Advanced Design of Steel Structures
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Lecture - 55
LTB example problem

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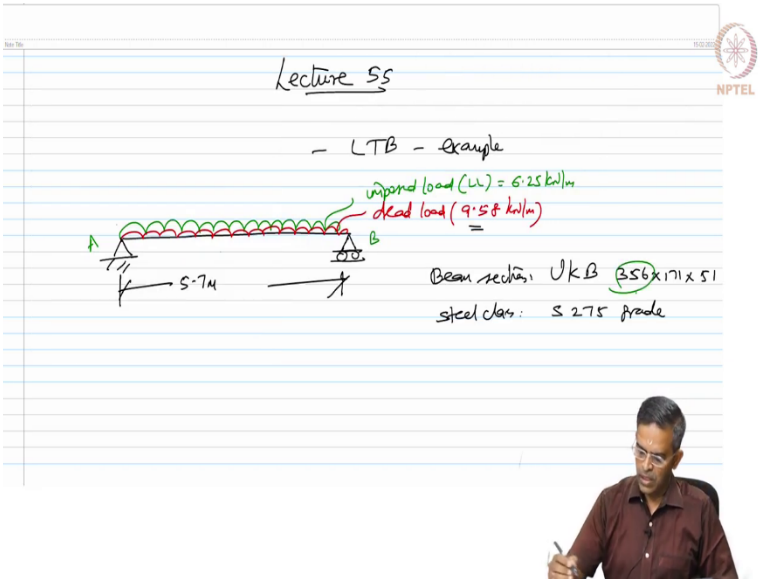

Friends, welcome to the lecture 55, where we are going to do an example problem for Lateral Torsional Buckling. We will take a simply supported beam for a span of 5.7 meters subjected to two kinds of loads. One load is a dead load, which is about 9.58 kilo newton per meter.

And over and above we have an impose load which is uniform distributed, and this is imposed load otherwise called as live load of intensity 6.25 kilo newton per meter. We will call this end as A, this end as B. Now, we are going to use a specific kind of trial beam section. The beam section what we chose is UK beam 356 by 171 by 51, which is S 275 grade.

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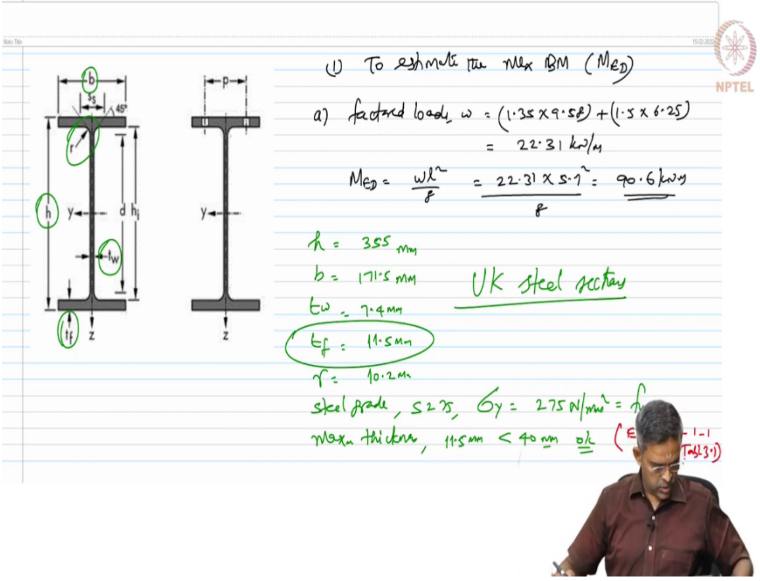

So, for the benefit of the users, let us show the cross section of the beam. This one the cross section of the UK beam 356, 171 and 51. Based on this, let us write down certain dimensions. Now, the first step is to estimate the maximum bending moment. We call this as M ED. Let us see what the factored loads w are, which is going to be 1.35 into 9.58; this value plus 1.5 into 6.25.

So, I am using a different factor for live load and dead load which is going to be 22.31 kilo newton per meter. So, I can quickly find out M ED as w l square by 8 because simply supported section. So, it is going to be 22.31 into 5.7 square by 8, which will give me 90.6 kilo newton meter, this is my demand.

Now, for the section shown on the screen the properties are like this; h is 355, that is why the section is called 356 355; b which you see here is 171.5. These are all millimeters friends; tw which you see here thickness of the web is 7.4 millimeter, tf thickness of the flange which you see here is 11.5 millimeters, r is 10.2 millimetre which is actually the radius of curvature being used for fabricating the ends of this rolled steel section.

These are available in the standard tables. They are referred as UK steel sections. Similar also available Indian code. We have Indian code sp 61 which will give you the section properties and so on. So, the steel grade which is being used is S 275, which means sigma Y is 275. Yield strength is 275 newton per mm square. We will use fy because that is a symbol used in Euro code.

Let us check quickly, what is the maximum thickness which is permitted for this kind of steel. The maximum thickness in the section available is 11.5. This is lesser than 40 that is a check, that is a check. So, this is according to I will write here this according to EN 1993-1-1 2005; table 3.1, that is what I have used.

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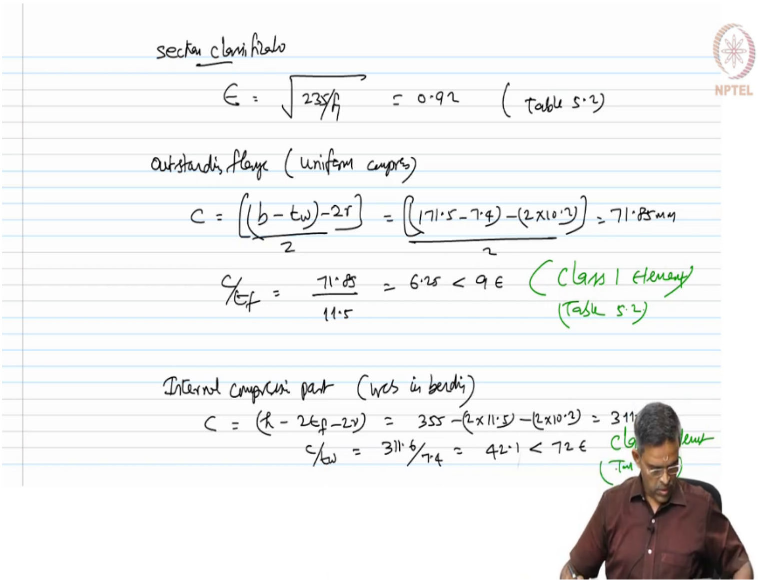

Now, let us come to section classification. Section classification depends on square root of 235 by f y which comes to 0.92. This is as per table 5.2, I am using the same code. Let us talk about the outstanding flange. The outstanding flange which is under uniform compression.

