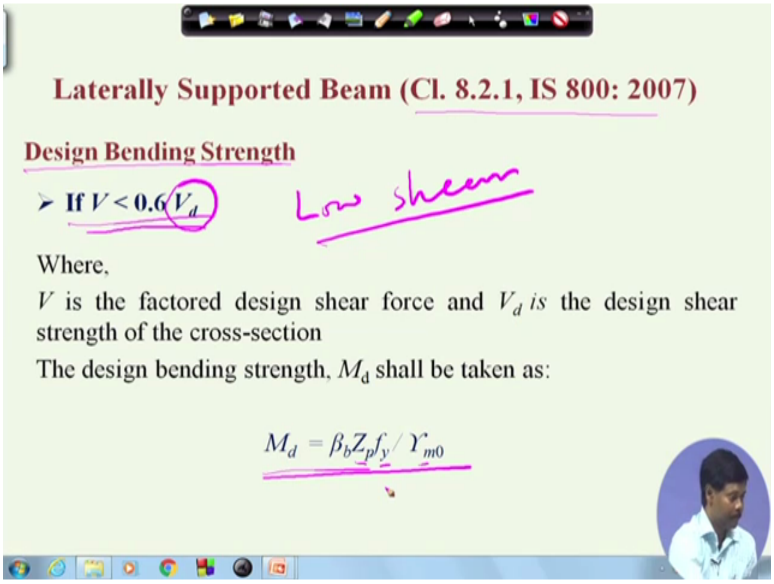
Course on Design of Steel Structures
Prof. Damodar Maity
Department of Civil Engineering
Indian Institute of Technology Kharagpur
Mod 10 Lecture 47
Laterally Supported Beams

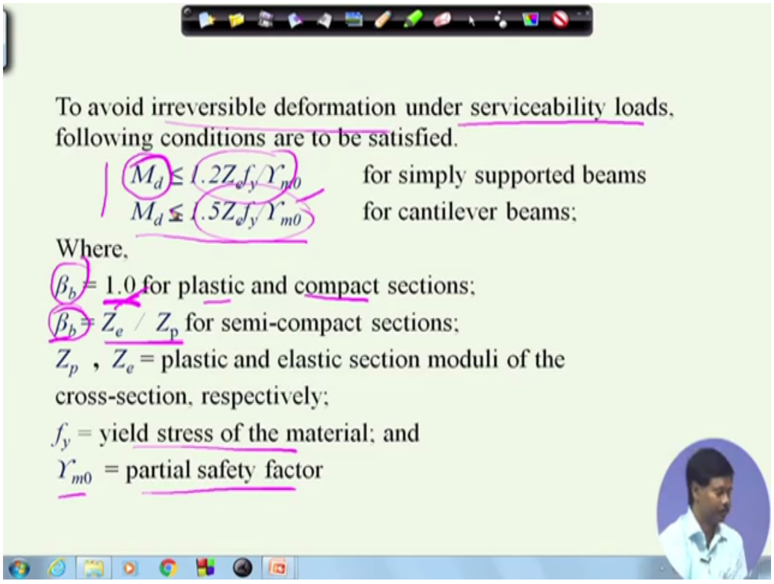
Today, I am going to discuss about the design procedure of the lateral supported beam. So beam will be designed on the basis of laterally supported or laterally unsupported. So today we will discuss only about the laterally supported beam where, its web will be supported laterally so that the lateral torsional buckling may be prevented.

(Refer Slide Time: 2:14)



So in this case we are assuming that lateral torsional buckling is prevented and with this what will be the design criteria that will be discussed and that is given in clause 8.2.1 of IS 800-2007, the detail has been discussed where the design bending strength can be calculated in two cases, one is for low shear another is for high shear. Low shear means when the shear force is less than the 0.6 time that design shear strength then it is called low shear, that means if Vd is a design shear strength of the cross section then uhh if V less than 0.6 Vd then we can called as low shear that means shear force is less. So in case of low shear we can find out the design bending strength simply by from this formula that is Md is equal to beta b into Zp Fy by gamma m0, right.

