Design of Steel Structures
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Module - 4
Lecture - 4
Tension Members
Design of Tension Member Subjected to Axial and Bending

Hello. Today I will be discussing on design of member subjected to axial load and bending. Bending stress will develop and tensile stress due to bending has to be taken care. If the bending moment is extra means additional to tensile forces is developed.

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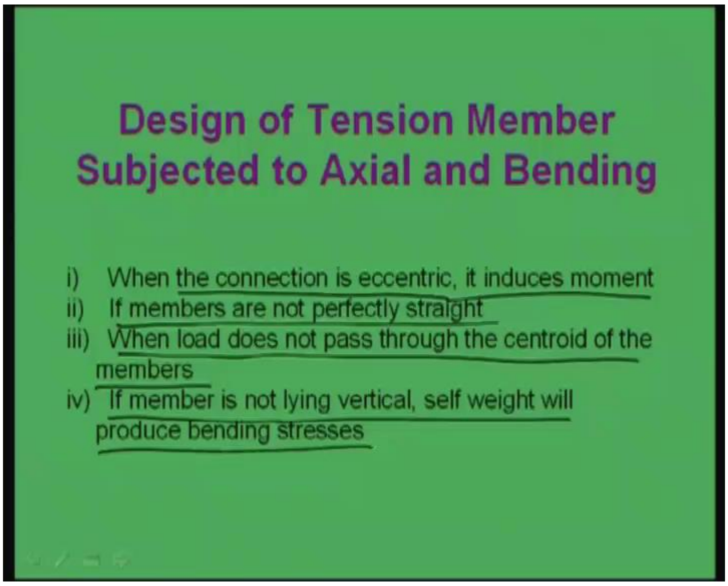

Now, when it develops, it develops basically when connection is eccentric. It induces moment. This is one case. Another case is if members are not perfectly straight and when the load does not pass through the centroid of the members. Another case if member is not lying vertical, self-weight will be producing bending stresses, right.

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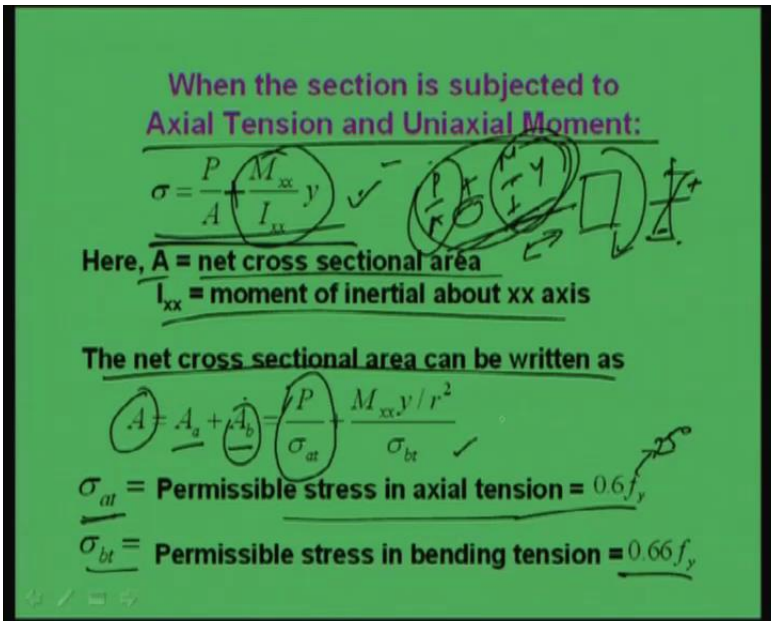

Now, how to analyze and design when the member is subjected to axial tension and say uniaxial moment? Now, there are two scope means one is axial tension and moment in one direction. Another is moment in two directions along with axial tension. That means axial tension along with biaxial moment. So, both the cases we will see.

Now, if the member is subjected to axial tension and moment, then we can write the stresses developed as P by A due to axial tension and M by I into y due to the moment. Now, if the moment is in x direction, then Mxx by Ixx into y we can make it. Now, if the section is like this and moment is providing like this, then we can find out the stresses like this. So, here you see not only axial hum means not only the stresses due to bending moment is coming, not only tension, but also compression. This is tension, this is compression, right. So, basically in case of axial force and moment, the stress will be P by A plus minus M by I into y.

