use plate to make a I section with the use of welded, say with welding we can make a I section from a plate, then for such type of section, we can use alpha LT as 0.49 otherwise for the rolled section we can use alpha LT as 0.21 and lambda LT is, I have told that is non-dimensional slenderness ratio lambda LT. So this can be calculated from this that is beta b Zp Fy by Mcr, right. Beta b into Zp Fy by Mcr and it has to be less than or equal to in any case 1.2 Ze Fy by Mcr, right.

So we will calculate the non-dimensional slenderness ratio from this expression, which is beta b Zp Fy by Mcr and this lambda LT value should be less than or equal to this that we will go for 1$2 into Ze Fy by Mcr. So this lambda LT also we can write as Fy by Fcr,b, where Fcrb is the Mcr by beta b Zp, right. So lambda LT we can find from this, right.

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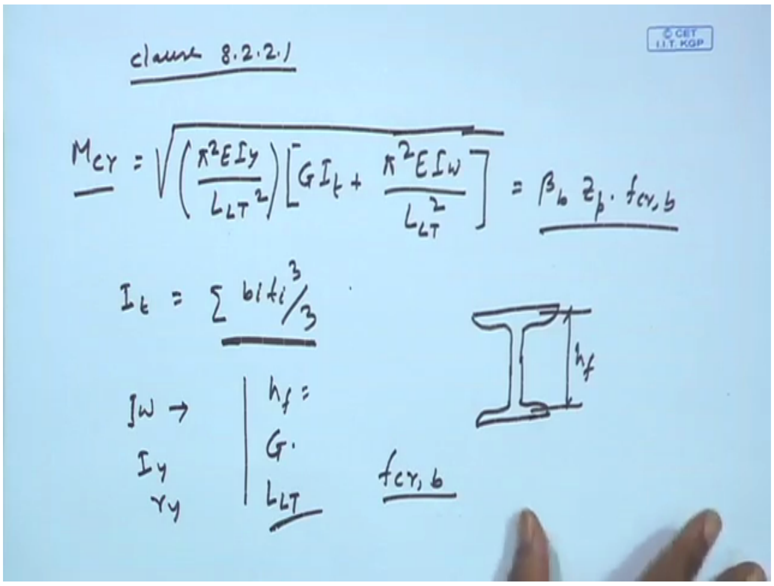

Now what is Mcr? Mcr is basically the elastic lateral buckling moment. This is given in clause 8.2.2.1 of IS 800-2007. We can find out the elastic lateral buckling moment Mcr and a formula has been given for calculating the value of Mcr that is as pi square E Iy by LLT square into GIt plus pi square E Iw by LLT square, right. So the elastic lateral buckling moment can be found from this expression. This can be writurn as beta b Zp into Fcr, b, right where here the different variables are given, which we can find out from clause 8.2.2.1 the parameters like It is a torsional constant. So It will be for open section, it will be bi ti cube by 3.

So how to calculate It that through one work out one example we will discuss details. Then Iw is the working constant Iw which is working constant Iy is the moment of inertia about weaker axis, similarly Iy is the radius of the erection (())(10:01) about weaker axis then hf is a center to center distance between flanges that means hf will be say, if I consider any I section then the hf value will be center to center distance of the flanges. This will be hf and G will be shear modulus and LLT will be the effective length for lateral torsional buckling, which is given in clause 8.3, right. So effective length for lateral torsional buckling LLT can be found in clause 8.3 and Fcrb Fcr,b is the extreme fiber bending compressive stress Fcr b Fcr,b is a extreme fiber bending compressive stress corresponding to elastic lateral buckling moment.

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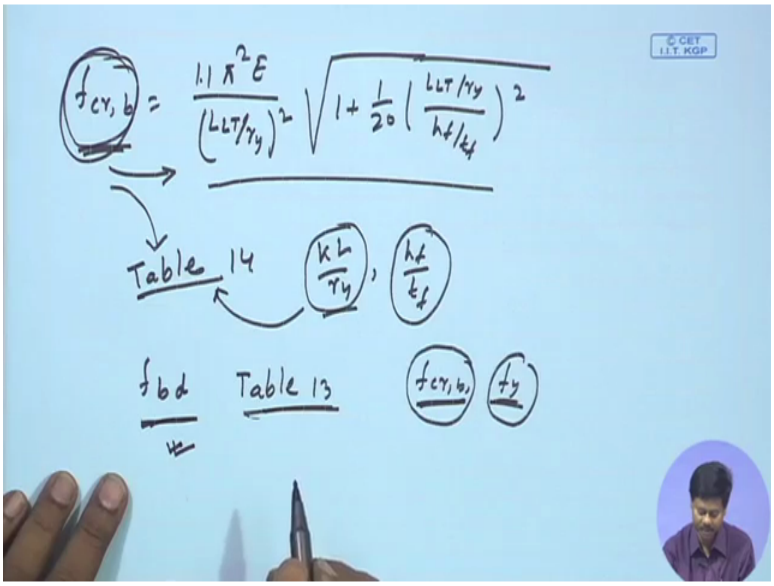