We will work out the c value is b minus t w minus 2r by 2, which will be b is 171.5, thickness of the web is 7.4 minus 2 times of 10.2, that is the radius given; divided by 2 which gives me 71.85 millimetres. So, a factor c by t f is 71.85 by 11.5 which is 6.25 which is less than 9 epsilon. So, this gives me that it is class 1 element. This is as per table 5.2 of the code. So, it is a class 1 element now.

Let us talk about the internal compression member. So, now, we are considering web in bending. Bending can also have compression, bending compression. Let us compute that for c is equal to h minus 2tr sorry 2tf minus 2r which is going to be 355 minus 2 times of 11.5 minus 2 times of 10.2 which gives me 311.6 millimetres. Now, c by t w which is 311.6 divided by 7.4 is 42.1 which is less than 72 epsilons, which also guarantees and classifies as class 1 element. This is as per table 5.2.

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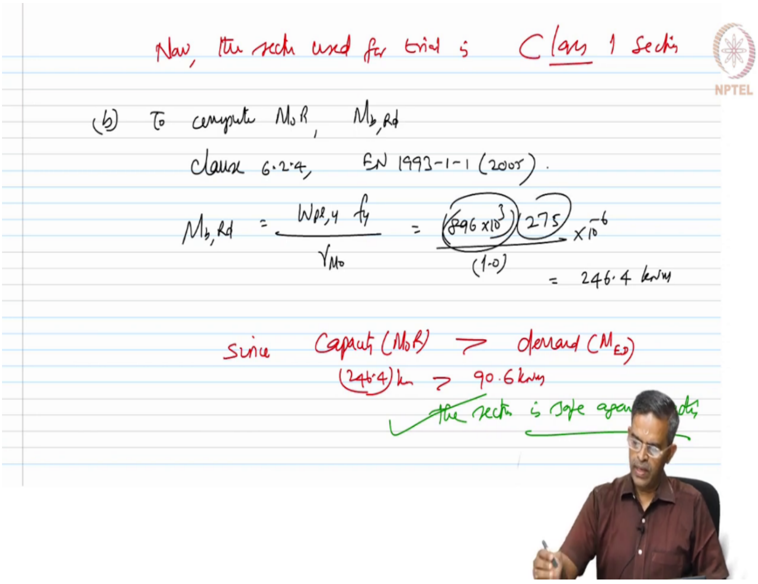

Having said this, we are now using; so, now, the section used for trial is class 1 section, we have we have clarified that. Now, let us do the second step which is to compute the moment of resistance which is M b R d. We will use class 6.2.4 of Euro code 1993-1-1 2005, according to this M b R d is given by W pl y into f y by γ M naught. So, we will say 896 is capital W, 275 is my yield strength. And γ m naught is taken as 1.0 to 10 power minus 6.

So, so many kilo newton meter which gives me 246.4 kilo newton meter. Now, friends please note, the capacity which is moment of resistance is higher than the demand, which is M, what we have used the symbol M ED. So, one can say. So, since that is 260 sorry 246.4 is greater than 90.6 kilo newton meter, we can say the section is safe against bending. We have checked it; we are now checking a trail section.

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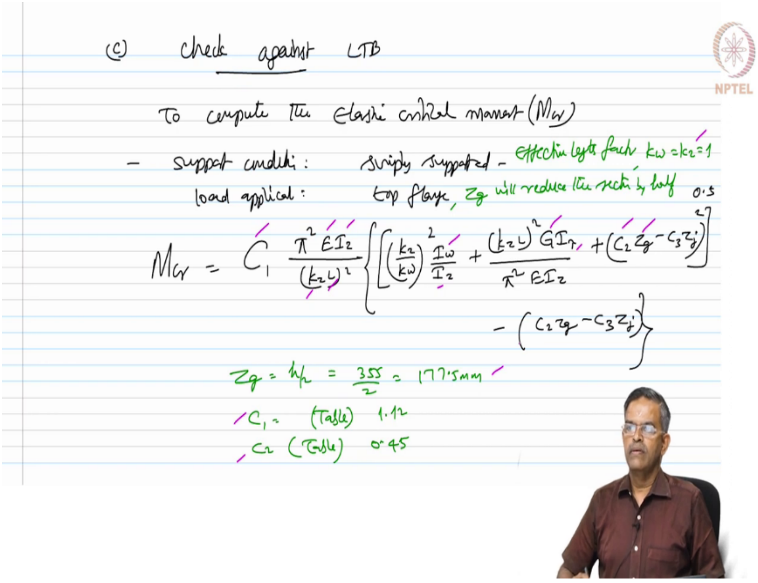

Now, let us check against LTB. So, to check against LSTB, LTB, we are going to check the elastic critical moment. Now, to compute the elastic; so, based on the support conditions and the loading applied at the top flange level. So, now, support conditions we should say simply supported, load application top flange. We can calculate M cr. We already derived this equation.

M cr is given by that is three parameter formula $C_1 \frac{\pi^2 EI_z}{(k_z L)^2}\left\{\left[\left(\frac{k_z}{k_w}\right)^2 \frac{I_w}{I_z} + \frac{(k_z L)^2 GI_\tau}{\pi^2 EI_z} + \left(C_2 Z_g - C_3 Z_j\right)^2\right]^{0.5} - \left(C_2 Z_g - C_3 Z_j\right)\right\}$. This equation only we wrote the previous lecture, please refer back. So, now we have to use the figures and tables.