Now, minus we are not considering, because minus is basically because of compression. Now, minus we are not considering, because if minus we consider, it will become reduce. So, if we design in terms of P by A, it can withstand P by A minus M by I into y also, but we have to see the worst case when it will come. When both the stresses are going to be added, when both the stresses are going to be added, in that case what will happen P by A plus M by I into y. So, we will be focusing our analysis and design only on the addition part that plus M by I into y not minus M by i.

If minus comes into picture, it is going to reduce or if M by I into y is more than P by A, then it is going to be compression member. No more it will become tension member. So, that also we have to check whether it is tension member or compression member. Now, here only we will focus on tension little things because we are now focusing our study into the tension forces, tension member design. We are studying that is why we will see only these aspects.

Now, if we see the stress developed due to tension force and the moment that sigma is equal to P by A. What is A? It is net cross-sectional area, this is member, it is net cross sectional area and not the gross cross-sectional area, and Ixx is the moment of inertia about x axis xx axis. Accordingly Mxx is the moment about x axis and y is the distance means the outermost distance. In fact the extreme distance. Now, we can write the net cross-sectional area which is A can be written as Aa and Ab, where Aa is the area required due to the axial force and Ab is the area required due to the bending moment. So, Aa is basically P by sigma where sigma at is the permissible stress in axial tension.

So, permissible stress in fact we know that is becoming generally 0.6fy. So, if fy is the characteristic hum value of the tension, I mean steel, then we can find out the sigma at value. In case of mild steel, this will become 250 as you have seen earlier. Similarly, sigma bt is the permissible stress in bending which can be written as 0.6fy, right. So, A we are getting P by sigma at and Ab area due to bending moment can be written as Mxx y by r square by sigma bt, right. This will be the area which you require for the moment. So, Aa plus Ab, we can write as this.

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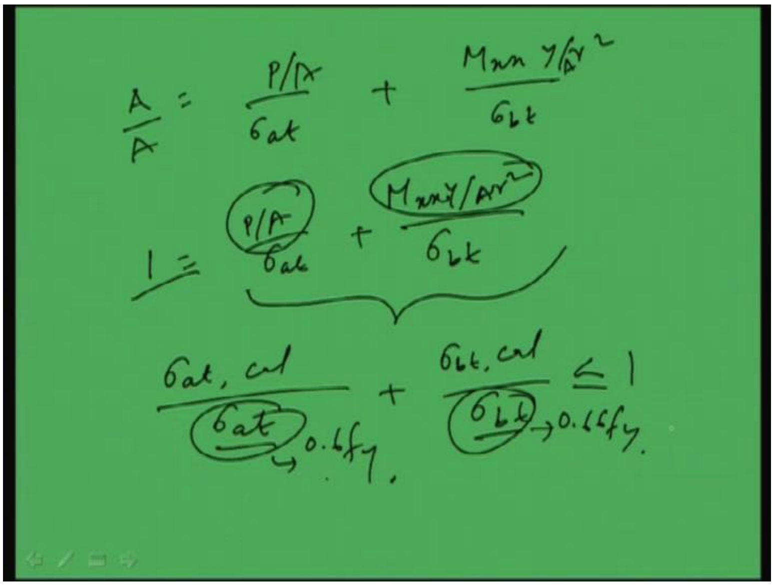

Now, if we divide the A means A is equal to we are writing P by sigma at plus Mxx y by sigma bt by r square. This is the thing we have written. Now, if we divide by A, what will happen? P by A means A by A is equal to P by A plus Mxx into y by Ar square by sigma bt. That means this should be P by A by sigma at plus Mxx y by Ar square by sigma bt. That means the summation of these two should not be greater than 1. So, now P by A is nothing, but the axial stress means axial tensile stress which can be denoted as sigma at calculated. That means the developed stress due to axial force. So, sigma at cal by sigma at we can write plus.

Now, this I can write as sigma bt cal because this is what My by Ar square which is nothing, but the calculated bending stress, that is sigma bt calculated and this is the permissible stress. So, this should be less than or equal to 1 to be in safer side. Now, this is what? This I can write as 0.6fy and this can be replaced by 0.66fy. So, finally, quotient will become sigma at calculated by 0.6fy plus sigma bt calculate by 0.66fy should be less than or equal to 1.

