Course on design of Steel Structures
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Mod 10 Lecture 49
Laterally Supported Beams with High Shear

Today, I am going to discuss about the design strength calculation of laterally supported beam with high shear. In last lecture we have discussed the design procedure for calculating the section size of a beam member due to laterally supported beam member due to low shear and we have seen how to calculate the design bending strength due to low shear and how to design the things, right.

Now in case of high shear, we have seen that certain reduction will be happen, because of the high shear in the bending moment calculation bending strength calculation. So bending strength due to low shear where we will come, it will be less, in case of high shear. So some reduction will be there that we will see and the formula whatever we have discussed earlier based on that we will try to find out the design bending strength due to high shear and let us go through one example.

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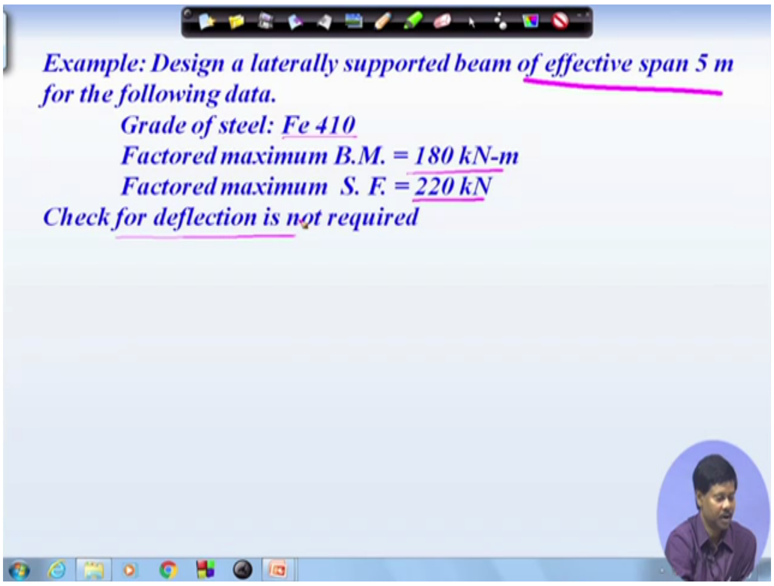

The example is this that design a laterally supported beam of effective span 5 meter with the following data, say grade of steel we use Fe 410 and maximum bending moment, we say suppose 180 kilo newton meter and maximum factor shear force is coming 220 kilo newton and as we are going to calculate only the means the bending strength due to laterally supported beam due to high shear. So we are not going to check for deflection as this will be same, as we have done earlier.

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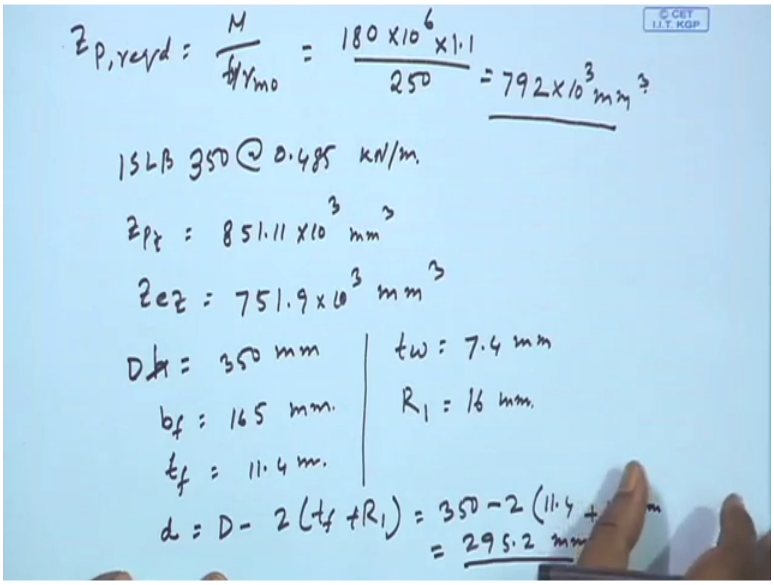

So let us see, so first what we will do we will try to find out, the Zp require that is plastic section modulus require Zp. So Zp require will become M by Fy by gamma m0. So the maximum bending moment factor bending moment has been given as 180 kilo newton meter, so 180 kilo newton meter means 180 into 10 to the 6 newton millimeter into 1.1 gamma m0 and Fy is 250, as we are using Fe410 grade of steel. Therefore, we can find out the Zp require as 792 into 10 to the 3 millimeter cube, right.