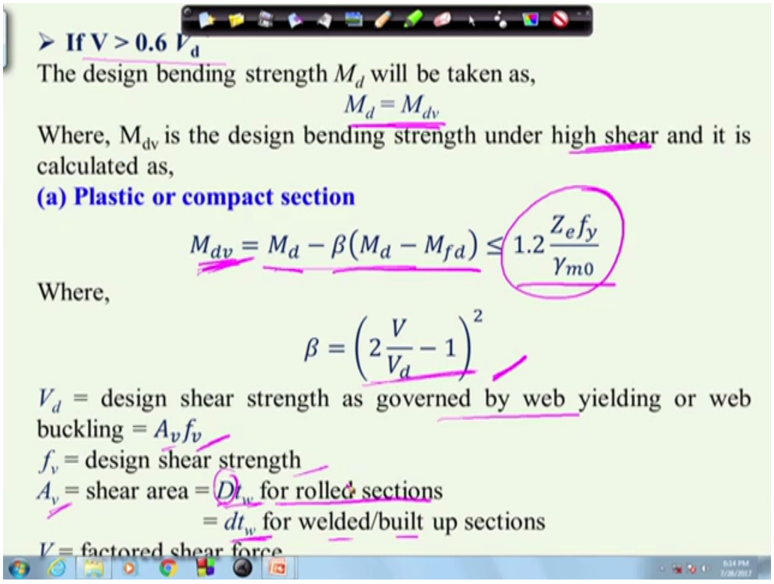
(Refer Slide Time: 4:54)



Md is equal to beta b into Zp into Fy by gamma m0 where Md is the design bending strength and beta b we can consider as 1 for plastic and compact sections, for plastic and compact section is value beta b can be consider as 1 and for semi-compact section, we can consider Ze by Zp as the beta b value right where Ze is the elastic section modulus and Zp is the plastic section modulus. So the ratio of Ze by Zp can be found as beta b and for semi compact section, this beta b value will be calculated and will be used and for plastic or compact section beta b value will be consider simply 1and whether the section is plastic or compact or semi-compact that will be decided from the codal permissions, because from the thickness of the web and width of the sorry, depth of the web and other criteria like flange, thickness flange width etcetera, we can find out whether a section is compact, plastic or semi-compact from the code and from that basis we can find out the beta b value, right and Fy is the yield stress of the material and gamma m0 is the partial safety factor.

So Fy can be found for different material to the the yield stress value will be different which also we can found from the code and gamma m0 is the partial safety factor which is found in table 5, right and to avoid irreversible deformation under serviceability loads, we have to maintain these condition, like for simply supported beam Md should be less than 1.2 into Ze Fy by gamma m0, so Md value whatever you have calculated there, in any case it should be less than this value that means the Md value calculated at there, if it is more than this then we will take this value Md. So Md is 1.2 into Ze Fy by gamma m0 for simply supported beam and for cantilever beam we can consider Md as uhh 1.5Ze Fy by gamma m0, so Md value should be less than this or this depending on the support condition.

(Refer Slide Time: 7:54)