So, the conditions are the beam is simply supported. Therefore, the effective length factor which is k w which is also equal to k z which is 1.0. Now, since the load is separated in top flange Z g will reduce the section by half. So, what does it mean? Z g will be actually h by 2, which is 355 by 2, which is 177.5 millimeters. C 1 from table which you already said is 1.12, C 2 from table is 0.45.

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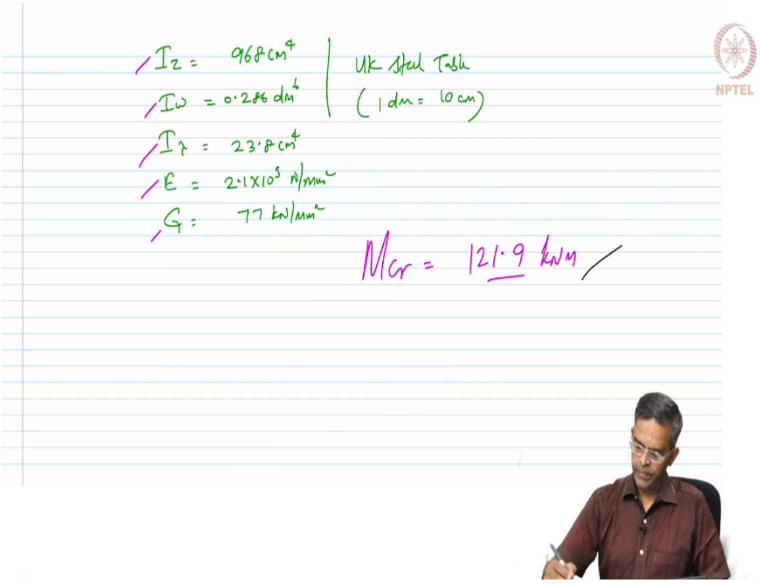

Then, from the table we will also know I z for the section which is 968 centimeter to power 4, I w is 0.286 d m to the power 6, this is given in UK steel tables. I am just taking the value directly from there. So, 1 decimeter is 10 centimetre. Let us have this connection here. I tau is 23.8 centimeter 4 and E of course, is 2.1 10 power 5 newton power square. And G is 77 kilo newton per m square.

Now, we know all the values. See here we wanted to know I am just checking we wanted to know E sorry C 1, we have E we have , I z we have k z, we have L of course, we have. I w we have, I z we have, G we have, I tau we have, Z g C 2 we have, Z g we have. So, you can compute these values directly and I will get M cr as 121.9 kilo newton meter,.

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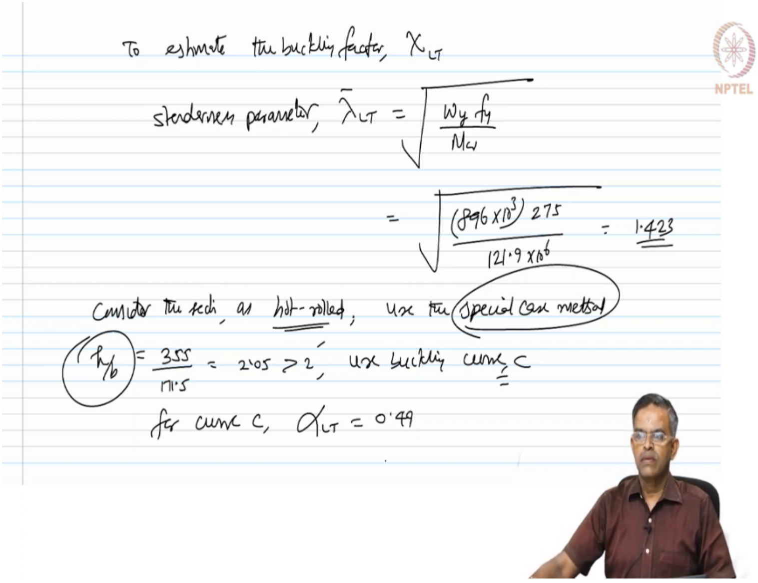

So, the next step is to estimate the buckling factor, which is psi LT. This depends on slenderness. So, slenderness parameter which is λ bar LT is given by square root of W y f y by M cr. We already have this value see here W y we have , f y we have, now M cr also we have. So, let us substitute that. It is going to be square root of 896 into 10 power 3 into 275 divided by 121.9 10 power 6. I get this value as 1.423, you can please check this.

So, now we consider this section as hot rolled. So, we will use this special case method. There are two methods by which we can do. So, we know from the table for h by b which is equal to 355 by 171.5 which is 2.05 greater than 2, we should use buckling curve C, am I right?

We have seen this in the last lecture. For rolled section for h by b more than 2, what buckling curve we should use? A special case method. Please refer to your notes. Now, from the buckling curve for curve C, we can directly find α LT as 0.49.

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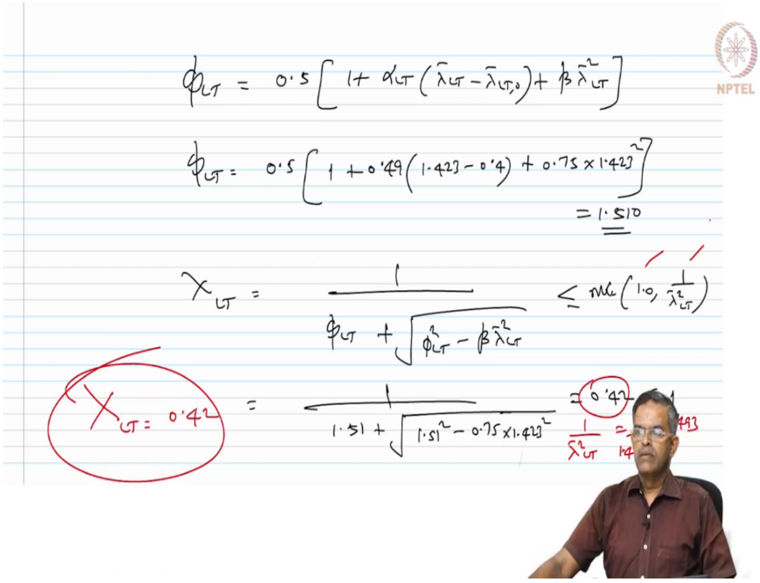

Then we can compute ϕ LT which is given by 0.5 times of 1 plus αLT times of λ bar LT minus λbar LT 0 plus beta λ bar square of LT. So, let us work out ϕLT in this case 0.5 times of 1 plus 0.49 1.423 minus 0.4 plus 0.75 1.423 square, which gives me 1.510. So, now, I can say psi LT is given by 1 by ϕ LT plus square ϕ square LT minus beta λ square LT. And which should be the minimum of 1.0 and 1 by λ square LT.