So now if we look into the sp6 (())(3:14) we can find out an appropriate section as ISLB 350 at say 0.485 kilo newton per meter. If we choose this section, we will see that Zp is coming 851.11 into 10 to the 3, which is more than the require plastic section modulus, right. So we can fact we can use higher section also; however we can try with this and a let us see whether it is safe or not.

So if we use ISLB 350 then we can find out its properties, properties like the elastic section modulus Zez also we can find out, which is 751.9 into 10 cube. Similarly, the overall depth h is 350 and the (data) other data which we will get in sp6 (())(4:25) is the flange width. Width of flange was given as 165 millimeter. Similarly the flange thickness was given as 7.4 millimeter and thickness of web is given 7.4 millimeter and root radius R1 is given as 16 mm. This will be the data which will be require for calculation of the plastic section modulus actual plastic section and then the bending strength of the section.

So here, the effective depth we can find out, effective depth will be say D minus, if we say this is h or D we can say D minus 2 into tf plus R1. So 350 minus 2 into 11.4 is the thickness of flange and root radius is 16 mm, right 16 mm. So after calculating this we are getting D as 295.2 mm. So the effective depth of the web we are going to find as 295.2 mm.

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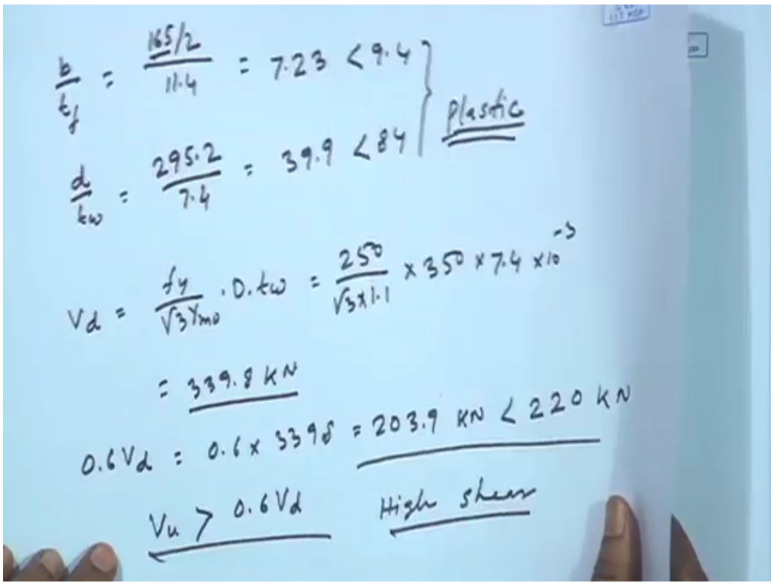

Now we have to classify the section whether it is plastic, compact or semi-compact. So for that we have to find out the b by tf, b by tf means the hanging portion beam is 165 by 2, this will be b, because width of the flange is 165 mm, so half of that will be b and tf is 11.4. So after calculating you can find out 7.23, which is less than 9.4 and d by tw, we can find out d we calculated as 295.2 and tw is given as 7.4. So this is becoming 39.9, which is less than 84.

So from this we can see that the section is plastic. So from this criteria, we can define the section as plastic. So if the section is plastic then we have to calculate the design bending strength accordingly, okay. So reaction of the strength will be calculated on the basis of the section as plastic. Then we have to see, before calculating the design bending strength we have to find out whether it is low shear or high shear, so for that we will check the shear capacity.

So design shear strength of the section we can find out Vd as Fy by root 3 gamma m0 into D into tw, right. So Fy is 250 and root 3 into gamma m0 is 1.1 and d is the overall depth 350 and thickness of web is given 7.4 and if I make it into kilo newton, this will become 339.8 kilo newton. So design shear strength of the section is coming 339.8 and 0.6Vd, because we have to check that is becoming 0.6 into 339.8 is equal to 203.9 kilo newton, which is less than the applied shear means the factor shear which are coming in the beam due to external loading that is 220 kilo newton, right.