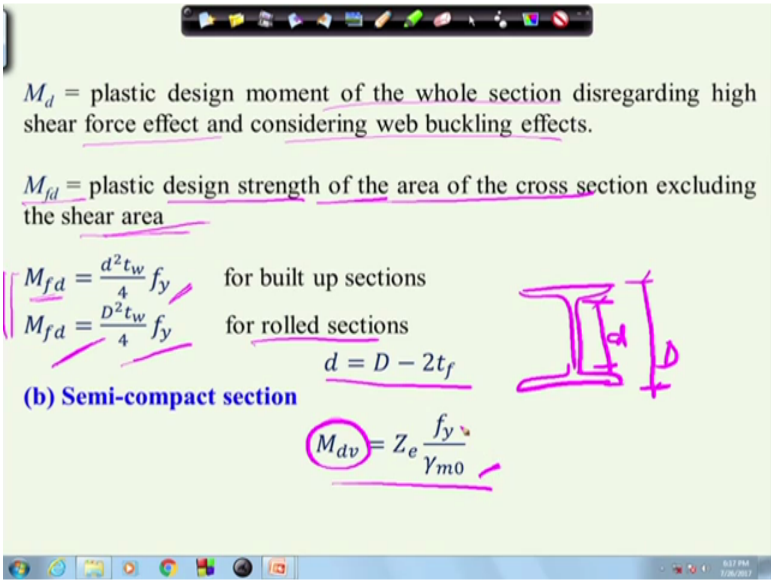


So once we find the value of Md then we can go ahead for next; however if we see that the shear force is more than the 0.6 times design shear strength of the beam section then we can use this formula that is Md will be equal to Mdv where Mdv can be calculated from this. So when the section is under high shear that means when the beam is under high shear that means when V greater than 0.6Vd then the design bending strength can be calculated as Md is equal to Mdv, where Mdv is a design bending strength under high shear and it can calculated as Mdv as like this and it can be calculated for plastic or compact section from this formula. If the section is plastic or compact then we can find the Mdv value as Md minus beta into Md minus Mfd, right and in any case, it should be less than or equal to 1.2 Ze Fy by gamma m0.

So you have to consider this criteria, it has to be less than this and Mdv can be calculated from this, where beta is this beta is 2 into V by Vd minus 1 whole square. So beta is a coefficient, which can be calculated from this formula and then we can find out the value of Mdv, right and here, Vd the design shear strength can be calculated as governed by the web yielding or web buckling and Vd is simply Av into Fv where Av is a shear area and Fv is a design shear strength.

So Av is the design shear uhh shear area can be calculated as D into tw for rolled section where D is the overall depth, tw is the thickness of web and d into tw for welded or built up sections where tw is a thickness and d is a effective depth, right. Here remember (the) for rolled section, this capital D is the overall depth, right. So Av can be calculated as D into tw for rolled section and small d into tw for welded or built up sections and Fv is design shear strength and v is the factor shear force, which we can calculate from the loading condition and from boundary conditions, right.

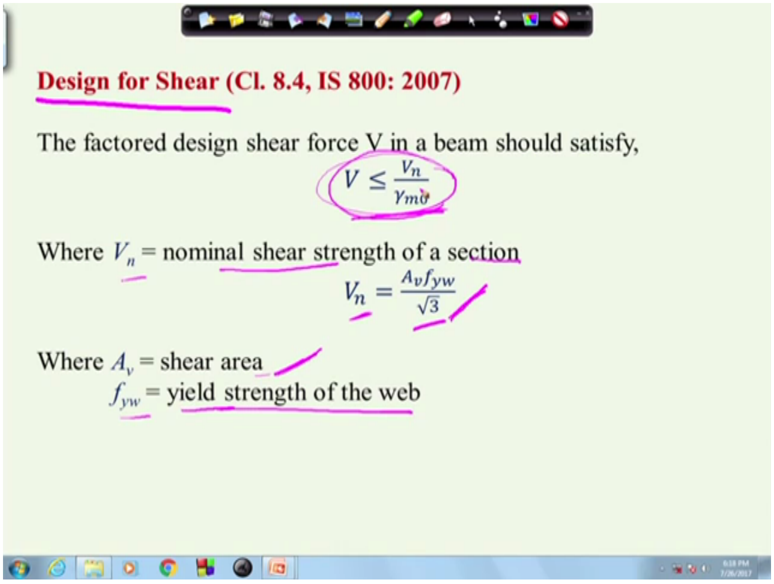
(Refer Slide Time: 10:15)



So once we calculate V and Vd then we can find out the value of beta and then we can find out the value of Mdv, right. So Md is a plastic design moment of the whole section disregarding high shear force effect and considering web buckling effect. So Md already we have calculated as a plastic design moment of the whole section uhh where we are not going to consider the shear force effect and Mfd is the plastic design strength which can be calculated from this formula Mfd, Mfd is a plastic design strength of the area of the cross section excluding the shear area, right.

So in case of a section we have to find out the Mfd value which is called plastic design strength of the area of the cross section excluding shear area. So Mfd value we can find out as D square tw by 4 gamma into Fy for built up section, right and Mfd is equal to capital D square tw by 4 Fy for rolled section where D is overall depth and small d the effective depth that capital D minus 2tf that means if we have a section like this then we can find out this is as capital D and this is as small d which is capital D minus 2tf, right. So Mfd can be found from this formula depending on the type of sections and then we can find out the Md value and then Mdv and for semi-compact section simply we can find out the value as Ze into Fy by gamma m0. So for semi-compact section with high shear the Mdv value can be calculated from this formula which is called Ze Fy by gamma m0, right.