So, now I get psi LT as 1 by 1.51 plus square of 1.51 square minus 0.75, that is the beta value into 1.423 square, which comes to 0.42 which is less than 1 and also 1 by λ bar square LT is 1 by 1.423 square which is 0.493, right. So, the value what we got is 0.42. So, I can now say psi LT can be taken as 0.4. It satisfies both the conditions no.

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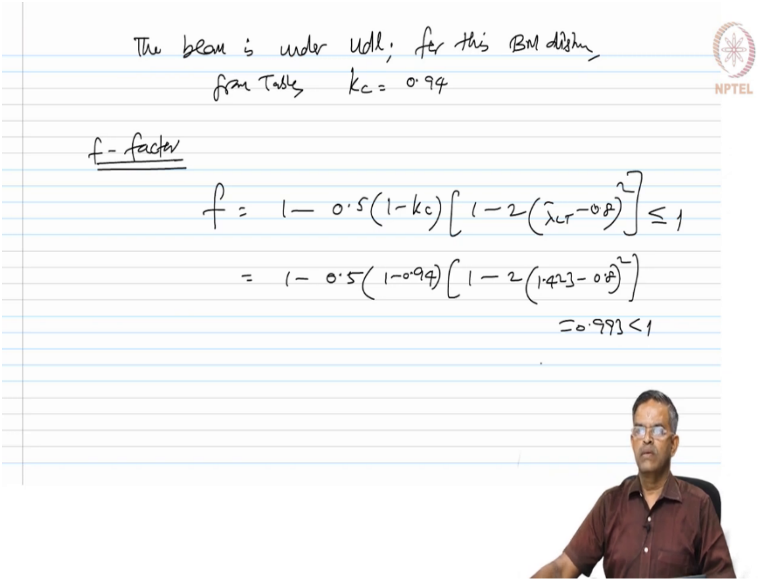

Now, we have the beam under uniform distributed load. So, for this load distribution or specifically, for this bending moment distribution, from the table which we discussed in the last lecture, I can find k c as 0.94. Please see the table. Now, I want to calculate the f factor because I am using the second method.

So, f factors required; f is given by 1 minus 0.5 times of 1 minus k c of 1 minus twice of λ bar LT minus 0.8 square should be less than or equal to 1. Let us check 1 minus 0.5 times of 1 minus 0.94 of 1 minus twice of 1.423 minus 0.8 the whole square, we get this value as 0.993 which is less than 1,. So, f factor is now computed.

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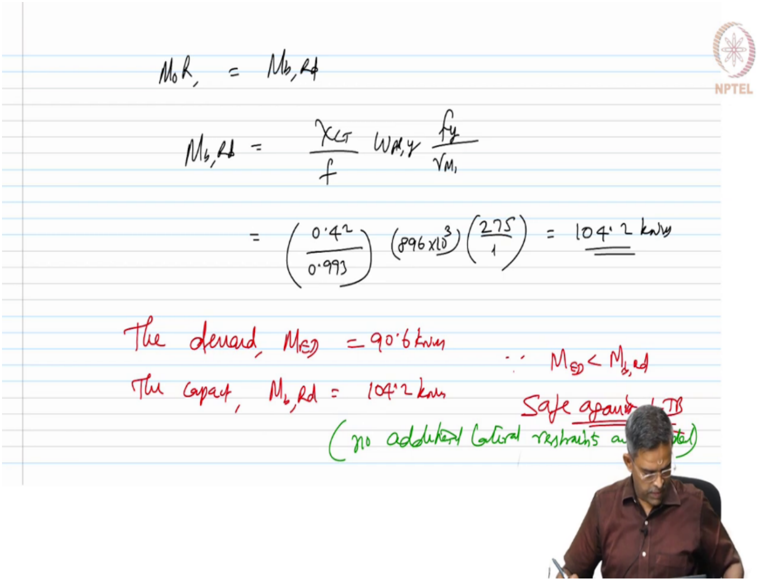

Therefore, we can then find the M o R which is actually M b of R d. M b of R d is given by psi LT by f W pl, y f y by γM 1. We will substitute. 0.42 that is psi LT, is it not? 0.42 f factor is 0.993 and W p is 896 10 power 3 into 275 by 1. We already said γ m is 1 for this kind of distribution. So, this value comes to be 104.2 kilo newton meter.

So, now the demand is M ED which is 90.6 kilo newton meter. The capacity M b, R d which is 104.2 kilo newton meter. Since the demand is lesser than the capacity, the beam is safe against lateral torsional buckling. So, we are just checking whether the beam is safe. So, what is the comment here? No additional lateral restraints are required. Otherwise, you have got to provide lateral restraints as we discussed in the previous lectures.

