Design of Steel Structures
Dr. Damodar Maity
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Compression Members
Module - 5
Lecture - 3
Design of eccentrically loaded tension member

Hello. Today I am going to discuss about the design of eccentrically loaded compression member. That means basically we will be going to design a beam column member. Beam column member means the member are having compressive load as well as bending. So, the stresses will be developing due to bending and due to compression axial compression. So, we have to take care of both the type of stresses and accordingly, we have to find out a suitable section.

So, in last classes I have given an overview which I will repeat once again very quickly. Then, I will go for the design procedures as how to start with a design for the beam column member. Here the difficulty is, we do not know what should be the sigma ac value and what should be the sigma bc. The compression stress due to bending what should be the allowable value which depending on the sectional properties of the member. So, while going for design we do not know the allowable stresses as well as the member properties of the section. So, at a time we cannot find out. So, we have to assume certain, either compressive stresses, then we have to find out or we have to assume certain dimension of the member properties. Then, we have to find out whether that is or not for the given load. So, those things will be clear here. However, before going to the design procedure, I like to give a summary of the earlier lecture with respect to the beam column things.

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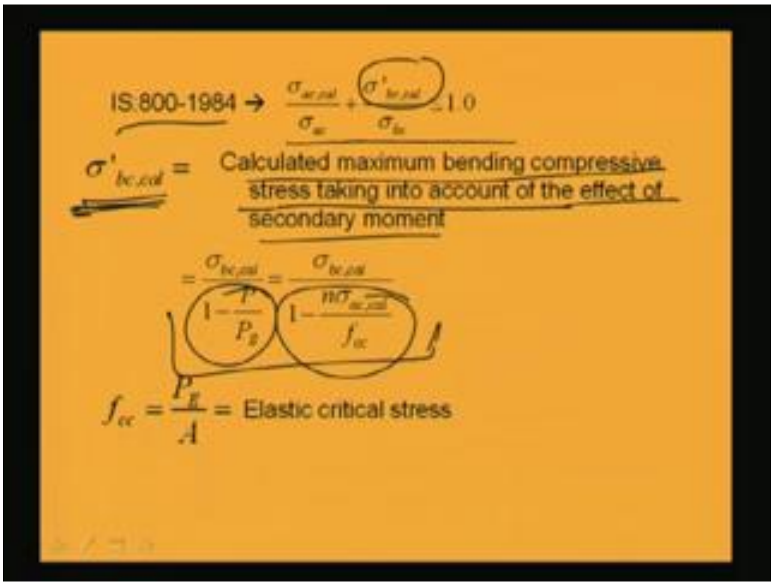

As per the IS: 800-1984 as I told in last lecture that sigma ac calculated by sigma ac plus sigma dash bc calculated by sigma bc should be less than or equal to 1, where sigma bc dash calculated is the calculated maximum bending compressive stress taking into account the effect of secondary moment. That means in the earlier version of this code IS: 800-1962, the secondary moment of the beam has not been considered. The effect of secondary moment has not been considered. Here what we will do? We will consider that one in the 1984 code that this has been multiplied with some constant or divided with some constant which is like this, where n is some constant and sigma ac calculated, we know fcc, we know elastic critical stress. So, from this we can find out the modified value of sigma bc calculated.

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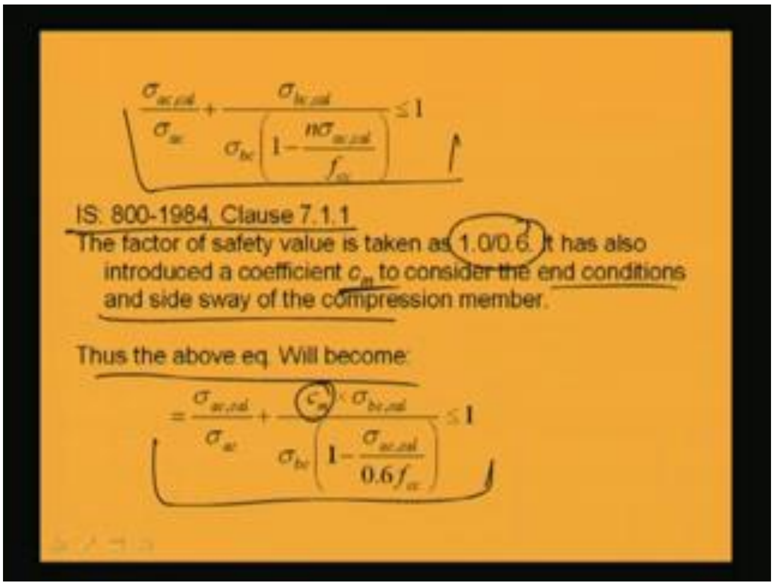

So, if we modify, the value will become like this and as per the clause 7.1.1 in 1984, the value of n is becoming 1 by 6 and Cm is given in the code, Cm is a coefficient which is introduced due to end condition and side sway of the compression member. The value of Cm depends on the n condition and the side way of the member. Thus, the above equation can be written in this way that Cm factor, we are going to give and n is 1 by 0.6. If we introduce this to the above application will become like this.

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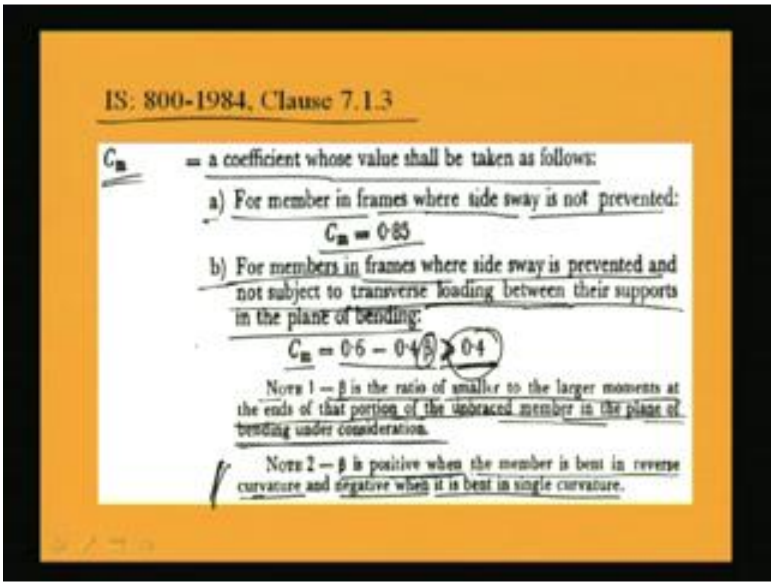

So, what is Cm? I have skipped that in the last lecture because of shortage of time. What is Cm? That is explicitly described in clause 7.1.3. Cm is a coefficient which value shall be taken as follows. One is for member in frames where side sway is not prevented. In that case, Cm value is given 0.85 where side sway is not prevented. The members in frames where side sway is not prevented, then Cm value can be taken as 0.85. Then, for members in frames where side sway is prevented and not subjected to transverse loading between their supports in the plane of bending, that means Cm is equal to 0.6 minus 0.4 beta which has been given in the code which should be greater than or equal to 0.4. In no case it should be less than 0.4. If it is less than 0.4, then we will take 0.4.

What is beta? Beta is the ratio of smaller to the larger moments at the end of that portion of the unbraced member in the plane of bending under consideration. Beta is positive when the member is bent in reverse curvature and negative, when it is bent in single curvature. Beta will be positive if it is bent in reverse curvature, and will be negative if bent in single curvature. So, sign of beta can be determined from the curvature. So, in this way we can find out the value of Cm.

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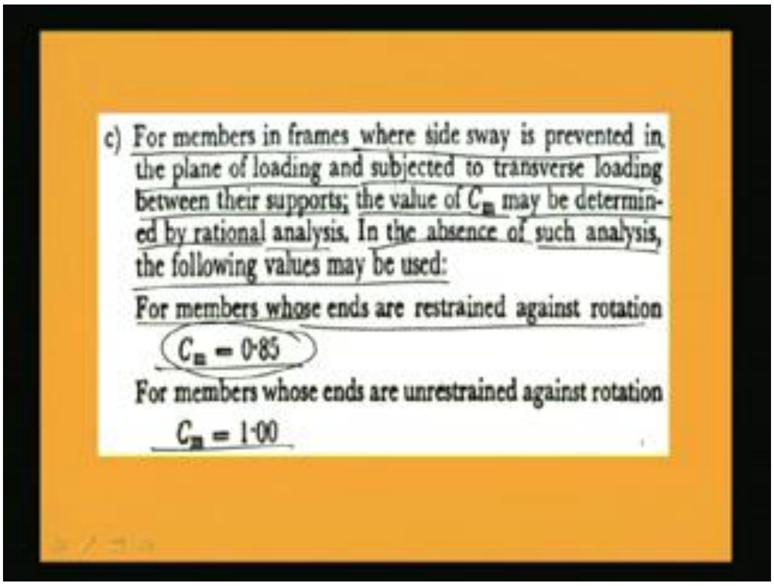

Also in the code, it has given that for members in frame where side sway is prevented in the plane of loading and subjected to transverse loading between their supports, the value of Cm may be determined by rational analysis. In the absence of such analysis, the following values may be used. If we cannot do the analysis, then we can use these values. That is for members whose ends are restrained against rotation. The Cm value can be taken as 0.85 and if the members whose ends are unrestrained against rotation, we can take the value Cm as 1, right. So, the constant Cm has certain values which can be taken from this clause 7.13 of IS: 800-1984. So, as per the condition, the value of Cm can be found and we can write the things.