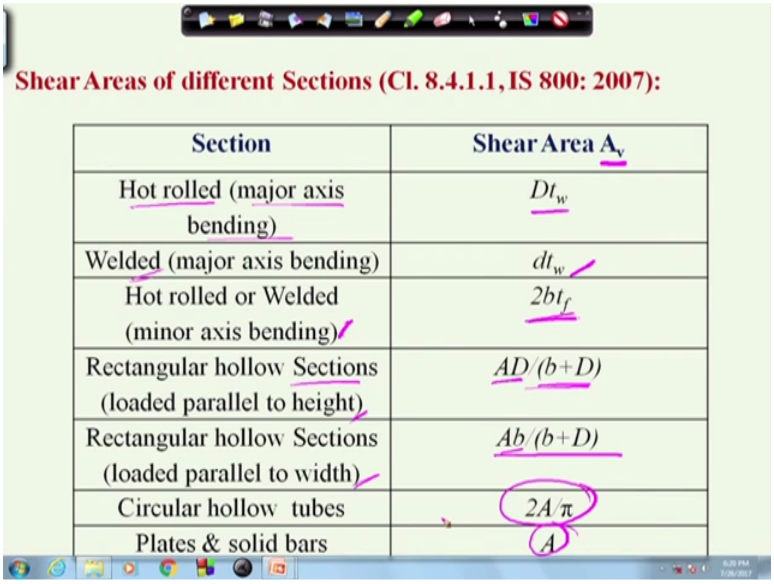
(Refer Slide Time: 11:35)



So after designing the shear bending then we will go for shear right. So regarding (()(10:29) shear uhh clause 8.4 describes the criteria. In clause 8.4, it says that the factored design shear force should be less than the nominal shear force by gamma m0, Vn by gamma m0, right. So V the factor design shear force should be less than or equal to Vn by gamma m0, where Vn is the nominal shear strength of a section and Vn value can be found from this formula Av fyw by root 3, Av is equal to shear area and we have shown how to calculated shear area and fyw is the yield strength of the web, right.

So, Vn the nominal shear strength of a section can be calculated from this formula where Vn is equal to Av into Fyw by root 3, where Fyw is a yield strength of the web and Av is the shear area and the factor design shear force V should be less than or equal to Vn by gamma m0.

(Refer Slide Time: 13:31)



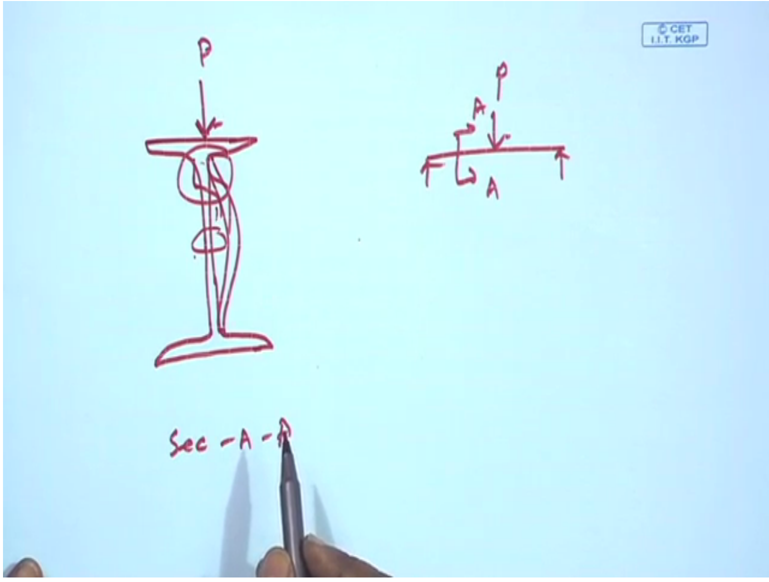
Shear Areas of different Sections (Cl. 8.4.1.1, IS 800: 2007):

Section	Shear Area A_v
Hot rolled (major axis bending)	Dt_w
Welded (major axis bending)	dt_w
Hot rolled or Welded (minor axis bending)	$2bt_f$
Rectangular hollow Sections (loaded parallel to height)	$AD/(b+D)$
Rectangular hollow Sections (loaded parallel to width)	$Ab/(b+D)$
Circular hollow tubes	$2A/\pi$
Plates & solid bars	A

Now shear areas can be calculated as given in clause 8.4.1.1, where it is told that the shear area Av can be calculated for different type of sections like for hot rolled section, if major axis bending is happening then this is D into tw, D is a overall depth and for major axis bending for welded section, it will be small d into tw for welded section and similarly, for hot rolled or welded section about minor axis, it will be 2 into b into tf, because the flange is in two side. So 2 into V into tf right.