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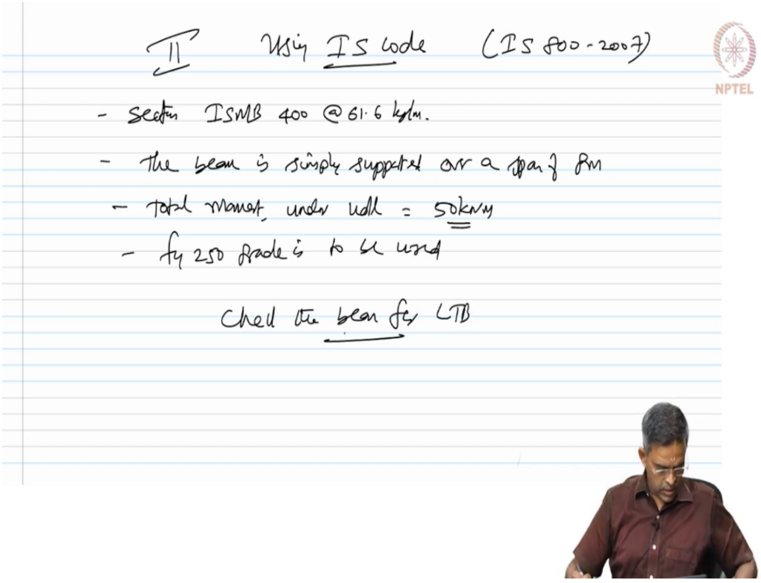

Let us solve the same problem using IS code. We are using IS 800-2007, that is the steel design code by checking the section. So, we will take the section as ISMB 400 at 61.6 kg per meter. So, let us say the beam is simply supported over a span of 8 meters. The total moment under uniform distributed load is 50 kilo newton meter, f y 250 grade is to be used. So, check the beam for lateral torsional buckling that is the question asked. Let us do that.

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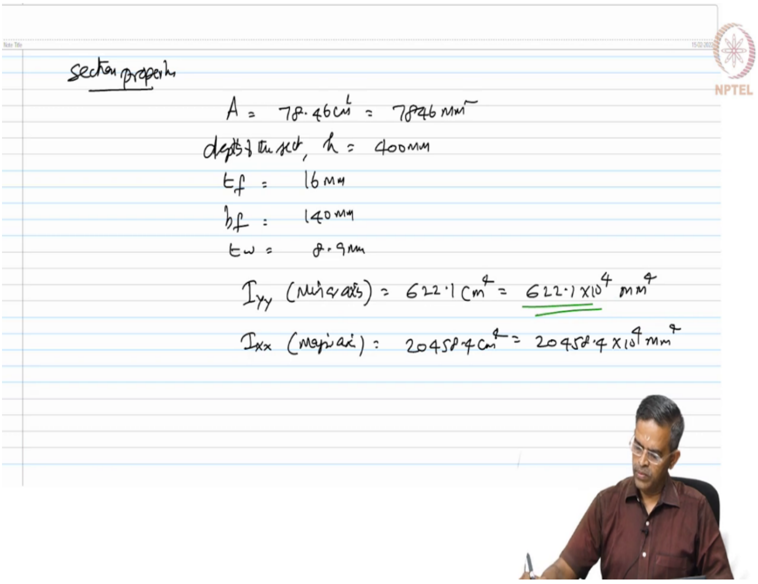

Let us first see the section properties. Area of the cross section which is 78.46 centimeter square which is 7846 millimeter square, depth of the section h 400 mm, thickness of the flange 16 mm, breadth of the flange 140 mm, thickness of the web 8.9 mm. This can be seen from steel tables,. Moment of inertia about the minor axis also given in the table which is 622.1 centimeter 4 which is 622.1 10 power 4 mm. I xx which is about the major axis which is 20458.4 which is 20458.4 into 10 power 4 mm 4.

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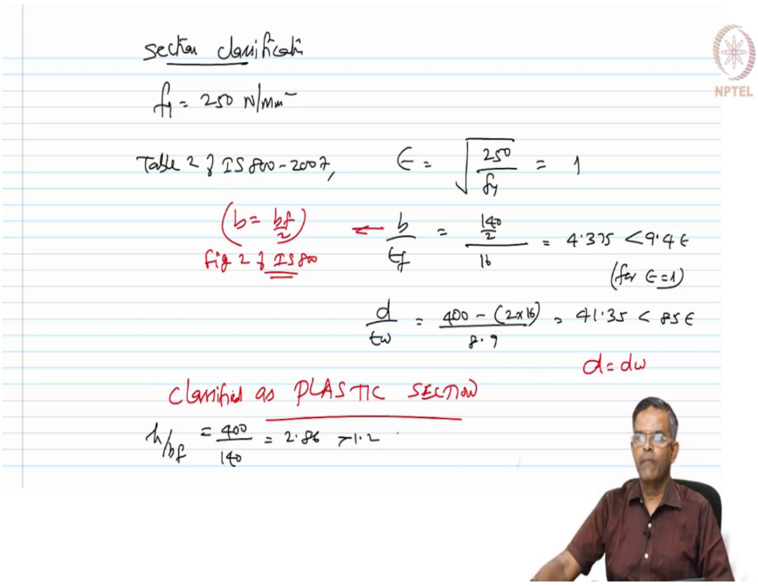

Then we will do the section classification. The first step is section properties, we know f y is 250 newton per meter square. Let us look into table 2 of IS 800 2007. So, epsilon is given by square root of 250 by f y which is equal to 1 and b by t f in our case is going to be over an. So, 140 by 2 divided by 16 which is 4.375 less than 9.4 epsilon 4 epsilon equal to 1,. And d by t w which is 400 minus 2 into 16 divided by 8.9, which is 41.35 which is less than 85 epsilon,.

So, friends in this equation if you note this b actually is b f by 2. Look at figure 2 of IS 800. And of course, d is d w, only the web. So, now, based on these data we can classify the section as , classify as plastic section. Furthermore, h by b f is 400 by 140 which is 2.86 greater than 1.2 and t f is 16 mm less than 40 mm.