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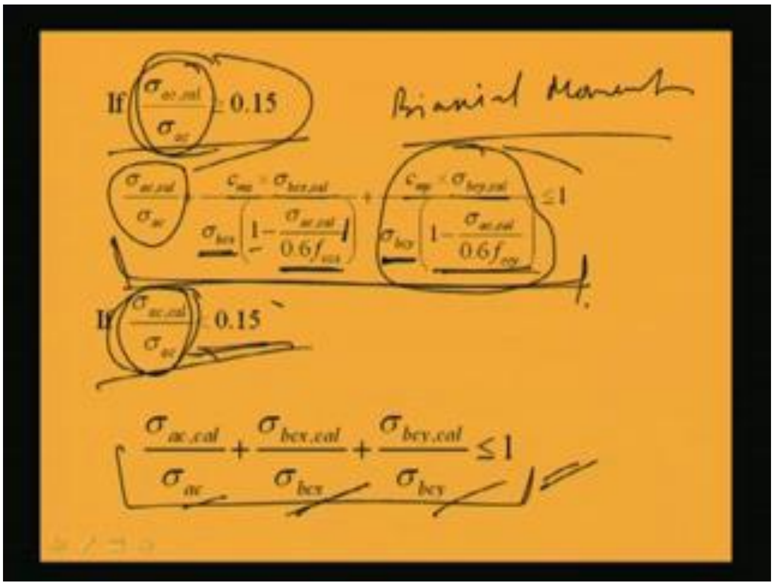

So, as per the codal provision, we will see that if sigma ac calculated by sigma ac is greater than 0.15, then this expression has to satisfy as per the codal provision. What is this expression? That is this is due to axial compressions sigma ac calculated by sigma ac. Then, this is for biaxial moment means in both the direction if the moment is there plus Cmx into sigma bcs cal by sigma bcx into 1 minus sigma ac calculated by 0.6 fc fccx, right. Plus again due to my, that will be this 1 Cmy into sigma bcy calculated by sigma bcy into 1 minus sigma ac calculated by 0.6 fccy. So, this expression has to be satisfied as per the codal provision. When sigma ac calculated by sigma ac, this ratio become greater than 0.15 and if the ratio is becoming less than 0.15, then simply we can use this formula where there is no modification factor. Sigma ac calculated by sigma ac plus sigma bc calculated by sigma bcx plus sigma bcy calculated by sigma bcy, right. So, these equations can be used if the ratio of sigma ac calculated by sigma ac is less than 0.15. That means if the stress is less means compressive stress is less, that means if the magnitude of the compressive load is comparatively less, we can use these types of things.

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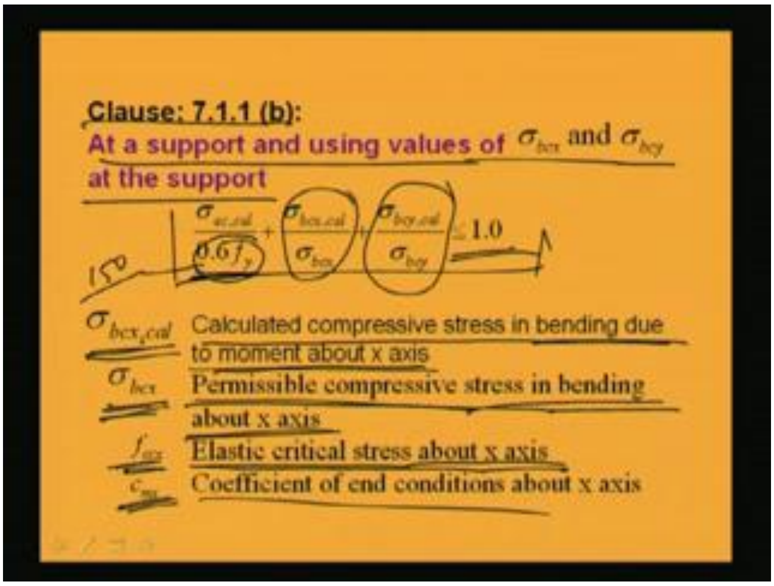

Next as per the clause 7.1.1 b at support and using values of sigma bcx and bcy, sigma bcy at the support we can write this equation. Sigma ac calculated by 0.6 fy, not sigma ac. Remember at the support we can use simply 0.6 fy, that is for ap 250, it will be 150 Mpa plus sigma bcx calculated by sigma bcx plus sigma bcy calculated by sigma bcy should be less than equal to 1, where sigma bcx calculated is compressive stress in bending due to moment about x axis. Similarly, sigma bcy calculated will be calculated compressive stress in bending due to moment about y axis. Sigma bcx is the permissible compressive stress in bending about x axis. Similarly, sigma bcy will be permissible compressive stress in bending about y axis. Fccx is elastic critical stress about x axis, fccy will be elastic critical stress about y axis, and Cmx Cmy will be coefficient of end conditions about x axis and about y axis.

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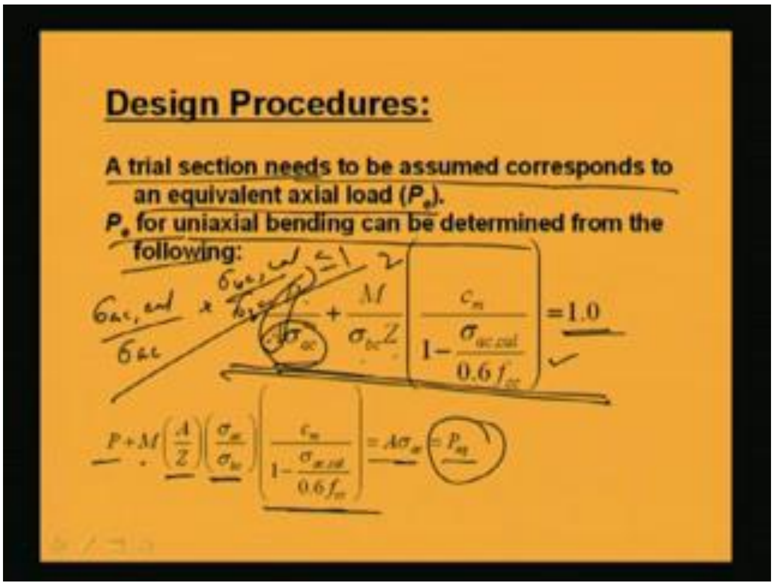

Now, we have to find some design procedures. As we have discussed in earlier steps, when the member is subjected to only compression load, we have told that how to assume pass the allowable stress. Then, how to start the design? Here allowable stress we cannot assume because we do not know what the total load is because allowable stress we can assume, but what will be the area of required cannot be determined unless we know what the total load is coming because here load is not only the compressive load, but also the moment in different directions.

So, we have to find out the equivalent moment, sorry equivalent load due to this moment. Equivalent load, equivalent compressive load due to the moment has to be found out and then, we can find out the approximate area considering an allowable stress. So, a trial section needs to be assumed correspondence to an equivalent axial load Pe, where Pe is basically for uniaxial bending which can be determined from this formula. We know this is P by A is sigma ac calculated. That means, sigma ac calculated by sigma ac. Similarly sigma bc calculated by sigma bc sigma ac calculated by sigma ac plus sigma bc calculated by sigma bc will be less than or equal to 1 for uniaxial moment.

So, if we make this equation in terms of load and area, then we might find out that P by A into sigma ac plus M by sigma bc into z into this equal to 1.0. That means, now if I multiply in both the sides as A into sigma ac, then we will get P plus M into A by Z into sigma ac by sigma bc into Cm by 1 minus sigma ac calculated by 0.6 fcc is equal to A into sigma ac which will be equal to P equivalent, right. So, what we are getting is that P equivalent equal to P plus M into A by Z into sigma ac by sigma bc into Cm by 1 minus sigma ac calculated by 0.6 fcc for uniaxial moment. Similarly, for biaxial moment another term will come. Another extra term of in y direction will come.

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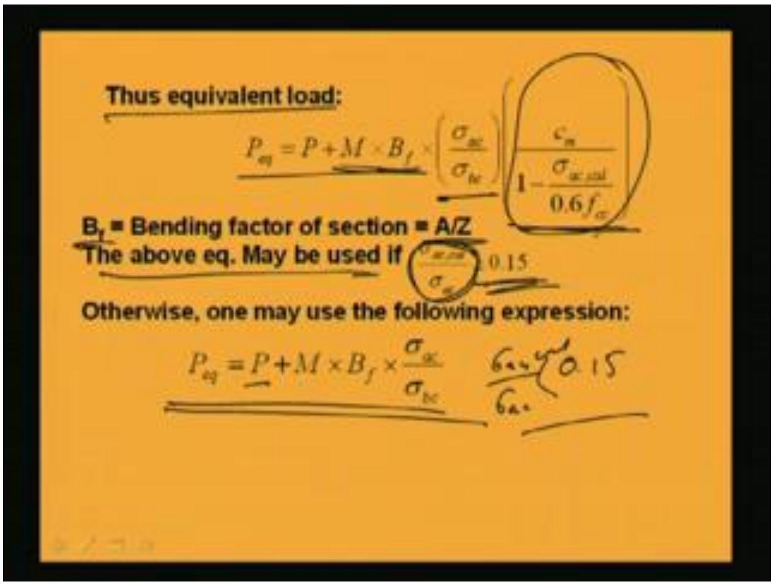

So, the equivalent load thus we can make that P equivalent is equal to P plus M into Bf, where Bf we can make as A by Z bending factor. A by Z is a factor which is called as bending factor of the section. So, M into Bf into sigma ac by sigma bc into same Cm by 1 minus sigma ac calculated by 0.6 fcc where bending factor Bf is equal to A by Z, and the above equations can be used if sigma ac calculated by sigma ac is greater than 0.15. If this is less than 0.15, then we can use the simplified equation because this portion is going to reduce. This is the modification factor because of the secondary moment. So, if the ratio of sigma ac calculated by sigma ac is less than 0.15, sigma ac calculated by sigma ac, then we can write equivalent load Peq is equal to P plus M into Bf into sigma ac by sigma bc. So, this is the way how we can find out the value of equivalent load.

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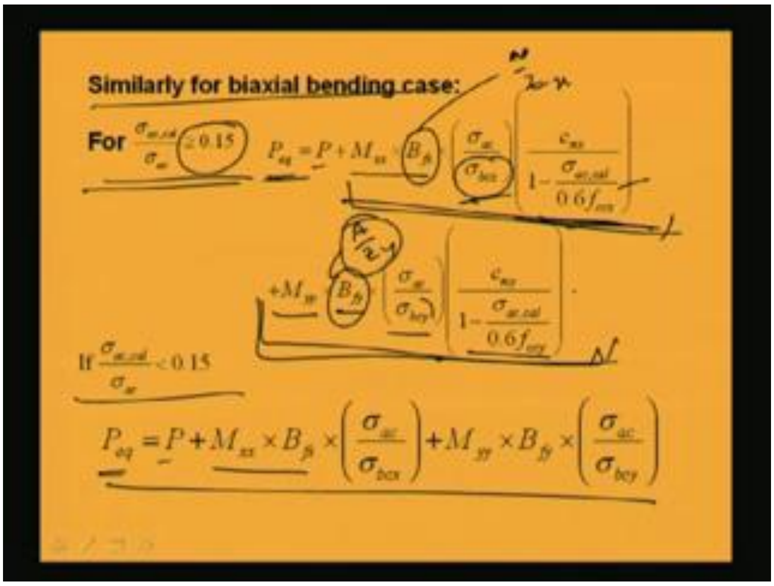

Now, for biaxial moment what will happen? For biaxial bending moment, both the cases will come and for sigma ac calculated by sigma ac. If the ratio is becoming greater than 0.15, what will happen? That equivalent moment will become equal to P plus Mxx into Bfx, where Bfx will be A by Zx into sigma ac by sigma bcx into Cmx by 1 minus sigma ac calculated by 0.6 fccx. This is for moment in the x direction. Similarly, moment in y direction is Myy into Bfy into sigma ac by sigma bcy into Cmy by 1 minus sigma ac calculated by 0.16 fccy, where the terms are known.