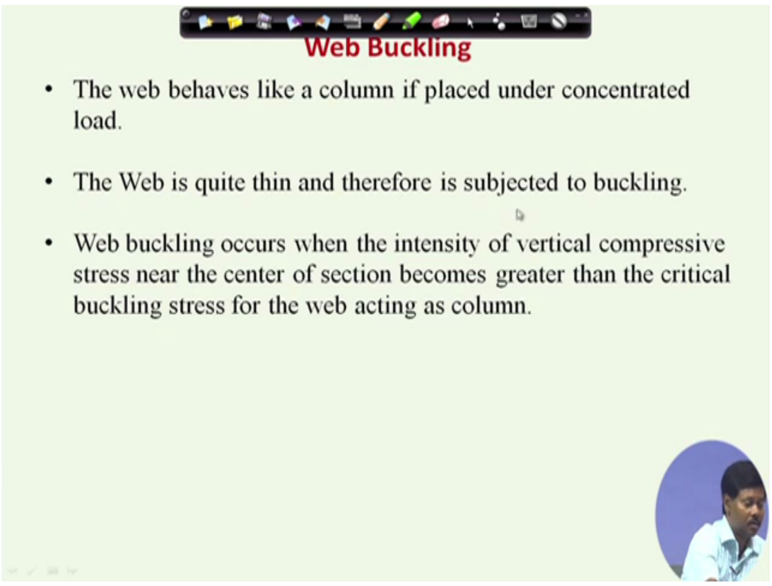
So for hot rolled or welded sections about minor axis bending the shear is a there will be 2 into b into tf. Similarly, the rectangular hollow section loaded parallel to high will be this, A into D by b plus D, D is the total depth and A is the shear area and rectangular hollow sections loaded with or loaded parallel to width will be A small b by b plus D. So one is A capital D by b plus D, another is A small b by B plus D and for circular hollow section, it will be 2A by pi and for plates and bars it will be A, A is a cross sectional area. So this is how the shear area of a section can be calculated, which has been given in clause 8.4.1.1 from which we can calculate the shear area Av.

(Refer Slide Time: 14:59)



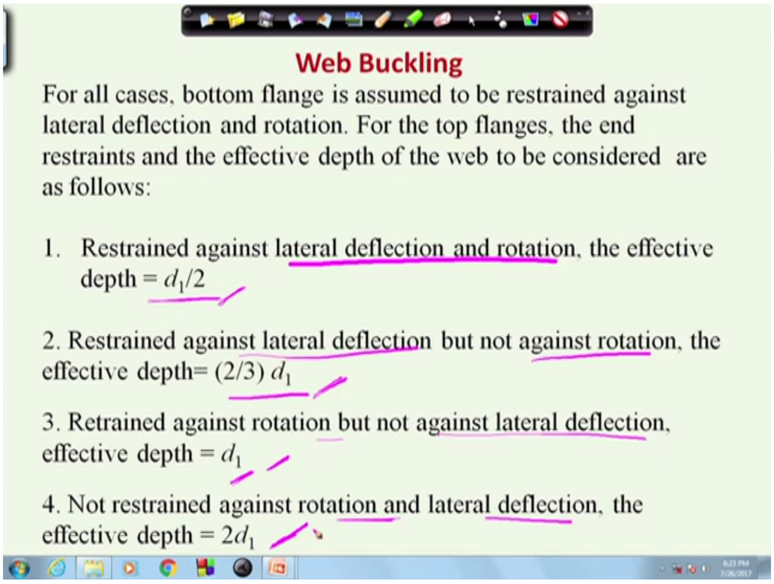
Then coming to web buckling, so now for web buckling we can see that the web behaves like a column if placed under concentrated load that means uhh if we have uhh I sections say for example, here then if we have a concentrate load say, this is a beam and if we cut this section, so this is section A-A right. So if we see, now because of the concentrated load on the web at a particular point, so this may buckle depending on the type of member it will buckle. So if the web is thin then it will come to buckling or sometimes it may cripple also, it may cripple because of the concentrated load. So we have to avoid this buckling and crippling we will come in detail, how to restrict this web buckling and web crippling.