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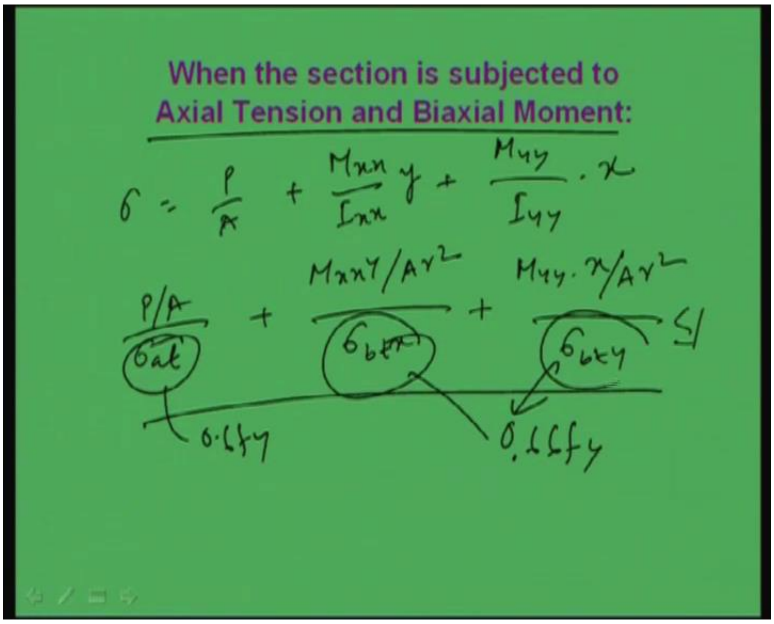

Now, when the section is subjected to axial tension and biaxial moment, what will happen? So, sigma can be written as P by A plus Mxx by Ixx into y plus Myy by Iyy into x, right. So, similarly I can write means P by A is basically sigma at calculated and from the earlier equations means in this way if I want to write. This will become P by A by sigma at by sigma at plus Mxx y by Ar square by sigma bt x plus Myy x by Ar square by sigma bt y should be less than 1. So, this will become again sigma at. This is becoming basically 0.6fy and this is 0.66fy and this is also point sigma bt y also will become 0.66fy.

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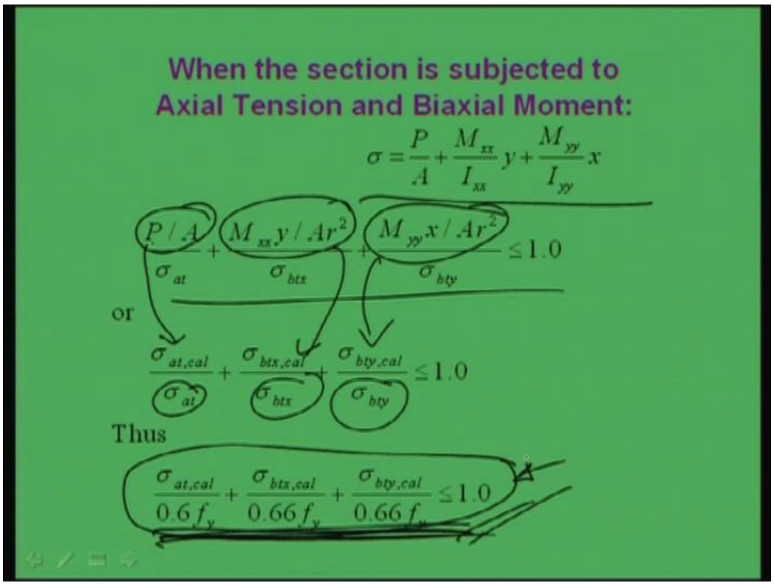

So, finally equations can be written in this form. That means what we are getting that the stress whatever is generating due to biaxial moment, if we make equilibrium, then we are going to get this condition as we have derived in earlier cases for uniaxial moment. Now, this can be written as sigma at cal and this can be written as sigma btx calculated and this can be written as sigma bty calculated. So, now we put these values as 0.6fy and 0.66fy because sigma btx and sigma bty is nothing, but some of the steel material we are taking. So, this condition has to be satisfied. So, these are the two conditions we have to satisfy for uniaxial moment. We have to satisfy this condition and for biaxial moment, we have to satisfy this condition, right.