And this Fcr b can be expressed as like this 1.1 pi square E by LLT by ry whole square into 1 plus 1 by 20 LLT by ry by hf by tf whole square, right. So Fcr,b the extreme fiber bending compressive stress corresponding to elastic lateral buckling moment can be expressed from this, okay. This is also given in the code, where the details can be found and also we can find out this value the Fcr,b value from table 14, instead of calculating all this we can find out the value from table 14 of IS 800-2007 with respect to KL by ry and hf by tf. So for different value of hf by tf and KL by ry, we can find out the value of Fcr,b in table 14 that means in place of calculating through this expression directly we can find out the value of Fcr,b from table 14.

And the Fbd value can also be found directly from table 13 corresponding to different Fcrb value and Fy value, for different Fcrb and Fy value we can find out the value of Fbd, Fbd the design compressive bending stress, right. So what we can do means without calculating through expression directly what we can do, first we can find out what is the KL by ry ratio? What is the hf by tf and from that we can using we can use table 14 and using table 14, we can find the value of Fcr,b and once the Fcr,b value is obtained then corresponds to Fcr,b value and Fy we can find out the value of Fbd. So directly I can find out the design compressive bending stress and then I can find out the design bending strength of the member.

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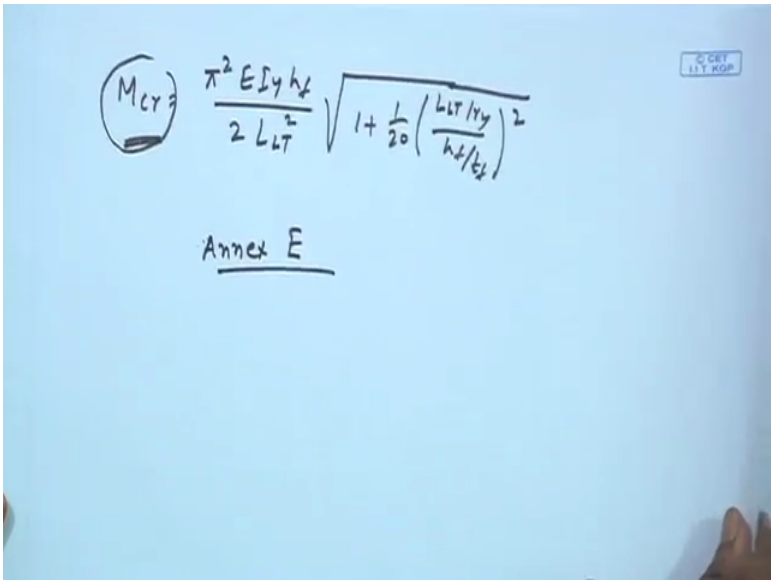

Now also we can find out the Mcr value in a simplified manner from this formula that is pi square E Iy hf by 2LLT square into 1 plus 1 by 20 LLT by ry, hf by tf whole square, right. This is the simplified equation which may be used in case of (())(14:26) member made of standard rolled section rolled I section and welded W symmetric I section. So to calculate the elastic lateral buckling moment Mcr, we can use this simplified formula, in case of (())(14:43) member made of standard rolled I sections and welded sections; however the Mcr for different beam section, considering loading support condition and non-symmetric section we can find out more accurately using the method given in annexure E of IS 800-2007. So in annexure E the details are given and more accurately we can find out the value of Mcr, see annexure E.