Sigma ac is the allowable compressive stress; sigma bcy is the allowable compressive stress. Due to bending in y direction, sigma bcx is the allowable compressive stress in bending in x direction sigma, sorry Bfx is the factor and Bfy also is the factor in y direction which is A by Zx and A by Zy. So, in this way the equivalent moment can be calculated. So, what we will do for the calculation of equivalent moment? First we will see what the ratio of sigma ac calculated by sigma ac is. If the ratio is becoming more than 0.15, then we can use this equation. Otherwise, we will use this equation that is P equivalent equal to Pe plus Mxx into Bfx into sigma ac by sigma bcx plus Myy into Bfy into sigma ac by sigma bcy. That means, the correction factor due to the secondary moment has been neglected if the ratio is less than 0.15, right. So, in this way we can find out the equivalent load.

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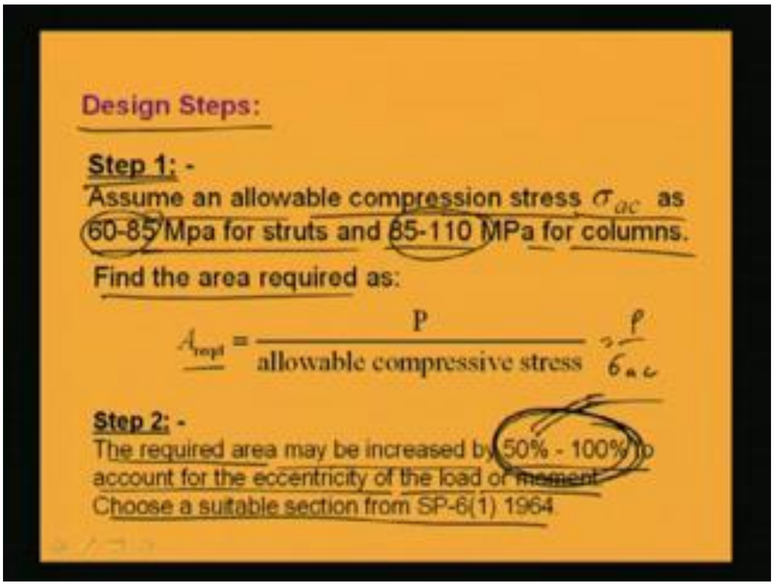

Now, I will discuss the design steps which have to follow for design of a beam column type member. So, in first steps what we will do? We assume an allowable compression stress sigma ac as 60 to 85 MPa for struts and 85 to 110 MPa for columns. As we have discussed in last class also that we will consider 60 to 85 MPa for struts and 85 to 110 MPa for the column members. This is the starting point.

Next, we will find out the area required. Area means that A required is equal to P by sigma ac P by sigma ac. Then, what we will do is the required area may be increased by 50 to 100 percent to account for the eccentricity of the load or moment. Choose a suitable section from SP: 61-1964. What we can do that is the area will be increased by 50 to 100 percent to account for the eccentricity of the load or moment. Now, this is how much we will increase that depends on what the magnitude of the moment is compared to the load and of course, the experience of the designer. The experienced designer can choose a suitable area which will be safe for that type of design moment, right.

So, basically if you are new, then what you have to do? You have to keep on trying and error means you have to try with some increased area. Then, you have to see whether it is or not if it is fine, otherwise you have to increase the area. That means, you have to increase the dimension of the member which have been chosen. Then, again we have to check similarly. So, those things will be clear when we will go through one example. Now, in step 3 what we will do?

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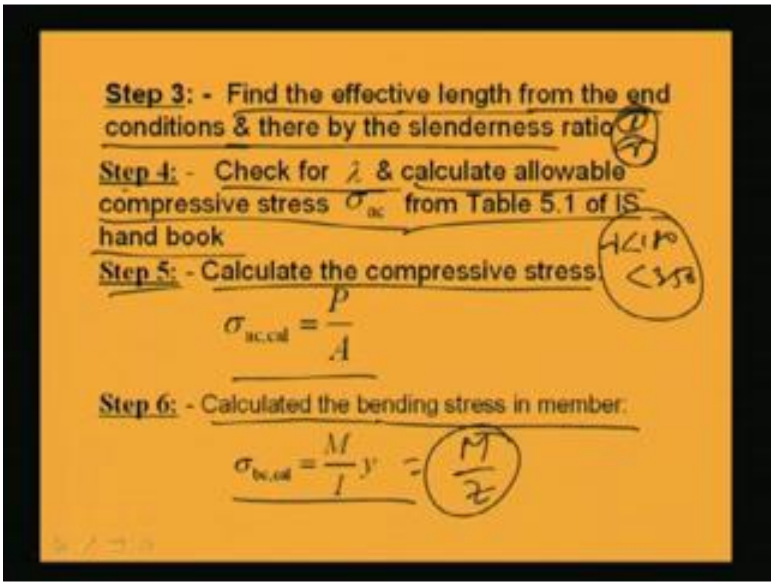

We will find the effective length from the end conditions and thereby the slenderness ratio, right. So, we will find out the effective length from the end conditions, and also the slenderness ratio as l by r because the effective length can be found out and r is the radius of gyration which is given in the tabular form in the hand book for a particular section. In next step, we will check for lambda. That means, the slenderness ratio which is either should be less than 180 or it should be 350 or 200 means as per the codal provisions, and calculate allowable compressive stress sigma ac from table 5.1 of IS hand book as we have done in the last lecture also. Next step what we will do is calculate compressive stress sigma ac calculated. That will be P by A P is the compressive load and A is the area. Then, what we will do? Calculate the bending stress in member sigma bc calculated. Sigma bc calculated will be M by I into y or simply M by Z. The maximum compressive stress will be at the extreme. So, we can find out the sigma bc calculated, right.

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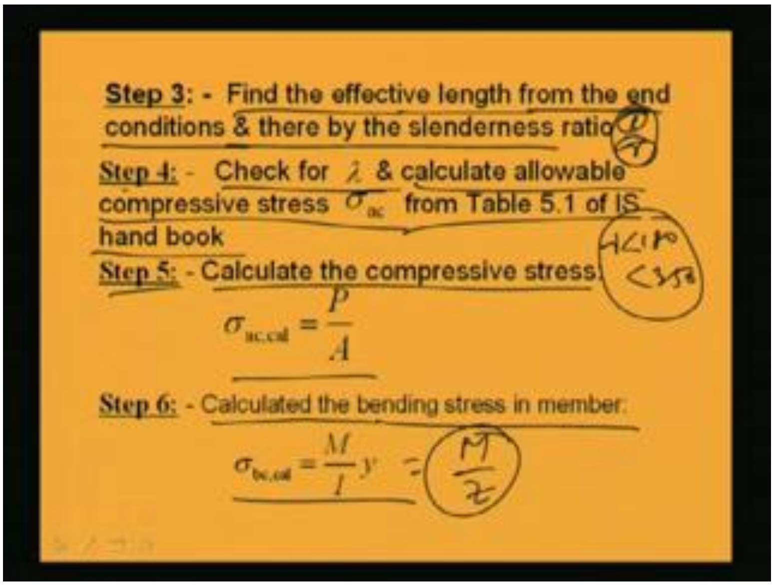

Now, what we will do for biaxial bending? What will happen? Biaxial bending in both the cases, you have to calculate sigma bcx calculated and that will be Mxx by Ixx into y or we can write Mxx y by Arx square because I is equal to Arx square. Similarly, sigma bcy calculated can be written as Myy by Iyy into x or equal to Myy into x by A into ry square. So, sigma bcx calculated and sigma bcy calculated can be found out for biaxial bending. Then, what we will do now? The permissible bending stress is 0.6 fy if bending is about minor axis.

So, permissible bending stress as per the codal provisions will be 0.66fy if bending is about minor axis, and if bending is about major axis, then these values can be obtained from table 6.1 of IS: 800, right. In table 6.1, the details have been given for different type of d by t ratio or t by t ratio and with the l by r ratio. What will be the value of sigma bc? That has been given in table 6.1. A, b, c, d, e, f like this, different type of tables are given. So, from that we have to find out. In fact, when we go for the design of beam members, you will know it thoroughly. However, this can be known from here also. I will show the table how it looks like.

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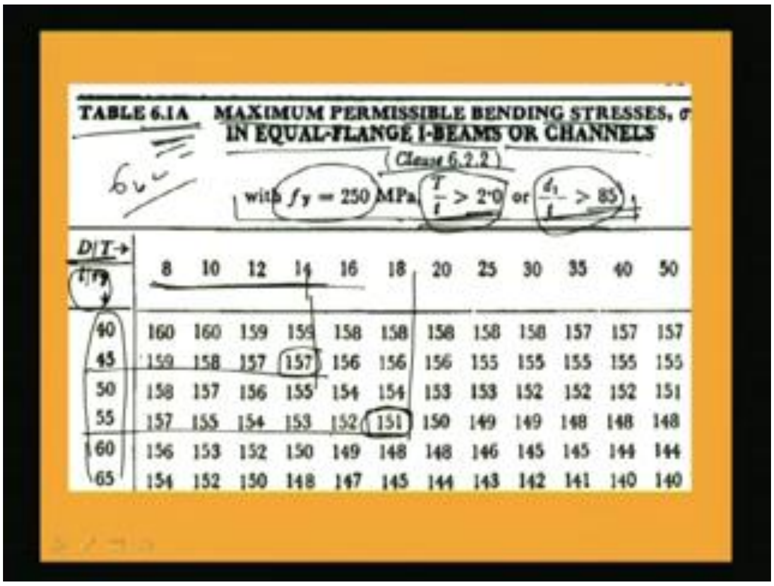
TABLE 6.1A MAXIMUM PERMISSIBLE BENDING STRESSES, σ IN EQUAL-FLANGE I-BEAMS OR CHANNELS

(Clause 6.2.2)

with $f_y = 250$ MPa, $\frac{T}{t} > 2.0$ or $\frac{d_1}{t} > 85$

l/r ↓ \ D/T →	8	10	12	14	16	18	20	25	30	35	40	50
40	160	160	159	159	158	158	158	158	158	157	157	157
45	159	158	157	157	156	156	156	155	155	155	155	155
50	158	157	156	155	154	154	153	153	152	152	152	151
55	157	155	154	153	152	151	150	149	149	148	148	148
60	156	153	152	150	149	148	148	146	145	145	144	144
65	154	152	150	148	147	145	144	143	142	141	140	140

Suppose there is table 6.1 A here. It is given that maximum permissible bending stress sigma bc in equal flange I beam or channels. So, for I beam or channels with equal flange as of the clause 6.2.2, the value of sigma bc has been given in the table. So, you will get table 6.1 is 6.1, 6.1 b. Like this you will get different type of tables. Here in the column wise for different l by r ratio, that means for the slenderness ratio it is given and here it is given for different D by T ratio. Again you see this table is valid for if T by t is greater than 2 and d 1 by t is greater than 85. If it is less than 2 and less than 85, then another table you have to proceed.