(Refer Slide Time: 15:24)



So as the web behaves like a column, therefore the web strength we have to calculate the strength means the, but it will compressive strength we have the center of the web we have to calculate and then we have to check whether it is safe or not.

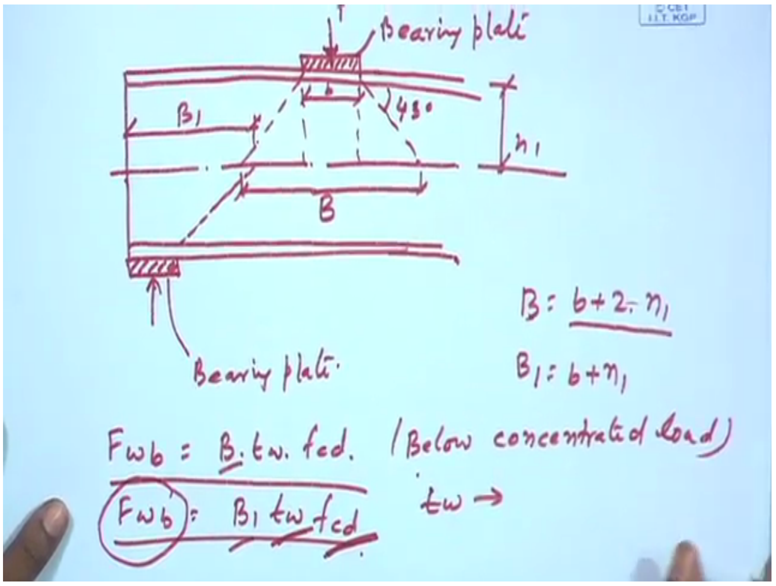
(Refer Slide Time: 16:53)



So for calculating web buckling, for different cases the effective depth has been given say for example, uhh when the web is restrained against lateral deflection and rotation, the effective depth is considered as d1 by 2, right where d1 is a depth of the web and if it is restrained against lateral deflection, but not against rotation then the effective depth will be 2/3 rd d1 and if retrained against restrained against rotation, but not against lateral deflection then effective depth will be d1and not restrained against rotation and lateral deflection the effective depth will be 2d1.

So the effective depth of the web can be calculated on the basis of the restrained condition and that is given here that if restrained against lateral deflection in rotation, it is d1 by 2, if restrained against lateral deflection, but not against rotation then 2/3 d1, if restrained against rotation, but not against lateral deflection then d1 and if restrained against both rotation and uhh sorry, if not restrained against rotation and lateral deflection then effective depth 2d1. So this is required to calculate the compressive stress of the web.

(Refer Slide Time: 21:37)



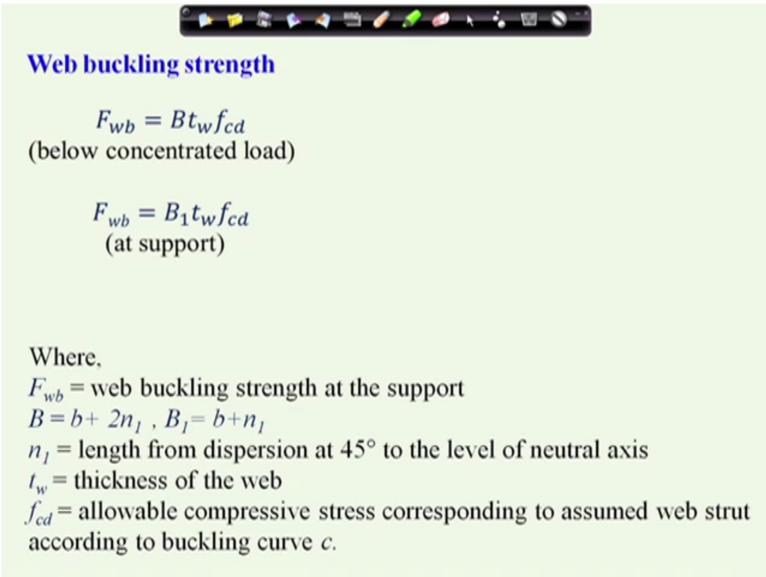
Now web buckling strength will we will like to calculate. So for calculation of web buckling strength we need to find out how the baring plate is going to be provided to minimize the web buckling means to reduce the web buckling, say for example, if a member is subjected to concentrated load at certain point, say concentrated load p is there and this is called bearing plate bearing plate.