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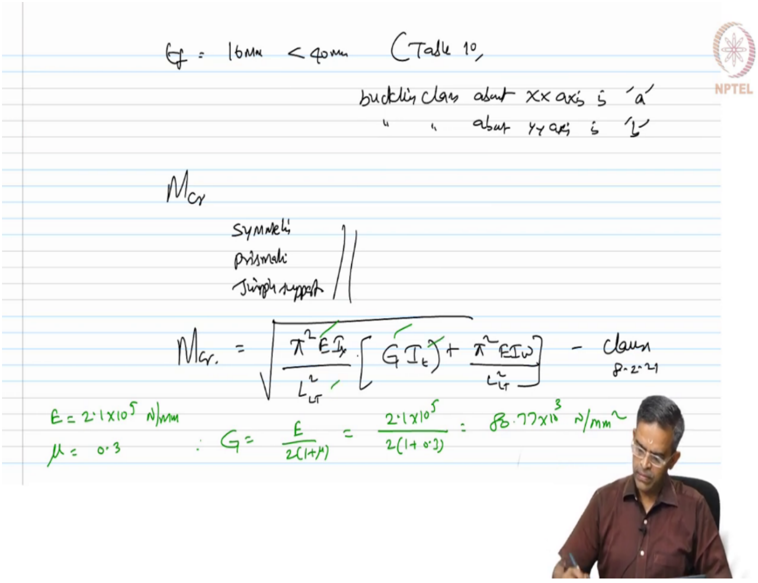

So, from Table 10 of the code buckling class about XX axis is a and buckling class about YY axis is b. So, then the next step is to find out M cr that is elastic lateral buckling moment. Now, the section is symmetric. It is prismatic and it is simply supported , because we should have the bending moment distribution also these are the conditions.

For these conditions, M cr is given by square root of pi square E I y by L LT square of G I tau plus pi square E I w by L LT square. This is as per class 8.2.2 2.21, sorry. So, in this let us substitute the values. E is 2.1 10 power 5. So, we have E mu is 0.3, therefore, G is E by twice of 1 plus mu which gives me 2.1 10 power 5 by twice of 1 plus 0.3. I get this value as 80.77 10 power 3,. So, I have G, I y already we have. Let us see what is I y 622.1.

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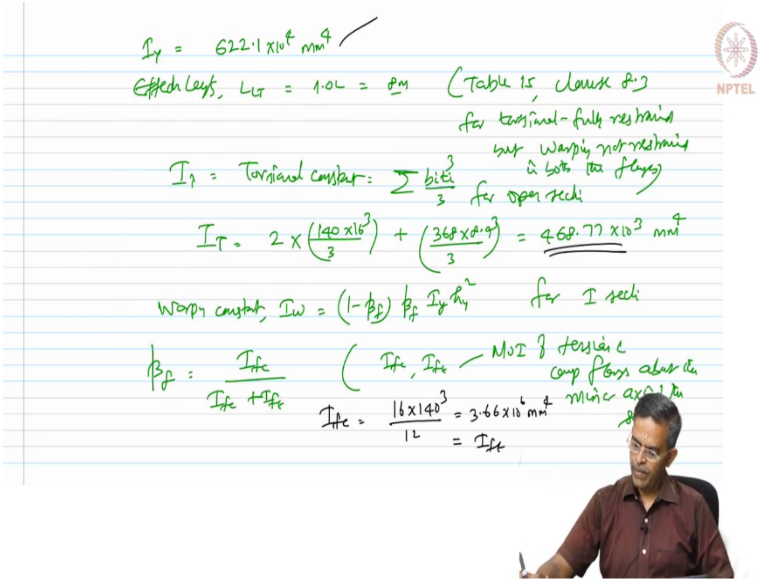

So, I y we have, 622.1 10 power 4. Effective length which is L LT, is 1 point L which is 8 meters. So, this is according to table 15 class 8.3 for torsional fully restrained, but warping not restrained in both the flanges. For this condition you have taken this effectively. So, I tau torsional constant which is summation of bi ti cube by 3, this is for open sections.

So, let us find out for our problem, I tau twice of 140 into 16 cube by 3 plus 368 into 8.9 cube by 3 , which comes to be 468.77 10 power 3 mm 4, warping constant. So, let say I tau we have, L LT we have, we want to find I w. So, warping constant I w is 1 minus beta f beta f I y h y square, this is for I sections.

So, now what is beta f? Beta f is I fc by I fc plus I ft where I fc and I ft are moment of inertia of tension and compression flanges about the minor axis of the section. Let us compute I fc that is very easy. So, I fc about minor axis. So, p t cube by 12, I can now say this is going to be 3.66 10 power 6 mm 4. So, we have the same as I ft tension and compression flange is minor axis moment of inertia is same,.

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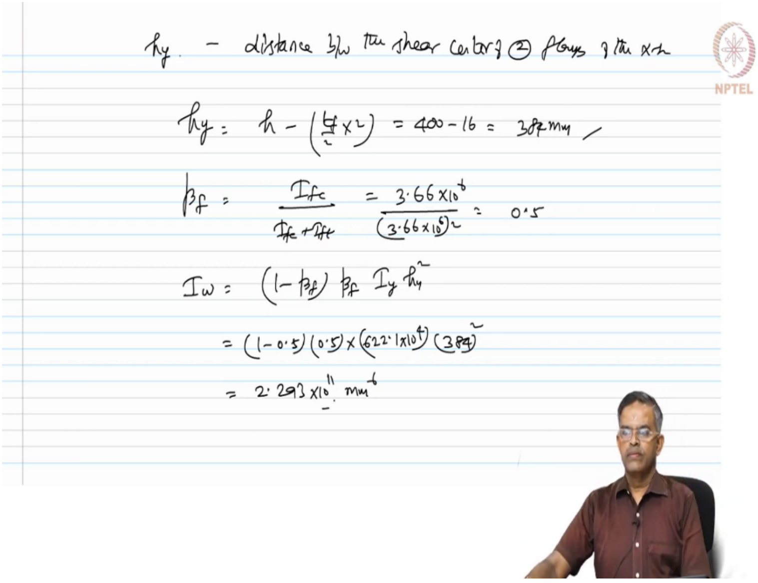

Having said this, let us now find what is h y which is actually the distance between the shear center of two flanges of the cross section. So, h y in my problem will be h minus t f by 2 into 2 which will be 400 minus 16 which is 384, beta f which is I fc by I fc plus I ft which 3.66 10 power 6 by 3.66 10 power 6 into 2 which is 0.5.

Now, let us work out I w which is given by 1 minus beta f beta f I y h y square. Let us substitute them. 1 minus 0.5, 0.5 I y 621.1 that is here, 622.1 10 power 4, h y is here 384 square which gives me the value as 2.293 into 10 power 11 mm 6,. Now, I can find M cr.