So, you have to first check what T by t ratio is and what d 1 by t ratio is and what the grade of steel is. Accordingly, we have to find out for different D by T ratio, the values are given. Suppose for D by T ratio of 14 and l by r ratio say 45. So, the sigma bc value will be 157 Mpa, right. So, we can find out the sigma of ac value from this table. Suppose, the l by r ratio is 55 and say D by T ratio is 18, then the sigma bc value will become 151 Mpa. So, in this way we can find out the values of sigma bc for different l by r ratio and different T by D by T ratio from the table 6.1.

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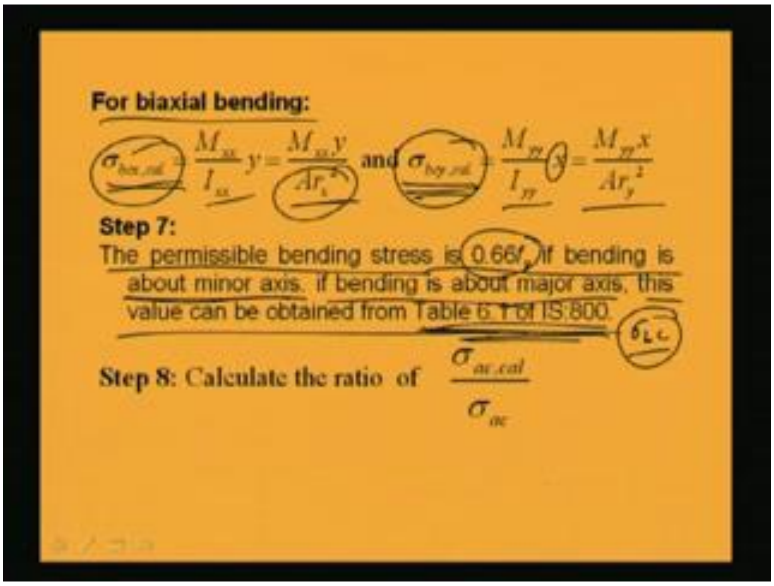

So, after getting this sigma bc, what we are getting? Sigma bc in x and y direction in minor about minor axis, this will be 0.66fy and about major axis, this will be finding from table 6.1. Now, we will find out ratio of sigma ac calculated by sigma ac.

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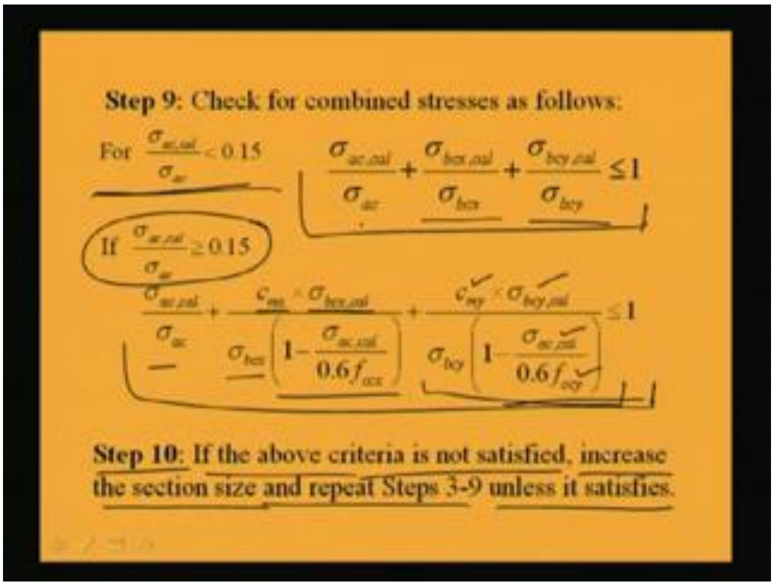

Then, we will see that whether it is less than 0.15 or greater than 0.15. If it is less than 0.15, the expression has to be satisfied. What is this expression? That is sigma ac calculated by sigma ac plus sigma bcx calculated by sigma bcx plus sigma bcy calculated by sigma bcy should be less than or equal to 1. If the ratio of sigma ac calculated by sigma ac is greater than or equal to 0.15, then the expression given here has to be satisfied which is given in the code, that is sigma ac calculated by sigma ac plus Cmx into sigma bcx calculated by sigma bcx into 1 minus sigma ac calculated by 0.6 fccx plus cmy into sigma bcy calculated by sigma bcy into 1 minus sigma ac calculated by 0.6 fccy. The parameter like sigma bcy calculated sigma ac calculated fccy, everything we know which is given in the code. Also all the parameters have been given in the code. So, this you have to check. Then, what you will do? If the above criteria is not satisfied, if it is greater than 1, then what will you do? Then increase the section size and repeat steps 3 to 9.

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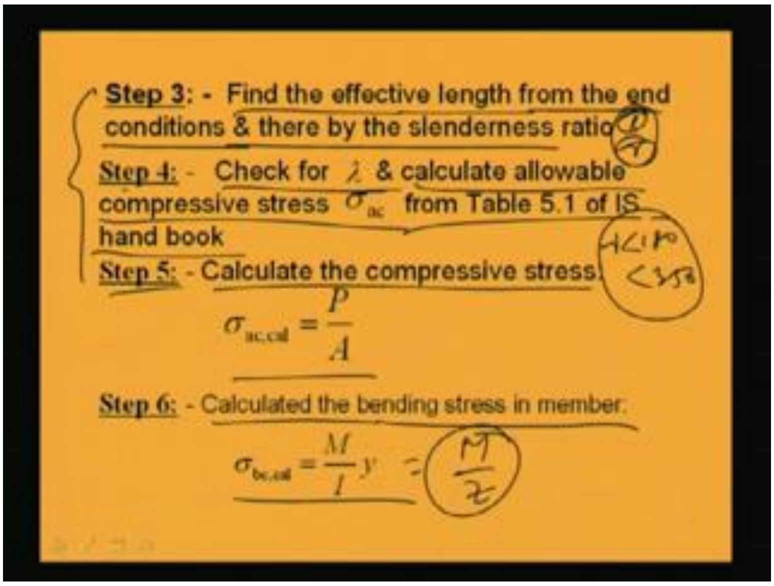

That means find the effective length from the end condition, and there will be a slenderness ratio with the new section. Then, we will go through these steps. So, unless the condition has been satisfied, we will go on increasing the size of the section and we will therefore be able to get a suitable section. So, this is the design procedure. Now, if we go through one example, we will be able to understand how to design a beam column like members.

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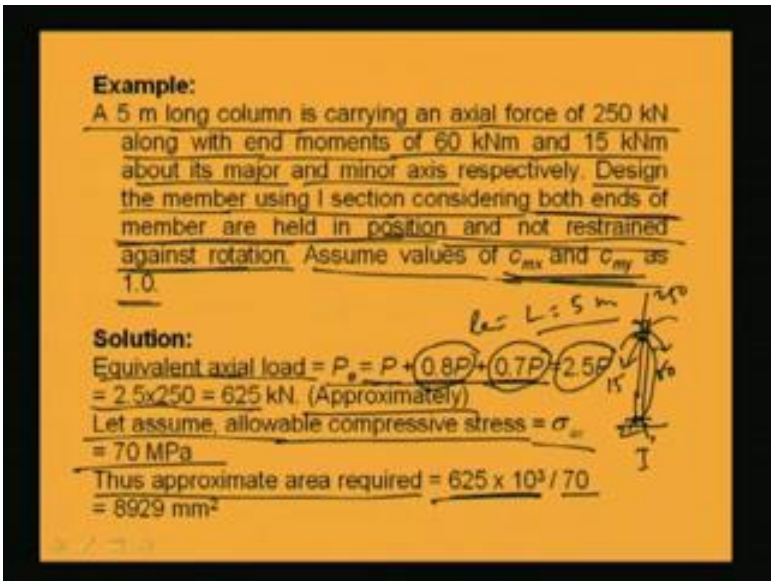

Now, this example is like this that a 5 meter long column is carrying an axial force of 250 kilo Newton along with end moments of 60 kilo Newton meter and 50 kilo Newton meter about its major and minor axis respectively. Design the member using I section considering both the ends of member are held in position and restrained against rotation. Assume values of Cmx and Cmy as 1.0. So, what we have seen here that length is given as 5 meters and the column is having moment in different directions along with load. Load is 250 kilo Newton and moment is one is 60 kilo Newton about major axis and 15 kilo Newton meter about minor axis, and you have to choose I section and values of Cmx and Cmy has been given as 1. It has been told that considering both ends of members are held in position and not restrained against rotation. That means hinge type things. So, l will be effective length, right.

So, first what we will do? As we told first we can find out some equivalent axial load. Equivalent axial load will be P plus, I do not know what will be the value due to moment. Say we are 80 percent increasing due to mx, and say 70 percent due to just approximately we are trying to find out some equivalent load because we cannot find out equivalent load unless we know the section. On approximate section has to be known from which I can find out A by Z ratio. Unless I know A by Z ratio, I cannot find out the equivalent load. So, for the means trial section at the beginning, we have to increase means we have to start with some dimension. So, just we are approximately arbitrarily we are increasing some percentage. Now, the experienced designer can increase this percentage appropriately, but at the beginning stage we may not be able to find out what should be the percentage which would increase. So, let us try with this 80 percent and 70 percent due to moment in x and y direction where going to increase. So, total load is coming say 2.5 P. In place of P, we are making 2.5 P.

So, equivalent axial load will become in place of 250, we are getting 625 kilo Newton. This is approximately. Let us assume some allowable compressive stress sigma ac say for this case 70 Mpa. Now, the approximate area will be how much? That will be the load by sigma ac P by sigma ac. Load is equivalent is 625 kilo Newton and allowable stress is 70 Mpa. So, we are going to get 8929 millimeter square approximate area. Now, what we will do?