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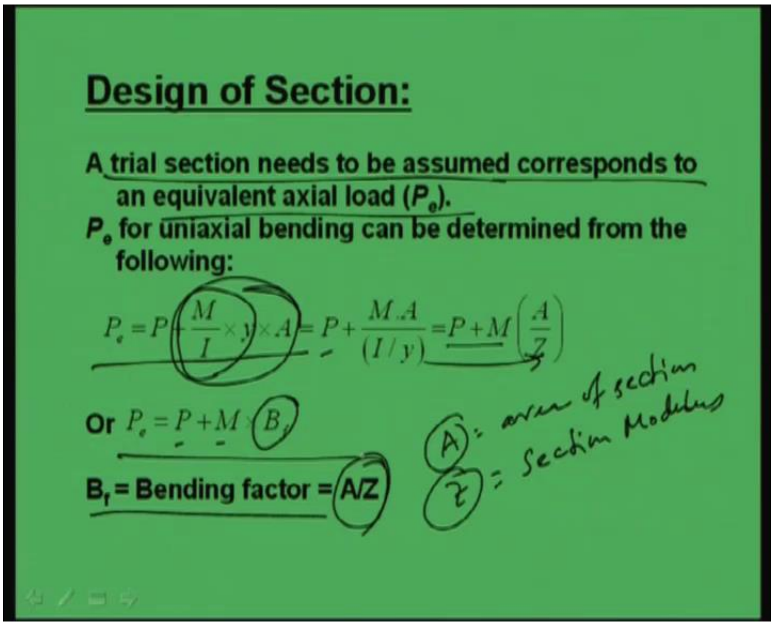

Now, let us go to the design. So, how to design the section? Now, in this case first we have to go for a trial section because we do not know which section we have to go. We have only the load and moment. So, through iteration we have to find out a suitable section. So, one way we can make that equivalent axial load, we can find out M. A trial section needs to be assumed correspondence to equivalent axial load, so that equivalent axial load can be written from this.

Pe is equal to P. P is the axial tension plus M by I into y. This is the stress due to moment into A will become force. That means equivalent force because of presence of moment, so this is becoming P plus if I make MA by I into y. So, I by y is nothing, but the Z. So, P plus M into A by Z or I can write Pe equal to P plus M into Bf, where Bf is called as bending factor. So, bending factor is nothing, but A by Z where A is the area of the section and Z is the section modulus. So, if the member properties we know, if we know the particular section, then we know A by Z. Then, we can find out what is the equivalent load, axial load due to axial tension and due to moment. So, in this way we can find out. Now, this is for the uniaxial moment.

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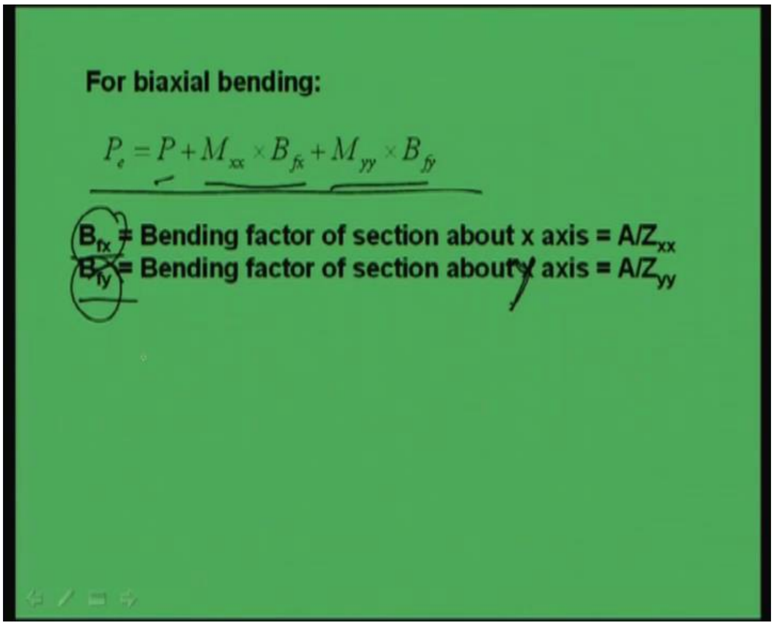