So here what we could see that Vu is greater than 0.6Vd right that means we can define this as high shear. So because of high shear certain amount of bending moment will be reduced with some reduction factor and then finally we will get the modified bending moment and because of this presence of high shear we will see, how to calculate the bending moment.

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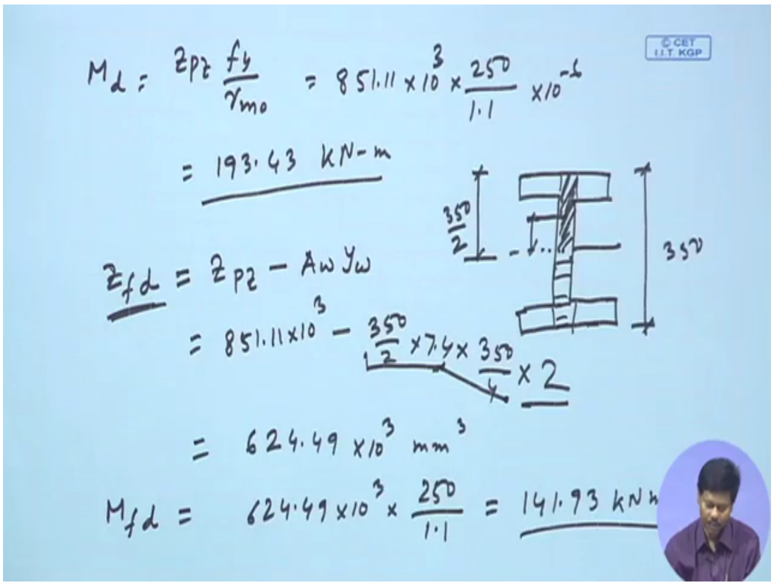

So first we know the plastic design moment of the whole section, this regarding high shear can be calculated as this Md is equal to Zpz Fy by gamma m0. So this is means if we do not consider the high shear, then this is the bending moment means bending strength we will get, which si Zpz is 851.11 for this section into 10 to the 3 into Fy by gamma m0. So to make it kilo newton meter, I can multiply 10 to the minus 6. So I am getting 193.43 kilo newton.

So disregarding the high shear the plastic design moment of whole section will become this; however we have to multiply with certain reduction factor to find out the plastic design moment in because of presence of high shear. So for that what we have to find out we have to find out the section modulus of the cross section excluding shear area, section modulus of the cross section excluding shear area, so that will become.

So section modulus of the whole section is Zpz and section modulus of the shear area will be Aw into Yw. So **so** for that we can find out this is as Zpz was given 851.11 into 10 the 3. So this is Zpz minus Aw. So if we see the section, the I section which we have consider; its overall depth is 350, right. So along the neutral axis, this depth will become 350 by 2, right.

Now we have to find out Aw. Aw is the area of this. So area of this and plus area of this, right. So Aw will become basically 350 by 2 into 7.4. This is Aw into Yw, Yw means the CG (()) (11:46) of the area from the neutral axis. So CG (())(11:50) of the area for this, CG of the area will become somewhere here that is 350 by 4. So it will be 350 by 4 and for two side, it will be into 2. So Aw into Y will be the plastic modulus section modulus of the web of one side and for two side, it will be multiplied by 2. So Zfd the section modulus of the cross sectional area excluding shear area will become 624.49 into 10 to the 3 millimeter cube. So Zfd we can find out from this.

Now we can find out the plastic design moment of the area of cross section excluding shear area Mfd. So excluding shear area, the plastic design moment of the cross section will become Mfd as, so this is Zfd, so Zfd 624.49 Zfd into Fy is 250, 50 by gamma m0 that is 1.1. So Mfd the plastic design moment excluding the shear area we found as 141.93 kilo newton meter, right. So this is how we can find out the value of Mfd.