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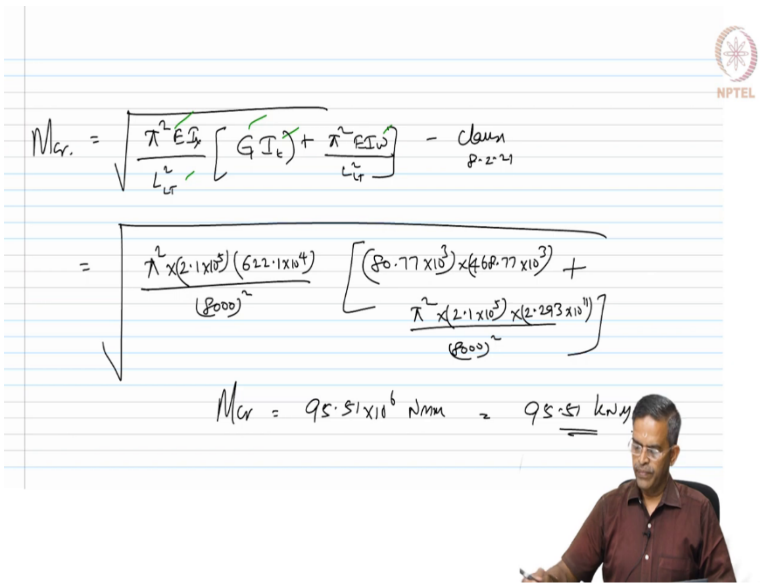

M cr let us copy this equation of M cr back again is given by this equation. Let us substitute which will be equal to square root of pi square 2.1 10 power 5 that is my E value, I is 622.1 10 power 4. This is 8000 square. I am doing it in millimetres, in newtons. Then 80.77 10 power that is my G value see here , that is my G value I tau is 468.77 10 power 3 that is my tau value plus pi square 2.1 10 power 5.

I warping constant we already have it here 2.293 , divided by 8000 square. So, I get M cr as 95.51 into 10 power 6 newton mm which will become 95.51 kilo newton meter,.

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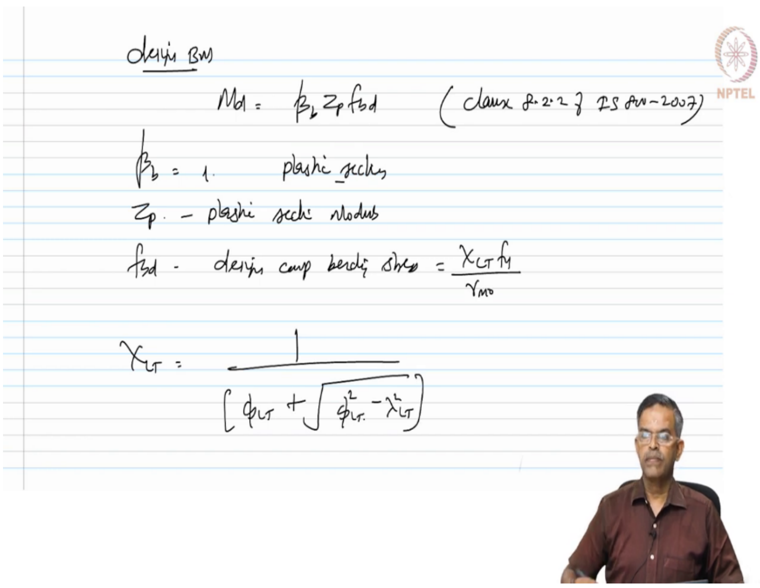

Now, let us compute the design bending moment. The design bending moment is M d which is beta b Z p f bd. This is as per class 8.2.2 of IS 800. So, what is beta b? Which is 1 for plastic sections. We already declared this the plastic section. What is Z p? Is the plastic section modulus, and f bd? Is a design compressive bending stress which is actually equal to psi LT f y by γ m naught. So, let us say what is psi LT, we already know this ϕ LT plus ϕ LT square minus λ square LT,.

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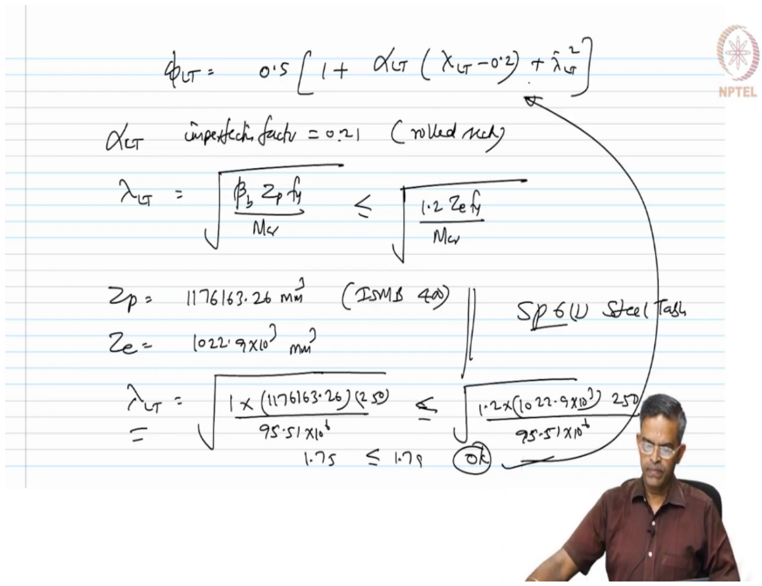

Φ LT is 0.5 times of 1 plus α LT into psi LT minus 0.2 plus α bar LT square α LT is the imperfection factor which is 0.21 for rolled sections given in the code. Let us calculate λ LT which is actually equal to square root of beta b Z p f y by M cr which is less than or equal to square root of 1.2 Z e f y by M cr. So, let us say what is Z p; 1176163.26. This is for ISMB 400 Z ce is 1022.9 10 power 3 mm cube,.

We can refer these values from SP 6 1 steel tables. So, now, α λ LT will be 1 into 1176163.26 into 250 by 95.51 10 power 6 which will become which should be less than or equal to 1.2 times of 1022.9 10 power 3 of 250 by 95.51 10 power 6. So, now we get this value as 1.79 less than or equal to one point this is 75 79. So, it is ,. Once I have this value we can substitute back in ϕ LT and cut ϕ LT, let us do that.