Now, in case of biaxial moment, what will happen in case of biaxial moment? In similar way we can write that P is equal to Pe is equal P plus Mxx into Bfx plus Myy into Bfy, where Bfx is the bending factor of section about x axis which will be A by Z axis and Bfy is bending factor of section about x axis which will be A by Zyy. This will be y axis, right bending factor about y axis. So, if we know Bfx and Bfy because if the section is known, then all the other sectional properties can be found out. So, from that we can easily find out the equivalent axial force due to axial tension and moment.

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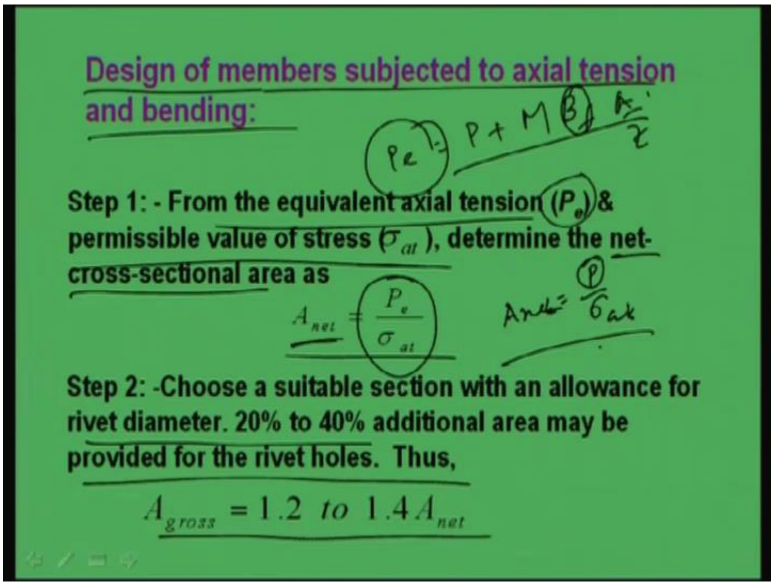

Now, we will see the design steps means if the members is subjected to axial tension and bending, then how to start for the design. So, what we can do? In fact, the things can be done in different way as per the convenient by the designer. He can start and finally, he has to check this equation. That sigma at cal by 0.6fy plus sigma btx cal by 0.6fy plus sigma bty cal by 0.66fy which is be less than or equal to 1. So, finally, the designer has to check this equation whether it is or not. If it is not, it has to increase. The section has to increase.

Now, how to start? It depends on the user means the designer how he will start. One way we can start is that first we can find out an equivalent axial tension Pe and permissible value of stress means from permissible value of stress and from the equivalent tension which has been found out from the earlier equation, we can find out net cross-sectional area which is required. So, what we will do first in first step? We will find out Pe is equal P plus M which is given here. No, M into Bf. Sorry M into Bf Bfx or Bfy, it depends on type of moment or Bf means A by Z. So, the equivalent axial tension first we can find out and from that value and from the permissible value of stress, one can find out the net cross-sectional area. Net cross sectional area can be find out from this equation Pe by sigma at.

Then, we can choose a suitable section with an allowance for rivet diameter. 20 to 40 percent additional area may be provided for the rivet holes. So, gross area can be made as 1.2 to 1.4 times of area net. So, gross area of the section can be found as 1.2 to 1.4 times of the net area because deduction of whole will be there. So, we have to take care. So, in this way we can make. In other way also, we can simply find out A net is equal P by sigma at where P is the axial tension. So, from that we can increase certain percentage, maybe more than 40 percent. Then, we can start, right.