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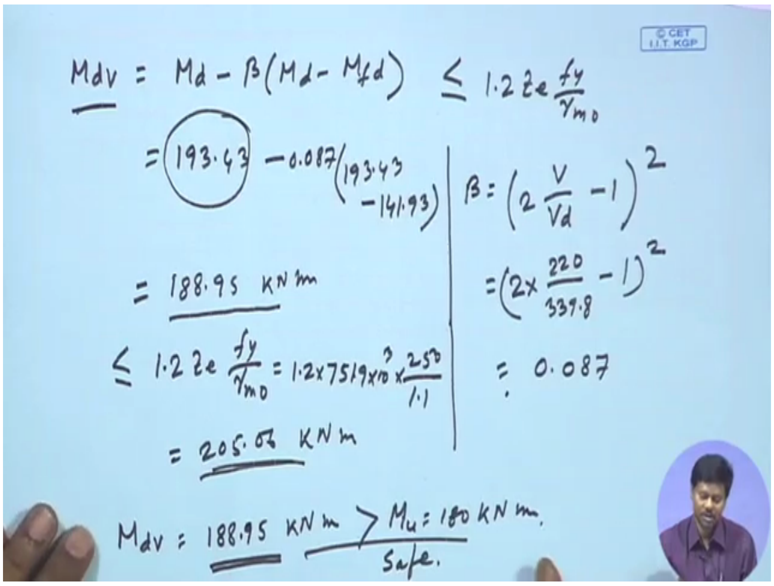

Now we can find out the value Mdv which will be the modified plastic design moment of the section due to high shear that is Mdv, which will be the modified plastic design moment of the section due to high shear that is Mdv. So Mdv will become basically Md minus beta into Md minus Mfd, right. So and it has to be less than or equal to 1.2Ze into Fy by gamma m0. So if we calculate this, we can see the Md value we have calculated earlier that is 193.43, which is the plastic design moment of the section. This regarding high shear and beta, beta value we have to calculate, right and beta into Md minus Mfd.

So beta is a reduction factor, which can be written as 2 into V by Vd minus 1 whole square. So beta value we can find out 2 into Vu is the 220 kilo newton the shear force and shear strength of the section we calculated 339.8. So after putting this value we will get beta as 0.087. So we will multiply beta means here with beta that is 0.07 into Md minus Mfd. Md is 1 93.43 minus Mfd is 141.93 which we have calculated earlier. So this is becoming 188.95 kilo newton meter, right 188.95 kilo newton meter.

Now it has to be less than equal to 1.2 Ze Fy by gamma m0. In any case it has to be less than this. So this if we calculate we can see this will be come 1.2 into 751.9 into 250 by gamma m0 1.1. So this is becoming 205.06 kilo newton meter, right. So what we could see that Mdv value is becoming 188.95 kilo newton meter and it has to be less than this, otherwise this will be consider.

So finally we can consider the Mdv value as 188.95 kilo newton meter, right and it is greater than the factor moment, which is 180 kilo newton meter. So I can say that the section whatever we have choosing is safe, right. So this is how one can find out the design bending moment of the section with high shear. So in fact what we could see that if it is not high shear means if it is low shear we could find out eth value as this 193.43 and because of the presence of high shear, the bending moment is reduce to 180.95 kilo newton; however this is greater than the factor moment. So the section. is okay.

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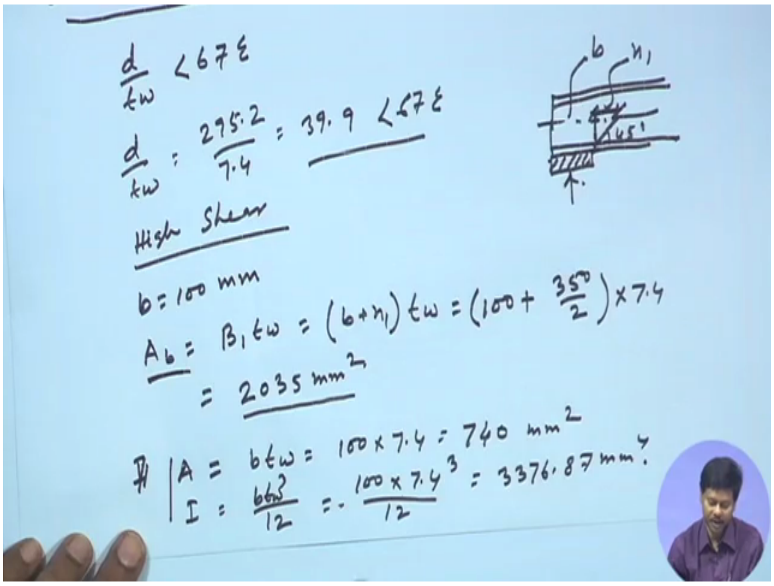

Now we will go for checking due to buckling web buckling. So we will go for check for web buckling. Now web buckling is not require if d by tw is less than 67 epsilon as per coder permission. Now here d by tw is becoming 295.2 by 7.4 which is 39.9 and this is becoming less than 67 epsilon. So in fact web buckling check is not require in general; however because of high shear we need to check this, because of high shear, right as high shear is present, so we have to check. In case of low shear we do not need to check this.