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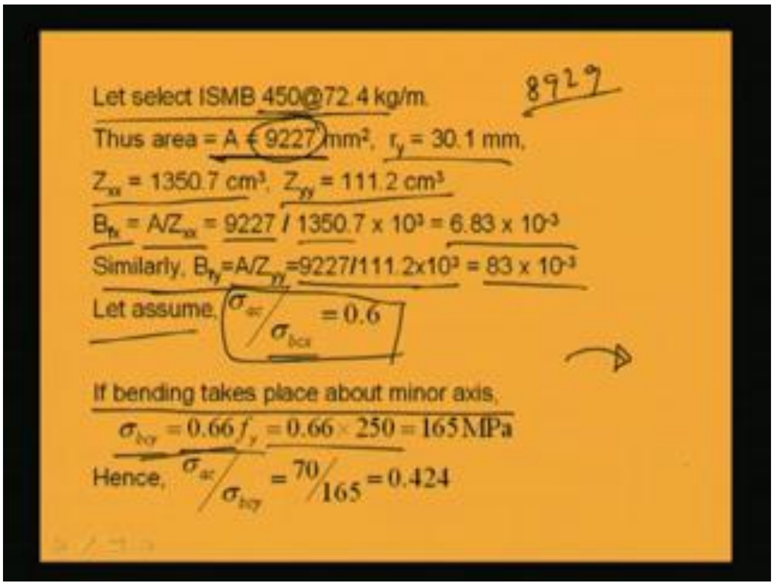

We will select some section. We are going to select ISMB 450 at 72.4 kg per meter. The weight is 72.4 kg per meter. So, we are tying with ISMB 450 because the area required is 8929. So, we are providing the closure area as 9227 millimeter square in place of 8929. This is the required area and we are providing 9227 millimeter square. The closure area we have providing. So, ry will become 30.1 millimeter for ISMB 450 from the SP 6 hand book. In the hand book, other properties are given like Zxx 1350.7 centimeter cube and Zyy is given 111.2 centimeter cube.

Therefore, Bfx is the bending factor will be A by Zxx. So, A is given 9227 and Zxx is given 1350.7 into 10 cube millimeter cube. So, we are getting A by Zxx as 6.83 into 10 to the power minus 3. Similarly, Bfy is equal to A by Zyy is equal to 9227 by 111.2 into 10 to power 3 is equal to 83 into 10 to the minus 3. So, Bfy and Bfx we are getting and let assume because we do not know what the value of sigma bcx is. So, at the starting point, let us assume say sigma ac by sigma bcx is equal to 0.6. If bending takes place about minor axis, then because bending takes place about minor axis that because of this 15 kilo Newton meter. So, sigma bcy will become 0.66fy as per the codal provision. So, we can find out 0.66 into 250 which would be 165 MPa. So, sigma ac by sigma bcy will become 70 by 165 which will be 0.424. So, one ratio is sigma ac by sigma bcx which is going to be 0.6 and another ratio sigma ac by sigma bcy is coming 0.424 is the two ratio we have.

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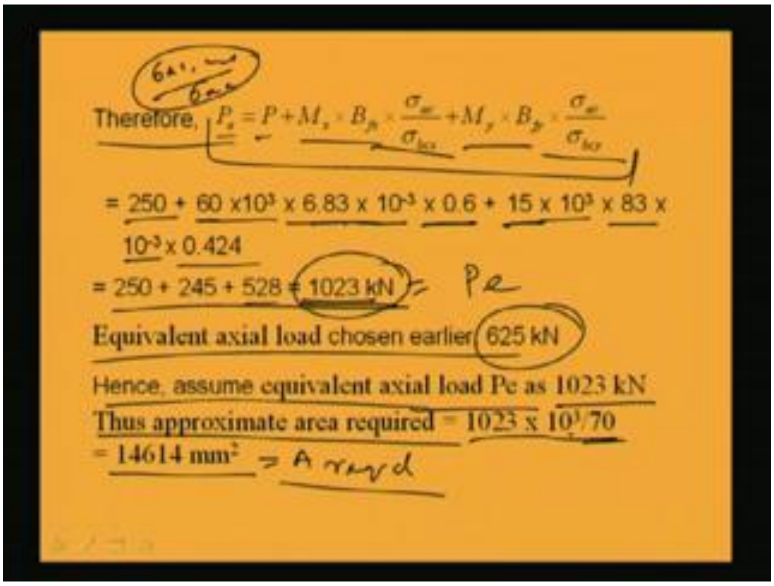

Now, we can find out the equivalent load. Pe is equal to P plus Mx into Bfx into sigma ac by sigma bcx plus My into Bfy into sigma ac by sigma bcy. Now, I do not know what the ratio of sigma ac calculated by sigma ac is. So, I am assuming the simplest one in the conservative side. So, Pe equivalent I am making with this because the modification factor along with Cmx etcetera, we do not know unless we know other details. So, we are getting the equivalent load as 250 plus Mx is 60 into Bfx is 6.83 into 10 to the minus 3 into sigma ac by sigma bc. That also we had assumed because we do not know sigma bcx value.

So, we are assuming 0.6 plus moment in y directing My is 15 into 10 cube into Bfy is 83 into 10 to the minus 3 into sigma ac by sigma bcy is 0.2424. So, if we put the values of Mx My Bfx Bfy and other stresses, we can find out the value as 250 plus 245 plus 528 is equal to 1023 kilo Newton. So, the equivalent load we are going to get is 1023 kilo Newton, and at the earlier we considered the equivalent load as 625 kilo Newton. So, equivalent load we are going to get as 1023 kilo Newton whereas, earlier we have considered 625 kilo Newton. So, this is how it varies means is very difficult to find what is the equivalent will come. Now, let us assume the equivalent axial load Pe as say 1023 kilo Newton. Now, we can find out the details. So, the approximate area we will require is 1023 kilo Newton by the sigma ac which will become 14614 millimeter square. This is the area required.

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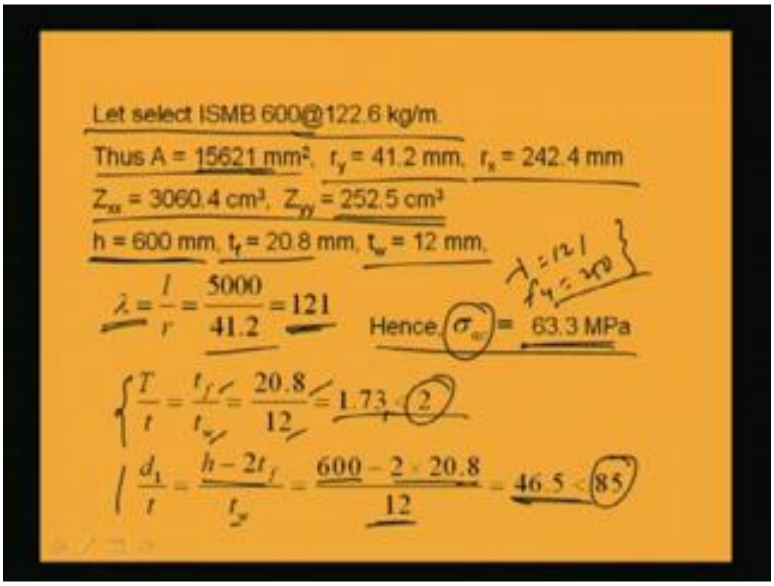

So, area required where we are going to get, we can find out the section and the section is coming ISMB 600 at 122.6 kg per meter. So, with this section, the area is provided as 15621 millimeter square. Radius of gyration is given 41.2 millimeter in y direction and rx is given 242.4 millimeter. So, from that table of SP 6 that hand book where you will get all the details like Zxx is 3060.4 centimeter cube, Zyy is 252.5 centimeter cube, and other parameters are also given all the required parameters is given in the table. Over all depth h is given 600 millimeter, thickness of flange is given 20.8 millimeter and thickness of wave is given 12 millimeter.

Now, I can find out the lambda. Lambda is the slenderness ratio l by r which will become 5000 by 41.2, that is 121. Now, for this lambda, I can find out sigma ac value as 63.3 Mpa. The allowable compressive stress is coming 63.3 MPa for lambda is equal to 121 and fy is equal to 250. For these two values in table 5.1, we can find out the value sigma ac as 63.3 Mpa. Again T by t is nothing, but the thickness of flange by thickness of wave that is 20.8 by 12 which is given. So, this is becoming 1.73 which is less than 2. Again d 1 by t is h minus 2 tf by tw. That means the h is the overall depth is 600 minus 2 into flange with thickness by wave thickness. So, this is coming 46.5 which is less than 85. So, T by t is less than 2 and d 1 by t is less than 85.

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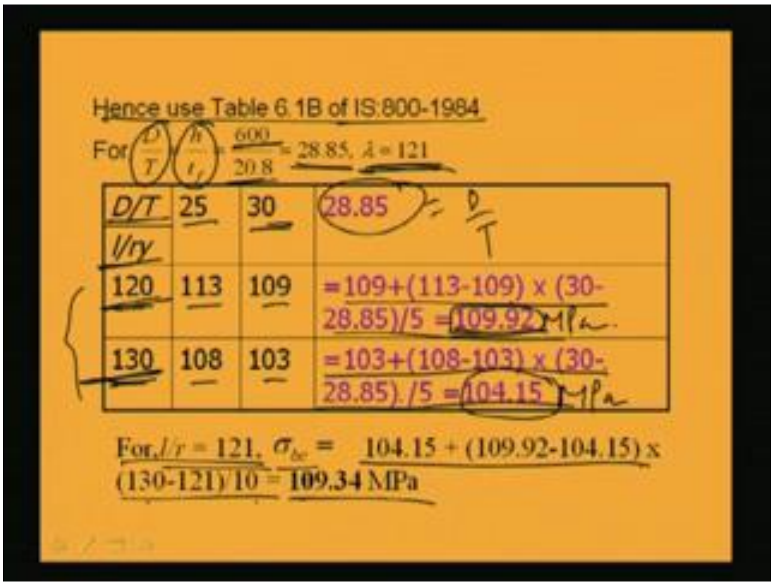

Accordingly, we will be referring table 6.1 B of IS: 800-1984. So, as per the table 6.1 B, now we have to find out what d by t ratio is. That is given as h by tf d means overall depth that is 600 by thickness of flange. So, this is coming 28.85 and lambda is given means we have calculated is 121. Now, for d by t ratio and for l by r ratio, it is given the sigma bc value has been given. Now, we have to find out for lambda is equal to 121. Now, for lambda 120, the values are given here and lambda 130, values are given here. So, at d by t as 28.85, the values can be interpolated from this. That will be 109 plus 113 minus 109 into 30 minus 28.585 by 5. 5 is the difference between these 230 minus 25. So, this is becoming 1092.92 Mpa. Similarly, for lambda is equal to 130, the values of sigma bc at d by t is equal to 28.85 can be obtained from this, that is 103 plus 108 minus 103 into 30 minus 28.85 by 5 is equal to 104.5 Mpa.

Now, for d by t at 28.85, we are getting the value as 1092.92 MPa and 104.15 MPa for lambda is equal to 120 and for lambda is equal to 130. Now, for lambda is equal to 121, again I can find out through the interpolation of the values. So, sigma bc can be found out 104.15 plus 109.92 minus 104.15 into 130 minus 121 by 10. 10 is the difference between these two. So, I am finally getting sigma bc value is 109.34 Mpa. So, this is how the value of sigma bc can be found out through the interpolation. So, in this way I can find out the value of sigma bc.