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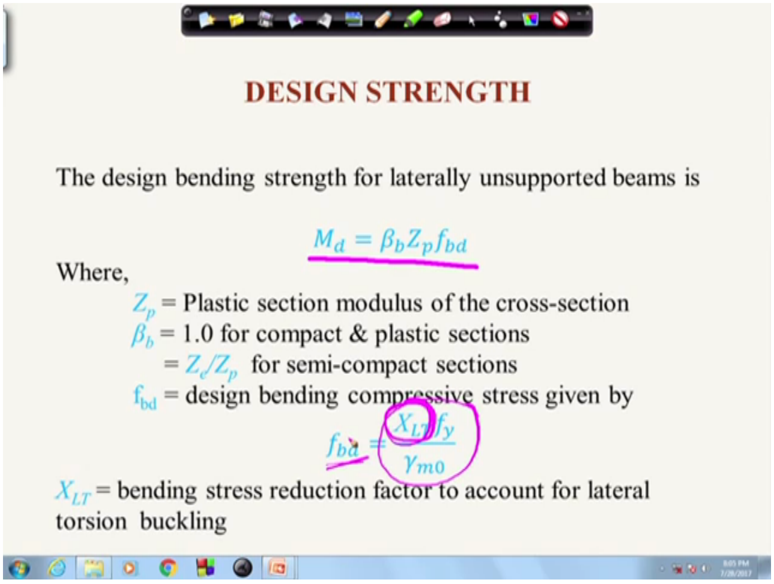

So the things whatever we have discussed, I am just quickly going through this power point that is first we can find out design strength. So the design strength for lateral torsional buckling has been calculated as per the codal permission and I am very quickly going through this formula, which I have written in hand. So you can see that first we have to find out, the design bending strength for laterally unsupported beam from this formula that is Md is equal to beta b Zp Fbd.

Now this Fbd we can find out from this, the design bending compressive stress that is XLT Fy by gamma m0. Now again I am repeating that this design bending compressive stress is reduced by this factor XLT. This XLT is called bending reduction factor bending stress reduction factor to account for lateral torsional buckling. So if lateral torsional buckling is present then this factor has to be multiplied to find out the design bending stress, right. So the our main job is to find out the XLT value.

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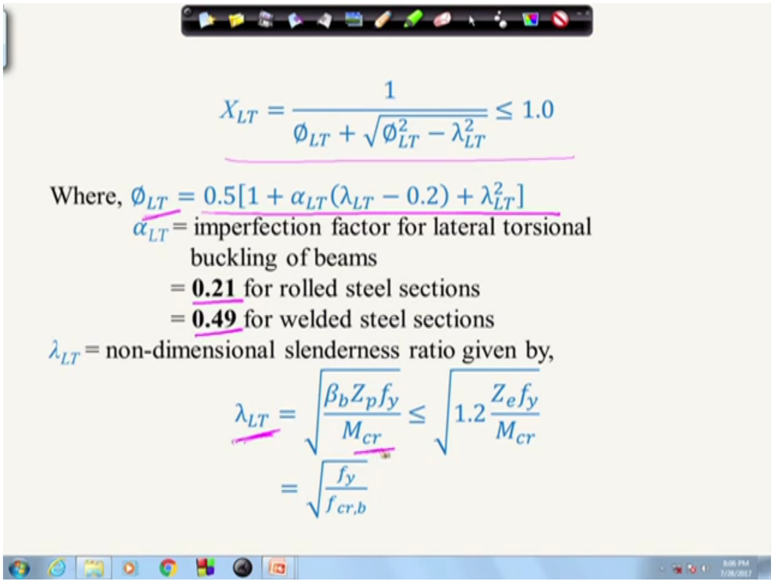

Now this XLT value can be found from this expression, right where Phi LT can be found from this expression and alpha is can be consider as 0.21 or 0.49. Then lambda LT the non-dimensional slenderness ratio we can find out from this, right. So the non-dimensional slenderness ratio can be found from this expression, so if we find the lambda LT value and if we know the alpha LT then we can find out the value of phi LT, but to find lambda LT we need to know Mcr value..

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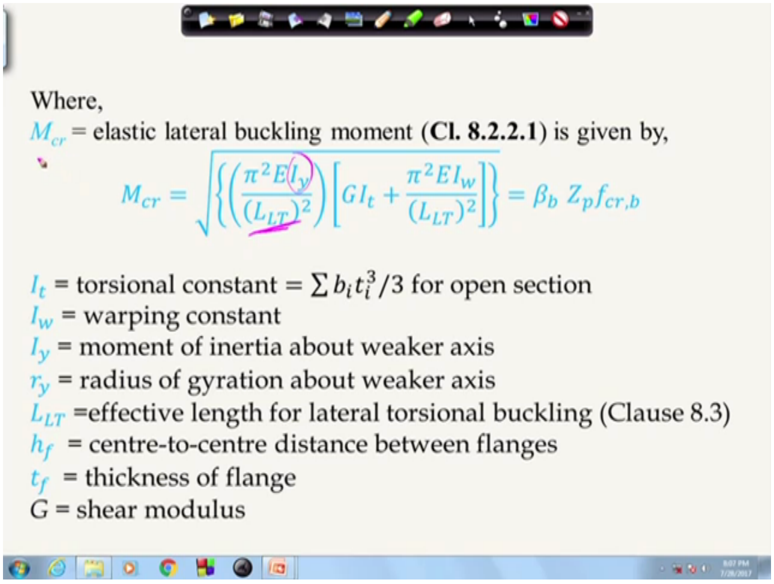