So now for high shear if we have to check we can check at the support right. So at the support maximum shear has been developed. So if we assume a bearing length of say b is equal to 100 mm (())(18:40) bearing length of b is equal to 100 mm. then the area of the bearing plate we can find out means the bearing area that will be Ab will become b1 into tw, right. So b1 means b plus n into tw the area influence area.

So if we see, if the support is here, say for example, this is the section. Now we have support and bearing length of 100 mm is given. So it will disperse with a angle of 45 degree and this will become n1, right and this is b. So b plus n1, this will become b is given as 100 mm, we have assumed and n1 will be n1 as this is 45 degree angle. So n1 will be this, this is the half of the depth that means 350 by 2 up to neutral axis, right and into tw the thickness of web is 7.4.

So if we calculate we will get this as Ab as 2035 millimeter square, right. So effective, sorry the bearing area under influence is 2035 millimeter square. Now moment of inertia of the web we have to find out of the web means this, because of the bearing that area we have to

(())(20:49) influence area we have to find out and accordingly, we can find out the I, before that let us find out A, the area of the web. Area of the web will be simply b into tw. So b will be 100 into tw 7.4, so that is 740 millimeter square. Similarly, we can find out I as btw cube by 12. So after putting the value we can find out the value of I as 3376.87 millimeter to the 4. So area and moment of inertia we could find.

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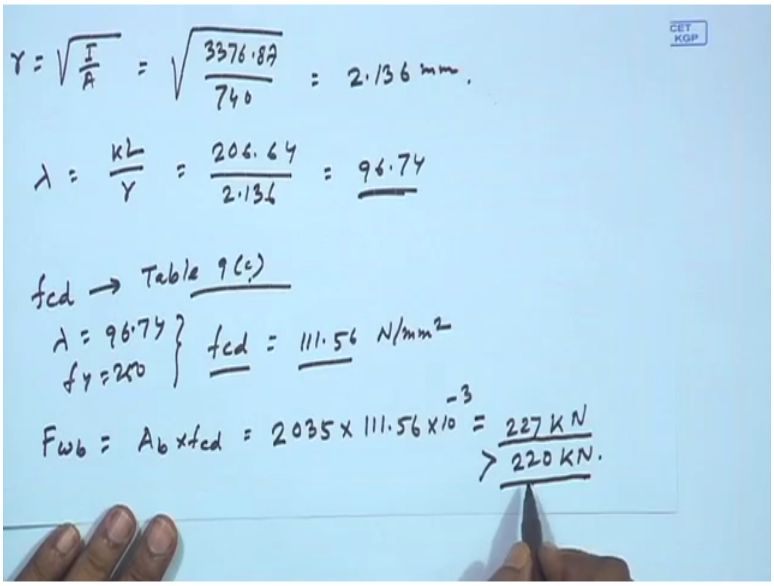

Now I can find out the effective length of the web **effective length of the web** KL will be 0.7 into d, so that is 0.7 into d we have found earlier that is 295.2. So this is becoming 206.64 kilo newton. So effective length of the web we could find out and so the radius of the eration (())(22:12) we can find out radius of the eration (())(22:15) will be square root of I by A. So I is 3376.87 and area is 740. So this is become a 2.136 mm and slenderness ratio lambda also we can find out as effective length by radius of the eration (())(22:43). So effective length we calculate earlier as 206.64 and radius of eration (())(22:52) we calculated 2.136. So this is becoming 96.74.

So slenderness ratio of the web, we could find out as 96.74. So if slenderness ratio is 96.74 then we can find out the, compressive stress of the web Fcd, design compressive stress and that can be found from table 9(C) of IS 800-2007, because here buckling class is (C) and according to this we will follow the table 9(C) of IS 800-2007 and for that with lambda is equal to 96.74 and Fy is equal to 250, we can find out the Fcd value as 111.56 newton per millimeter to interpolation of the data given in the table we can find out the Fcd value as 111.56 newton per millimeter square.