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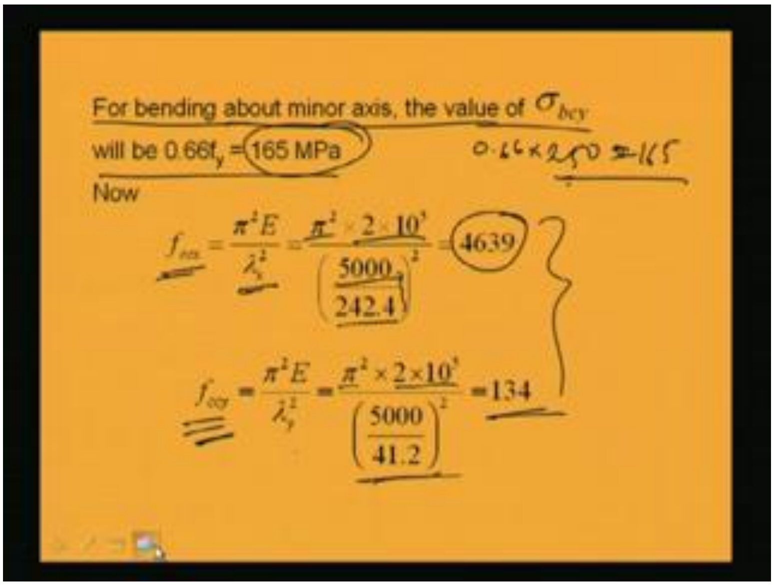

Now, for bending about minor axis, we know sigma bcy will become 0.66fy. That means 0.66 into 250 that will become 165 MPa. So, sigma bcy will be 165 Mpa. Again fccx and fccy, we have to find out fccx is pi square E by lambda x square. So, pi square into E means 2 into 10 to the 5 and lambda is l by r l is 5000 and r is 242.5 rx which is given. So, we are going to get 4639. Similarly, fccy will be pi square E by lambda y square is equal to pi square into 2 into 10 to 5 by lambda y square means 5000 by 41.2 whole square is equal to 134. So, we are getting fccx and fccy as these two.

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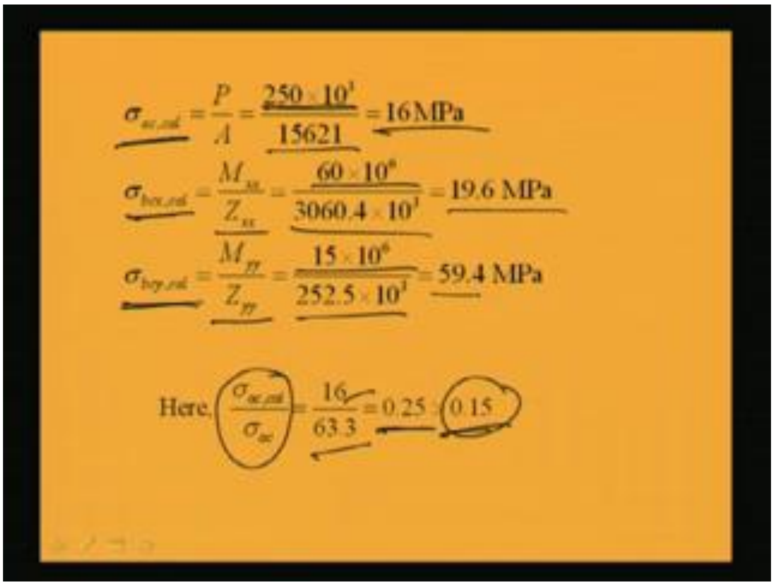

So, we can calculate the sigma ac. Sigma ac calculated to be P by A, where P is the axial force and area is the cross-sectional area of the selected member 15621 millimeter square. This is coming 16 Mpa. Similarly, sigma bc is calculated will be Mxx by Zxx. So, Mxx is 60 kilo Newton meter and Zxx is 3060.4 centimeter cube. Now, if we calculate those values, we will get 19.6 Mpa. Similarly, sigma bcy calculated will be Myy by Zyy. Myy is given 15 kilo Newton meter and Zyy is given 252.5 centimeter cube. So, we are getting 59.4 Mpa. Now, again we have to calculate the ratio of sigma ac calculated by sigma ac. This is becoming 16 by 63.3 is equal to 0.25. This is greater than 0.15.

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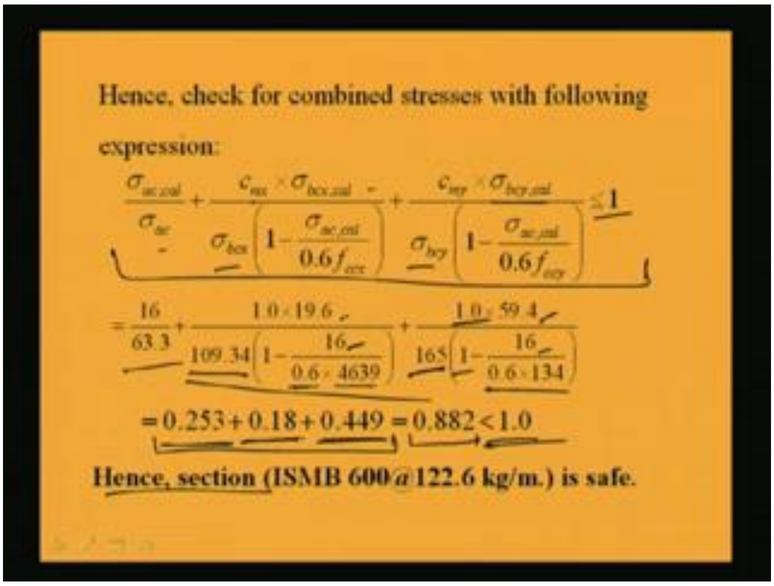

So, if it is greater than 0.15, we have to check with this equation, that is combined stress can be found out sigma ac calculated by sigma ac plus Cmx into sigma bcx calculated by sigma bcx into 1 minus sigma ac calculated by 0.6 fccx plus Cmy into sigma bcy calculated by sigma bcy into 1 minus sigma ac calculated by 0.6 fccy which is less than or equal to 1. So, if I put the value, this will become 16 by 63.3 plus 1 into 19.6 by 109.34 which is sigma bcx into 1 minus sigma ac calculated is 16. This 0.6 into fccx is value is 4639 plus cmy also has been taken as 1 as it is given and sigma bcy calculated as 59.4 and sigma bcy is the permissible stress which is 165, because of minor axis, it is bending and then, 1 minus 16 into 16 by 0.6 into 134. 134 is the fccy value.

So, if you calculate all those, we will get sigma ac calculated by sigma ac as 0.253 and then, 0.18 plus 0.449 if we add all these, we will get 0.882 which is less than 1. So, if it is less than 1, section is safe. That means the section whatever we had provided IAMB 600, that is same. So, in this way we can design a compression member along with moment. That means a beam column member can be designed in this way.

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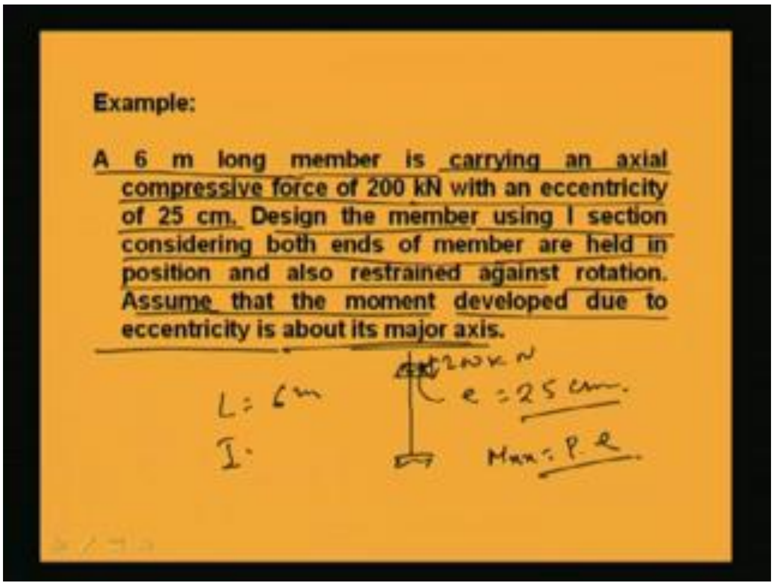

Another example we will be solving which is little different type that is a 6 meter long member is carrying an axial compressive force of 200 kilo Newton with an eccentricity of 25 centimeter. Design the member using i-section considering both ends of members are held in position and also restrained against rotation. Assume that the moment developed due to eccentricity is about its major axis. So, length is given as 6 meter and this is restrained against rotation and its displacement. That means both side is fixed, and 200 kilo Newton force is given with an eccentricity of 25 centimeter, right. We have to choose I section for making and moment is developed about due to eccentricity about major axis. That means Mxx will be P into e. So, we have to find out accordingly. So, what we will do?

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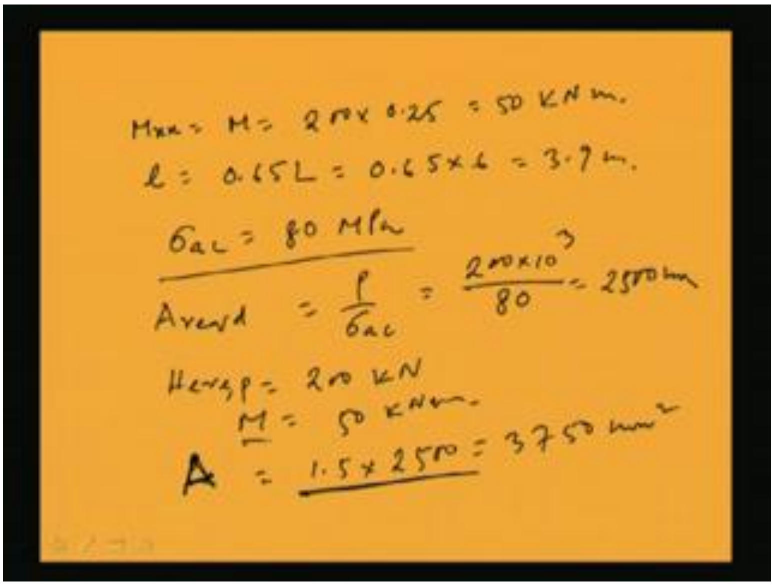

So, M is a uniaxial case. So, we can find out P into e that is 200 into 25 centimeters means 0.25 meter that is coming 50 kilo Newton meter and effective length will become 0.65 L because of this condition of the end. So, 0.65 into 6 is becoming 3.9 meter. Assume allowable sigma ac value as say 80 MPa this case let us assume sigma ac as 80 Mpa. So, area required will be how much? It will be P by sigma ac. So, this will become 200 by 80. This is 2500 millimeter square. Here P is equal to 200 kilo Newton and M, we are getting 50 kilo Newton meter. So, let increase the load by say 50 percent. So, if we increase 50 percent, so area also will increase by 50 percent. So, 1.5 into area required. So, area required I have increased by 50 percent due to the presence of moment. So, the required area is becoming 3750 millimeter square.