Now and if we have a support here then also there is a chance of web buckling here, because of the reaction at the support, so here also we need to provide bearing plate and below concentrated load if we provide the bearing plate then the load will be dispersed with 45 degree angle. This is the flange and if this is neutral axis depth, then this will be the width for which we have to calculate. This is B right and this B value will be B plus 2 into n1, n1 means if if the angle of dispersion is 45 degree then this value is called n. So n1 is the length from dispersion at a 45 degree angle to the level of neutral axis.

So so we can find out B as a b plus 2n1 where small b is the uhh bearing length, this is small b right. So this is n1, so b plus 2n1 right. So and in this case if it is like this, so if I consider this is as B1 then at the support B1 will be simply B plus n1, right. So the buckling strength below the concentrated load Fwb, I can calculate it as B into tw into Fcd buckling strength can be calculated as this below concentrated load, right and at support buckling strength (()) (20:52) will be b1 into tw into Fcd, right. So where Fcd is the allowable compressive stress corresponding to the assumed web strut (())(21:05) according to buckling curve C (())(21:07), right. So Fcd value is the allowable compressive stress and it can be calculated corresponding to it the buckling class C.

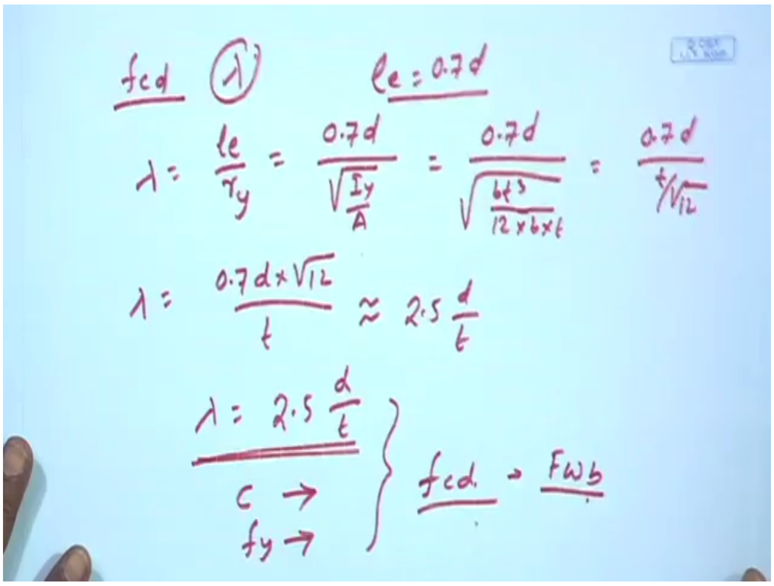
So if we know tw is the uhh thickness of web tw is a thickness of web, so if we know the value of Fcd value of tw and value of B or B1 then we can find out the buckling strength of the member right.

(Refer Slide Time: 21:50)



Now here the when we are going to calculate the uhh design compressive stress Fcd we need to know what is the value of lambda, right.

(Refer Slide Time: 23:57)