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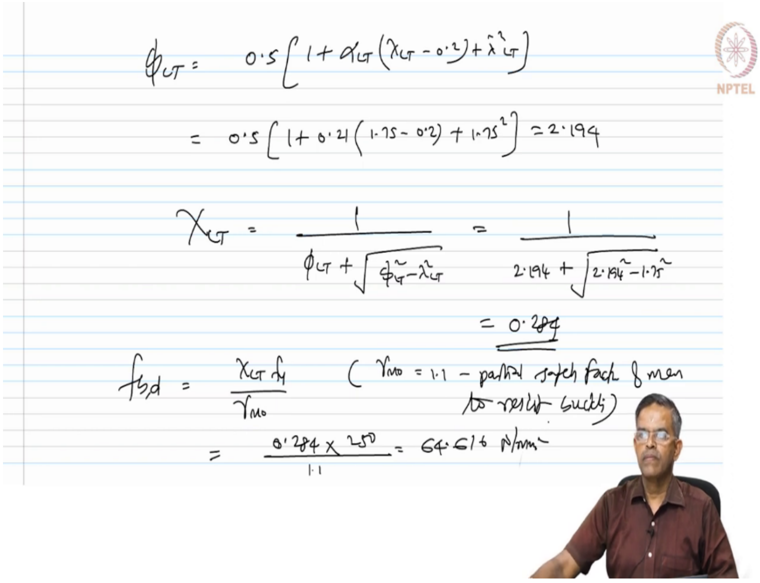

So, therefore, ϕ LT is going to be 0.5 times of 1 plus LT LT minus 0.2 plus λ bar square LT which will be 0.5 1 plus 0.21 that is what my α LT is 0.21 into 1.75 minus 0.2 plus 1.75 square , which comes to 2.194. So, now can calculate this value as 1 by ϕ LT plus ϕ LT square minus λ square which will be 1 by 2.194 plus 2.194 square minus 1.75 square which comes to 0.284. Now f bd bending stress in compression is LT fy by γ M naught.

Now, γ M naught is equal to 1.1 which is the partial safety factor of member to resist buckling. So, let us substitute that which will become 0.284 into 250 by 1.1 which comes 64.616.

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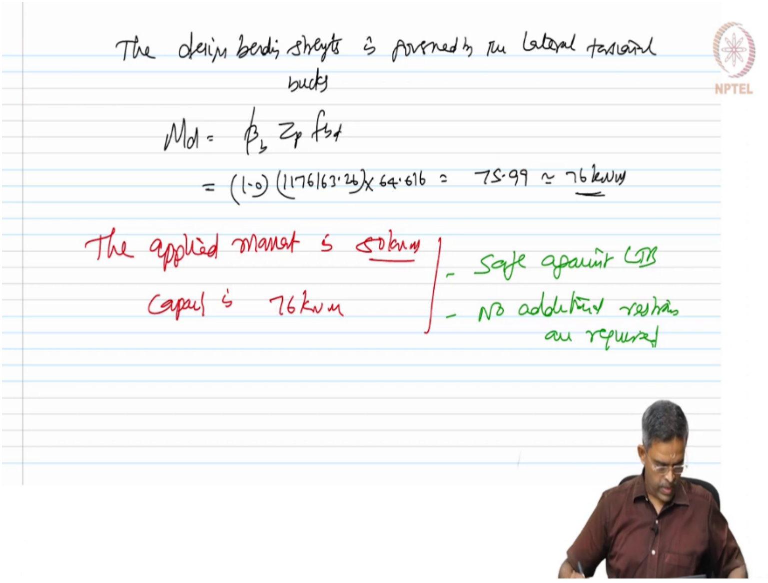

So, now the design bending strength is governed by the lateral torsional buckling. So, M d is beta b Z p f bd which is 1.0 1176163.26 into 64.616 which is 75.99 or 76 kilo newton meter,. The applied moment is 50 kilo newton meter, the capacity is 76 kilo meter. Therefore, we can say the beam is safe against lateral torsional buckling no additional restraints are required,.

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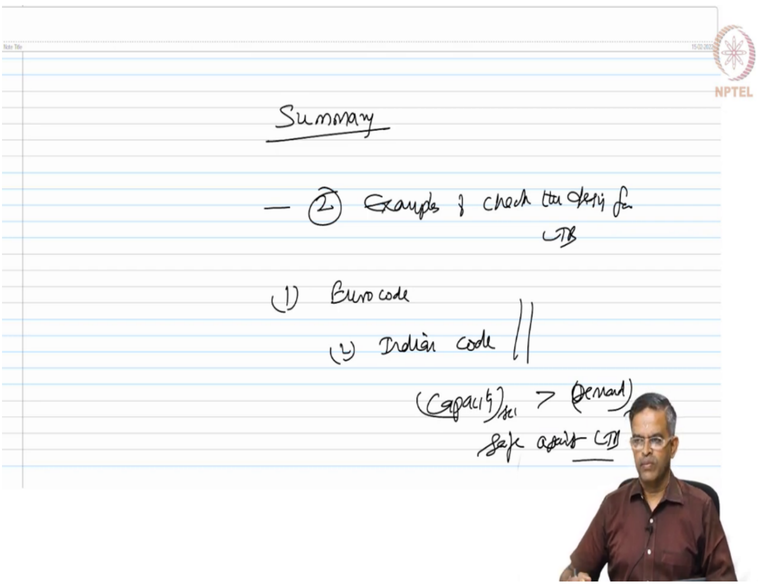

So, friends, in this lecture, we learnt two examples of checking the design for lateral torsion work. 1, we did the Euro code, 2nd one we did with Indian code. In both the cases, since the capacity of the section is larger than the demand of the section. So, we declare they are safe against LTB.

So, the procedure is very straight forward. It is well illustrated in both the course, equations and supporting tables are available to you. So, only I got to practice more number of problems. So, take some sample sections, work it out and see whether the chosen section is safe against lateral torsional buckling,.

Thank you very much and have a good day.