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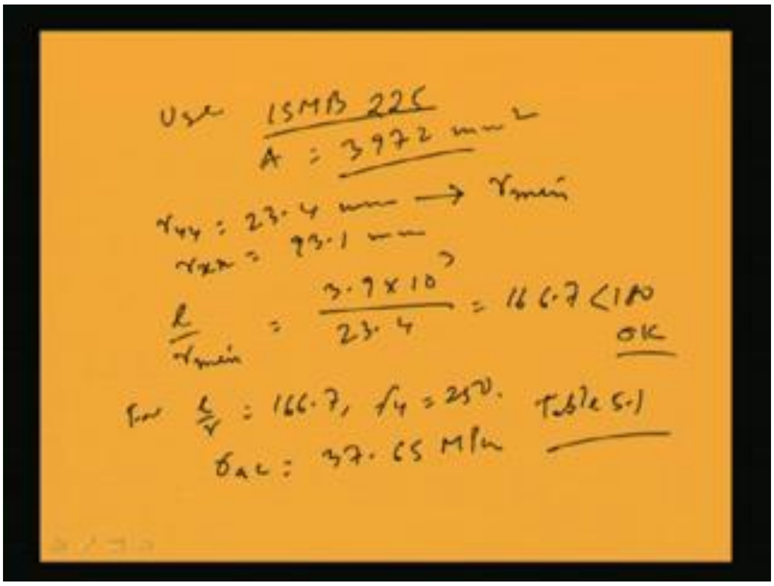

Accordingly, we can use ISMB 225, where the area is given 3972 millimeter square and we need area 3750 millimeter square. So, the area has been chosen as ISMB 225. So, from the structural we will get other properties like ryy 23.4 millimeter. Similarly, rxx will be 93.1. So, ryy will be the r minimum, right. So, l by r minimum I can find out l is the effective length which we calculated as 3.9 meter by 23.4. Ryy this is coming 166.7 which is less than 180. So, I can make it as from slenderness ratio point of view. Next what I will do? Now, for l by r is equal to 166.7 and fy is equal to 250. I can find out sigma ac value as 37.65 MPa from table 5.1. So, sigma ac value I can find out.

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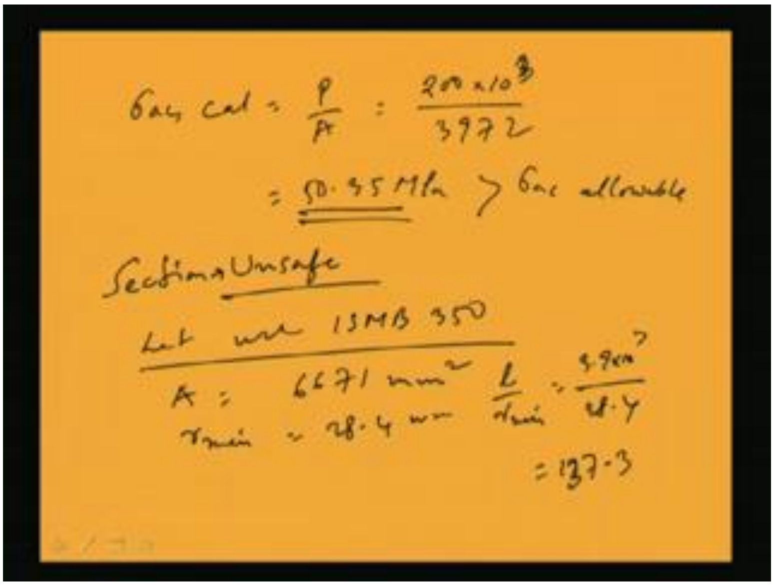

Now, the moment I am finding out sigma ac value, I can find out also sigma ac calculated because I have to find out the ratio. So, P by A is equal to 200 into 10 cube by area is 3972. So, this is becoming 50.35 MPa which is greater than sigma ac allowable because sigma ac allowable value is given as 37.65 MPa and calculated value is coming 50.35 Mpa. So, this is unsafe. The section is unsafe. So, you have to increase the sectional dimension. So, now let us use ISMB 350. If we use ISMB 350, then area is becoming 6671 millimeter square. So, area we are getting and r minimum can be found as 28.4 millimeter. So, lambda can be found out l by r minimum which will be 3.9 into 10 cube by 28.4. This will become 137.31 by r.

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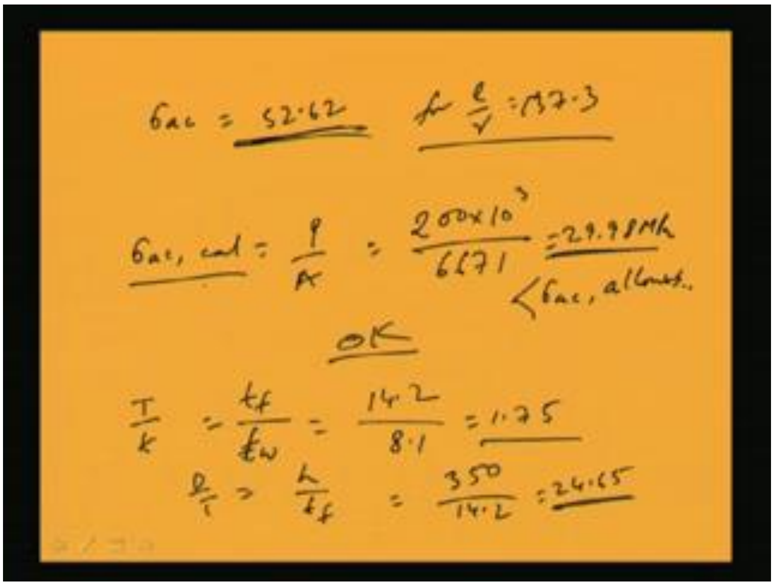

Now, from table 5.1, I can find out sigma ac value. This will become 52.62 for l by r as 137.3. Sigma ac value can be found out from the interpolation of that data given in table 5.1. Now, sigma ac calculated can be found out as P by A. This will become 200 cube by 6671. So, this is coming 29.98 Mpa. This is becoming less than sigma ac allowable. So, what we are saying if we increase the sectional properties means sectional dimension to ISMB 350, then we are getting the section from compressive stress point of view because sigma ac calculated value is coming 29.98 whereas, allowable stress is coming 52.62.

Now, I have to find out sigma bc. So, here we have to find out fast T by t. T by t is basically thickness of compression flange. So, tf and then thickness of wave tw, right. So, thickness of compression flange is given 14.2 and thickness of wave is given 8.1. So, this is coming 1.75, right. So, T t ratio I am getting as 1.75. Similarly, d by T ratio is the overall depth by the thickness of compression flange. So, this will become overall depth is 350 and the thickness of flange is 14.2. So, this will become 24.65. So, D by T is I am getting 24.65.

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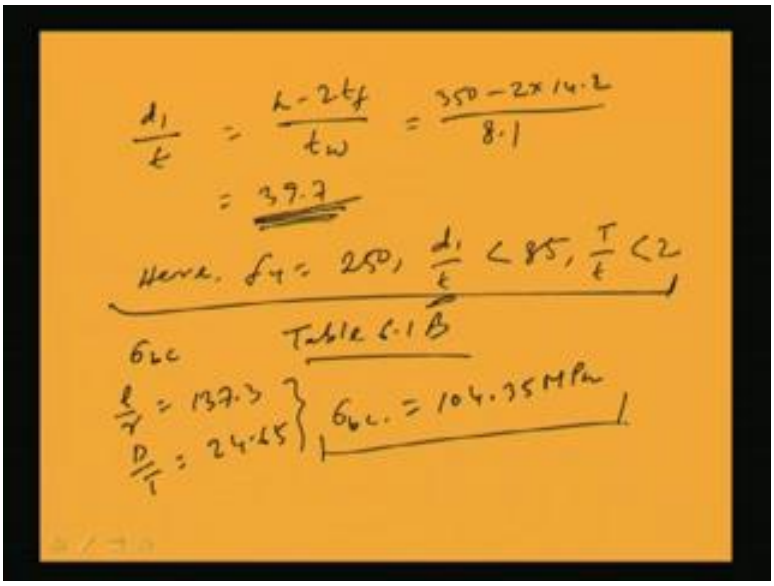

Another thing is required is d 1 by t that is basically h minus 2 tf by tw. So, this will become 350 minus 2 into thickness of the flange 14.2 by 8.1 is equal to 39.7. So, d 1 by t is coming 39.7. So, here what we are seeing that fy is 250 d 1 by t is less than 85 and T by t is less than 2 because T is coming 1.75 and d 1 by t is coming 39.7. So, corresponding to this, we can use table and we can find out the value of sigma bc from table 6.1 b. So, sigma bc we can find out for l by r is equal to 137.3 and D by T is equal to 24.65 which we have calculated. So, for these two values, I can find out the value of sigma bc. So, this sigma bc value will become 104.35 Mpa, right. So, the sigma bc value, the allowable stress due to bending in compression will be 104.35 Mpa.

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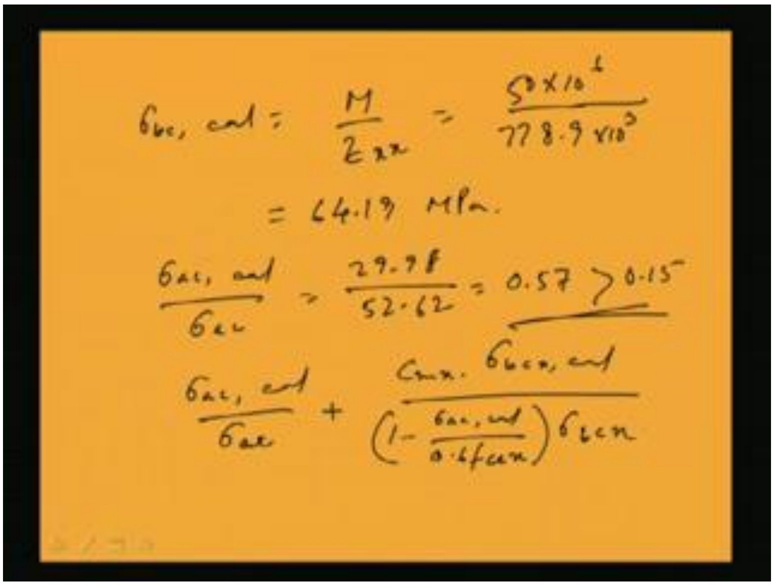

Now, we have to calculate the sigma bc calculated value. This is M by z axis. So, M is 50 to 10 to the power 6 and Zxx is 778.9 centimeter cube. So, we are going to get sigma bc calculated as 64.19 Mpa. Again sigma ac calculated by sigma ac will be 29.98. The calculated value is 29.98 and permissible value is 52.62 which we have calculated. This is coming 0.57 which is greater than 0.15. So, we have to put the equation accordingly. That means the equation will be sigma ac calculated by sigma ac plus Cmx into sigma bcx calculated by 1 minus sigma ac calculated by 0.6 fccx into sigma bcx. Now, we have to put the values of all details.