So now capacity of web section we can find out, say load carrying capacity of the web Fwb that we can find out the Ab into Fcd. so Ab we found out as 2035 into Fcd as 111.56, right and to make it kilo newton we can multiply as 10 to the minus 3 and this is becoming 227 kilo newton, which is greater than 220 kilo newton. So this is effect, because the buckling strength of the web is coming as 227 kilo newton and the factor shear was given as 220 kilo newton.

So buckling strength is more than the factor shear. So the section whatever we have chosen is okay, otherwise what we can do? If section is not okay then we have to increase the section size or we have to increase the bearing length, either we have to increase the bearing length to accommodate this capacity or we have to increase the section size, right.

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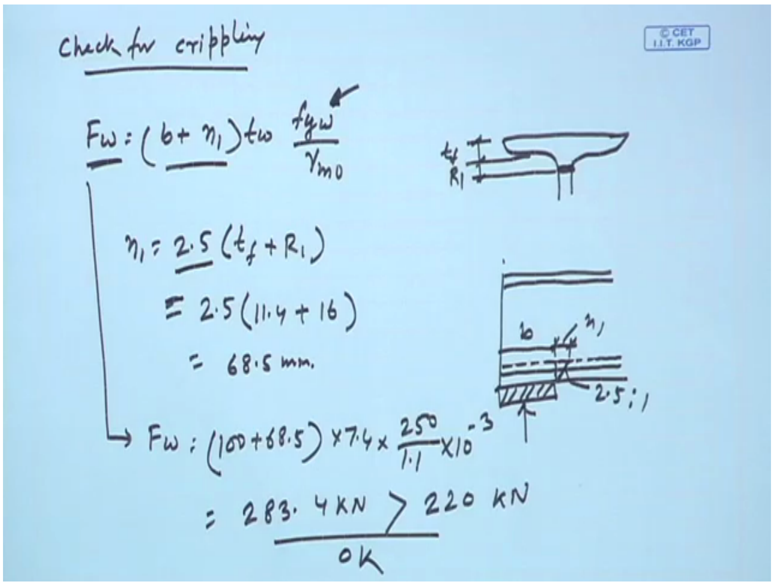

Now we will check for crippling. So crippling strength we can find out, say Fw will be b plus n1 into tw into Fyw by gamma m0, Fyw is the yield strength of the web. Now Fy and Fyw is same here, because same material we are using, but if the material of the web and flange are different then we have to consider Fy and Fyw accordingly and here Fyw and Fy is basically same.

Now to find out the crippling strength, we have to find out the value of b plus n1. Now b we know is given as 100 and n1 we have to find out, n1 will be as we know, it will disperse with 2.5 slop say, this for example say crippling will happen here. So we have to find out the dispersion and this is tf and this is R1, right. So if we see, because of the bearing at the support, so dispersion will happen like this. This is the flange and up to this, it is the root of the web, so it will disperse up to this with 2.5 is to 1. So we have to find out this is as n1 and this is as b. So b plus n1, the length of this. So I can find out n1 as 2.5 into tf plus R1 right, because with a slop of 2.5, it is disperse in, this is the assumption we have made earlier. So 2.5 into 11.4 is the thickness of flange and root radius is 16 mm. So this is becoming 68.5 mm, right.

So now we can find out the value of Fw. So Fw value will 100 plus 68.5 into thickness of web is 7.4 into Fyw is 250 by gamma m0 and to make it into kilo newton, we can multiply with 10 to the power minus 3. So this is becoming 283.4 kilo newton and this is also more than the shear force acting at the support, which is 220 kilo newton. So we can say, this is a okay. So this is how we can check for crippling web crippling and web buckling, right.

So today what we have seen an example, to find out a section size, because of high shear. So in case of high shear, what extra additional things we have done is the calculation of the, erection factor for **for** bending moment means bending strength calculation, right. So only additional thing will be the reduction factor and that reduction factor will be calculated based on the full bending strength for plastic bending strength and the plastic bending strength without shear area. So from those data we can finally find out the modified bending strength of the whole section due to high shear. So this is how we calculate. So thank you.