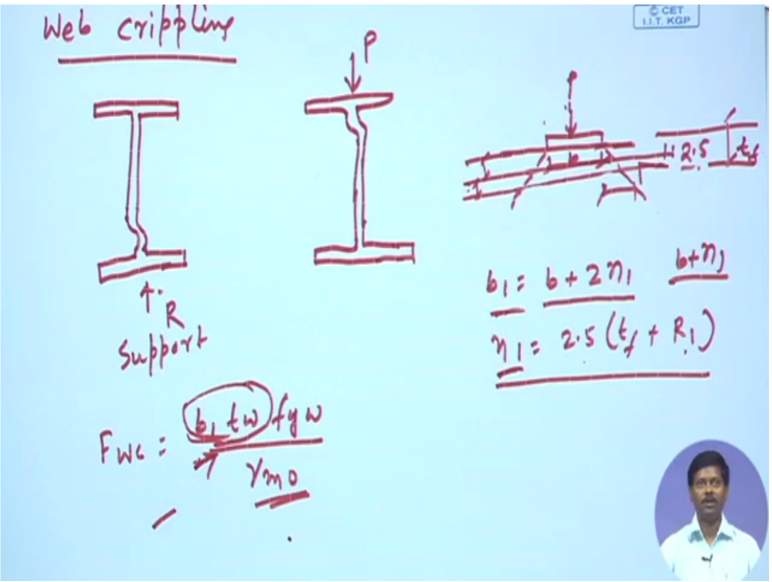


So lambda means the slenderness ratio. So slenderness ratio we know we can find out le by r, r means in this case ry, right. So le the effective length of the strut (())(22:09) le will be 0.7d, so if we consider this 0.7d by ry ry means Iy by A. So I can find out 0.7d by uhh, this is Iy by

A, Iy means bt cube by 12 into b into t. So this will be 0.7d by t by root 12, right. So lambda we can find out as this.

So after calculation lambda will be 0.7d into root over 12 by t. This will be around 2.5d by t. so for an idealized web strut the slenderness ratio lambda can be found as 2.5 into d by t from which (())(23:22) the slenderness ratio can be found and for bucking class C, we can for a particular grade of steel we can find out the value of Fy, we can find out the Fcd value from this parameters. So Fcd value we can find out the compressive stress allowable compressive stress. Once we can find out the Fcd value I can find out Fwb that is the uhh buckling strength web buckling strength can be found.

(Refer Slide Time: 28:43)



Now we will discuss about the web crippling for which it may fail. Web crippling means when a member is under concentrated load, say for example, we have a support condition here we have a support condition here, so it may fail at the root like this. So web crippling may occur due to concentrated force at the support due to concentrated force, right otherwise in other case also, it may fail like say if a concentrated force is applied at the beam at certain point then also web crippling may happen.

So now we have to find out the web crippling strength so that we can design accordingly, right. So here it is uhh the concentrate force is p right. Now to know this we have to find out the Fwc, Fwc is uhh basically b1 into uh tw into fyw by gamma m0 right. So b1 into tw is a area and fyw is the yield strength of the web, right. So b1 into tw we have to find out, this is the area. So this b1 is what b1 is the bearing length. So b1 we can find out uhh considering an empirical dispersion that the through flange to the web flange uhh connection at a slop of 1 is to 2.5 that means if we have a load here with a bearing length of b say, this is bearing length b and we assume that a dispersion of 1 is to 2.5 slop, it is dispersing.

So at the uhh if we consider this, if this is a flange and if this is the root radius then this value will be basically tf plus R1 root radius tf plus R1 and this b1 will become b plus 2n1 right 2n1 and n1 is basically, 2.5 into tf plus R1, right. So what we can see that we have to find out the uhh dispersion length which is b plus 2n1 for concentrate load and if it is under uhh support condition then it will be b plus n1, right. Now n1 is 2.5 into tf plus R1, because uhh this is tf and this is R1. So tf plus R1 will be the depth, so dispersion will be tf plus R1 into 2.5.

So once we find the dispersion length then we can find out the total length b1 and b1 if we find out we can find out the Fwc, the crippling uhh web crippling strength. So if tis web crippling strength is more than more than the load coming into uhh into the member at that point then it is find otherwise we have to uhh increase the section uhh or increase the web width so that web crippling can be avoided, right.

So you today discuss what we have seen that primarily the beam has has to design due to the moment and then we have to design due to shear and then criteria. So moment uhh carrying capacity, the design bending strength of the member can be found for two criteria, one is for low shear, another is for high shear. So in the codal permission, it is given you for low shear how to calculate the design bending strength and for high shear how to calculate design bending strength.

Then once design bending strength is calculated we will go for calculation of the shear strength and the design shear strength if it is more than the design if it is more than the shear force acting on the member then it is find otherwise again we have to redesign by increasing the section size, right and also we have to check whether it is uhh means it is safe under web crippling and web buckling. So those criteria has to be also fulfilled.

Of course we have not discussed about that deflection criteria, which also need to be fulfilled that means we we will find out what is that maximum deflection coming on the member due to the load and support condition avoiding (())(30:16) limiting deflection and if the criteria is satisfying then fine otherwise again we have redo. So this is how we can design a beam which is supported laterally. So laterally supported beam how to design has been discussed.

In next class we will go through one example of the laterally supported beam and we will see how to design that beam, okay. Thank you.