So our next step is to find out the value of Mcr, which is given through this expression Mcr. This is available in the code in clause 8.2.2.1 the details are given, so from that the value of Mcr can be found. Now where here the different parameters are defined like It the torsional constant are defined as summation bi ti cube by3 and Iw is a working constant, Iy is the moment of inertia about weaker section, ry is the radius of the eration about weaker section, LLt is the effective length for lateral torsional buckling and hf is a center center distance between flanges, tf is the thickness and G is the shear modulus.

So from these parameters, I can find out the value of Mcr and (())(18:24) to mention here that this elastic critical buckling moment depend on the few factors like one is LLT that is effective length of lateral torsional buckling then the shape of the section for which, the Iy value and other value will be dependent right. So depending on those factor finally we can find out the value of Mcr, okay.

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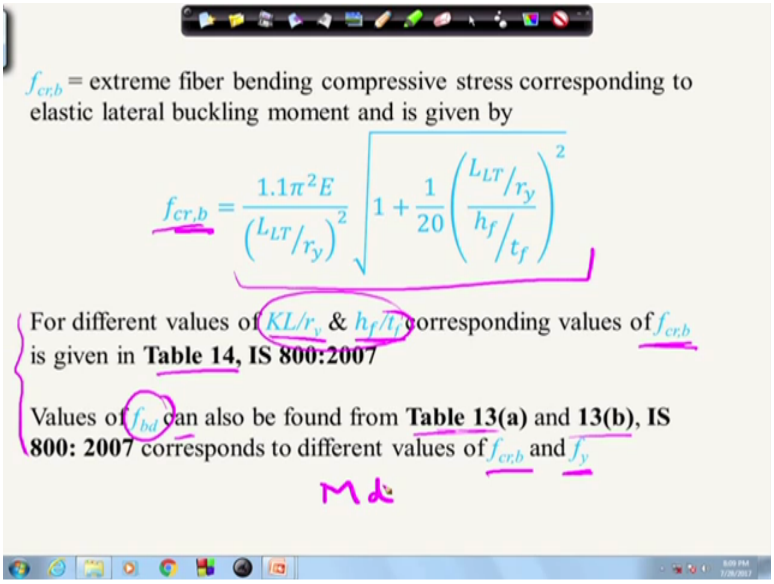

Also we can find out the Fcr,b value, which is the extreme fiber bending compressive stress corresponding to that elastic lateral buckling moment. So Fcr,b value also we can find out from this expression that is 1.1 pi square E by LLT by ry whole square into root over 1 plus 1 by 20 into LLT by ry by hf by tf whole square. So Fcr, b value can be found from this expression otherwise very quickly, we can find out the Fbd value from table, the code as made us, easy to find out the value of Fbd without calculating through that those expressions which are given. So what we can do? We can find out the value of KL by ry and hf by tf.

So once we find the KL by ry and hf by tf, we can find out the value of Fcrb, which is given in table 14. So in table 14 correspondings to these value we can find out the extreme fiber bending compressive stress Fcrb. So once we finds Fcrb value then corresponding to that Fcrb and Fy we can find out the design compressive bending stress. So design bending compressive stress Fbd can be found from this Fbd from table 13(a) or 13(b) depending on the type of means section, okay. So the Fbd value once we get we can find out the value of Md. So this is how we can find out the section, sorry bending moment.

So in today's lecture what we can see that due to unsupported uhh unsupported length of the member laterally unsupported length of the member. There is a chance of lateral torsional buckling if the member the cross section is not stocky in nature then lateral torsional buckling may play an important role and because of lateral torsional buckling before developing the full bending stress, the member may fail and therefore, we have to find out what is the lateral torsional buckling moment. So what we have done we have calculate the lateral torsional buckling moment.

Then we have found the extreme bending stress due to this lateral torsional buckling moment Fcrb and then we can find out the Fbd. So Fbd the design compressive bending stress is nothing but Fy by gamma m0 into some reduction factor, which is called XLT. So because of the presence of lateral torsional buckling of the section, the reduction factor has to be calculated, which is call XLT and once reduction factor is calculated then we can find out the design bending stress compressive design bending compressive stress and then from that we can find out the design bending moment. The design bending strength of the section, which is the section, which is laterally unsupported can be found in this way. So in next lecture, we will go through one example then the detail of the things will be clear. Thank you.