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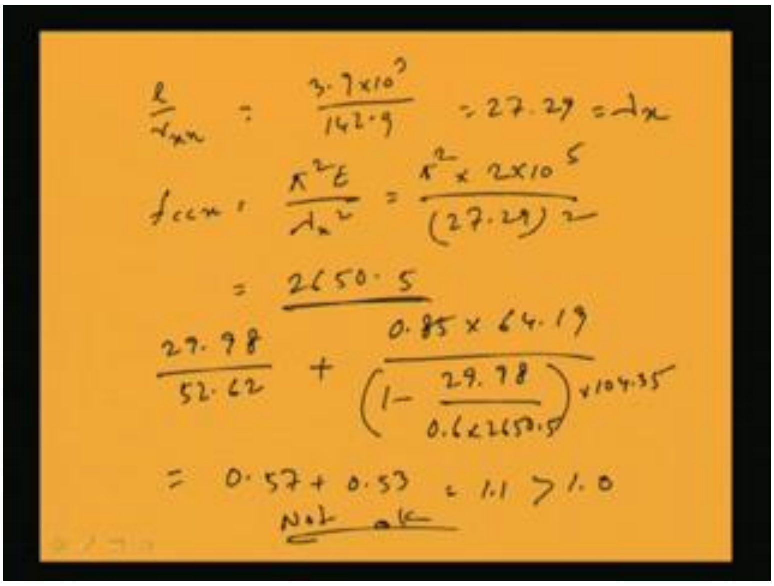

Here l by rxx we know as 3.9 into 10 cube by rxx was 142.9. So, this is coming 27.29 which is basically lambda x. So, fccx can be calculated pi square E by lambda x square. So, if we put those value is 2 into 10 to the power 5 MPa and lambda x is 27.29. So, we can find out the value as 2650.5. So, fccx values we are getting. Now, if we put this equation, this fccx value and other details if we put in this equation, we will get 29.98 which is sigma ac calculated and sigma ac is 52.62. Cmx as per the condition, this is 0.85 into 64.19 is the sigma bcx calculated which we have calculated already into 1 minus sigma ac calculated is 29.98 by 0.6 into fccx. That is given means calculated as 2650.5 into 104.35. This is becoming 0.57 plus 0.53 equal to 1.1 which is greater than 1. So, you have to go for redesign.

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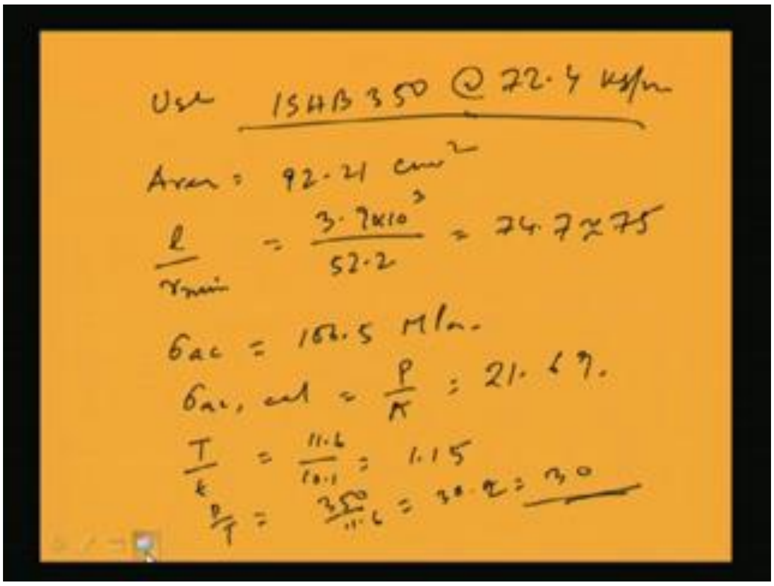

Now, if we redesign say use ISHB different types of I section 350 at 72.4 kg per meter. The weight is this. So, what we can get here? We will get area that is 92.21 centimeter square. L by r minimum will be l is 3.9 and r minimum is 52.2 becoming 74.7. So, now we can find out sigma ac value from table 5.1 that we are going to get 106.5 and sigma ac calculated will be P by A. So, that we will be getting 21.69 and here T by t ratio is 11.6 by 10.1 which will be 1.15 and d by T is 350 by 11.6. This will be becoming 30.2 say 30.

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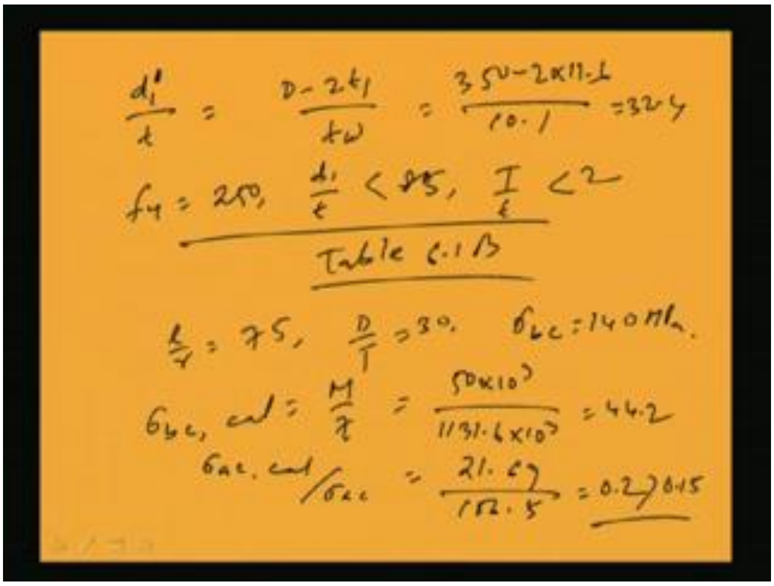

Another thing is d 1 by t. This will be D minus 2 t 1 by tw. So, 350 minus 2 into 11.6 by 10.1 is 32.4. So, here fy is equal to 250 d 1 by t less than 85 and T by t less than 2. So, refer to table 6.1 B. So, for l by r is equal to 75 and d by T is equal to 30. We can find out sigma bc value as 140 Mpa, right and sigma bc calculated will be M by z. So, 50 into 10 cube is M and z is 1131.6 into 10 cube. So, from this I am going to write as 44.2 Mpa and again sigma ac calculated by sigma ac, we are going to get 21.69 by 106.5 which is 0.2 greater than 0.15.

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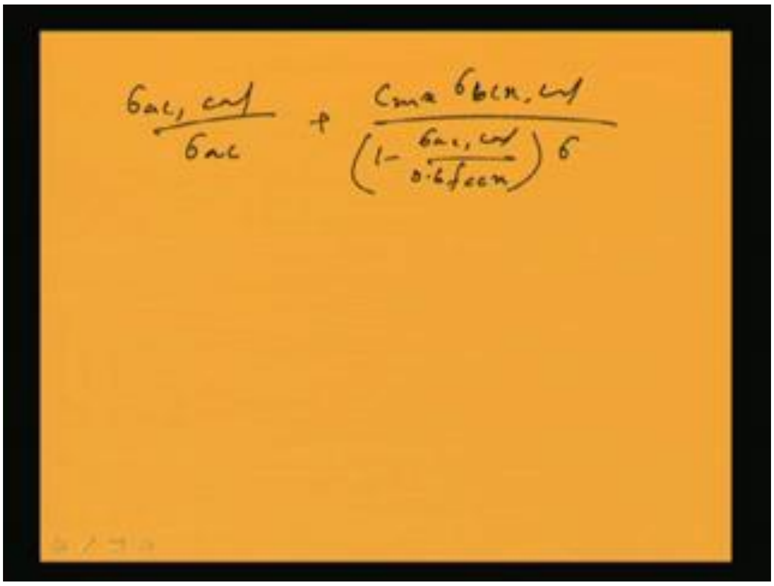

So, we have to use the earlier formula that is sigma ac calculated by sigma ac plus Cm x sigma bcx calculated by 1 minus sigma ac calculated by 0.6 fccx into sigma which is less than 1.0.

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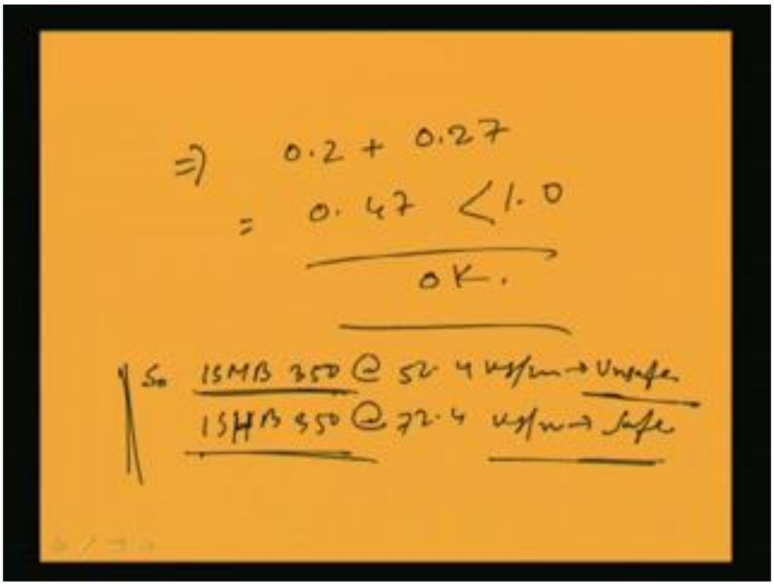

So, ISMB 350 at 52.4 kg per meter, this is unsafe we have seen whereas, ISHB 350, this weight is 72.4 kg per meter. That is safe. So, we have to be little bit cautious about selection of the section. Same size of section with ISHB this is safe whereas, ISMB is unsafe. So, in this way we can try and we can find out a suitable section which will be economy in terms of material properties, material cost and then, we can design the appropriate section. So, in this way we can design a beam column. With this today I like to conclude this lecture.

Thank you.