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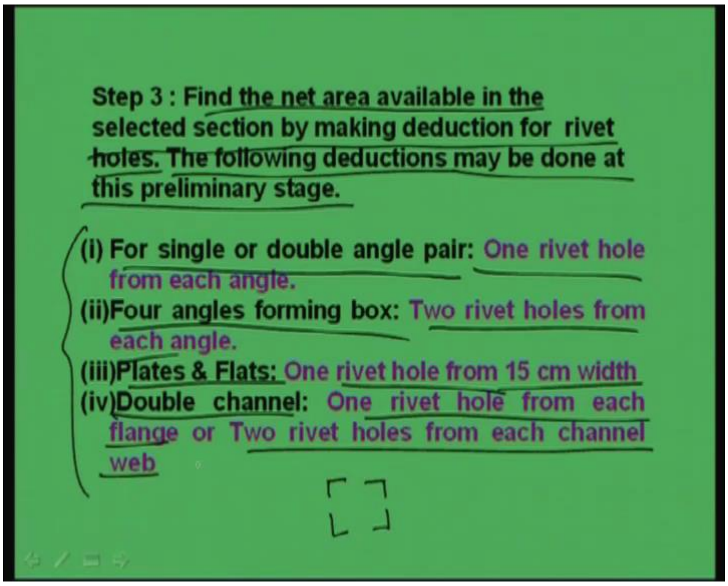

Then, what we will do now? We have to find out the net area. Net area means after deduction of whole and other things, what is the net area available in the section? So, find the net area available in the selected section by making deduction for rivet hole, and the following deductions maybe done at this preliminary stage. So, some conventional things has been given which I have discussed in earlier lecture also that for single or double angle pair, one rivet whole from each angle can be detected, and four angles forming box type means if the angles are like this which is forming box type, 2 rivet whole from each angle can be deducted, and for plates and flats, one rivet whole from 15 centimeter width can be deducted.

So, these are some means guidelines through which we can deduct the appropriate whole means appropriate area from the gross area. Now, in case of double channel, one rivet whole from each flange or two rivets whole from each channel can be deducted.

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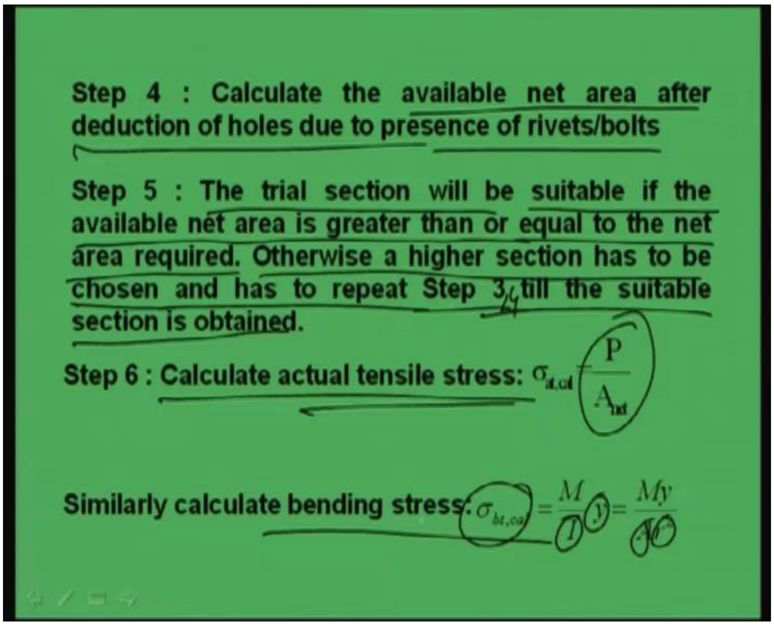

So, with these provisions, we can find out the available net area after deducting the whole due to presence of the rivets and bolts. Then, in step 5 what we will do? Then, the trial section will be suitable if the available net area is greater than or equal to the net area required. That means available net area if it is larger than the net area required, then it is. Otherwise, a higher section has to be chosen and has to repeat step 3 till the suitable section is obtained. So, if this condition does not satisfy, then we have to choose a higher section and we have to again repeat the step 3. In fact, step 3 and 4 till the suitable section is obtained. Then, what we will do?

Then, we will find out the actual tensile stress sigma at calculated which will become P by A net because P is the axial force. So, sigma at the axial stress will become P by A net. So, actual tensile stress we can calculate. Similarly, we can calculate the developed bending stress due to bending sigma bt calculated which is M by I into y or My by Ar square, right. So, for a particular section we know what is I value or A and r square value means radius of gyration, and y is also known. So, we can find out the sigma bt calculated.

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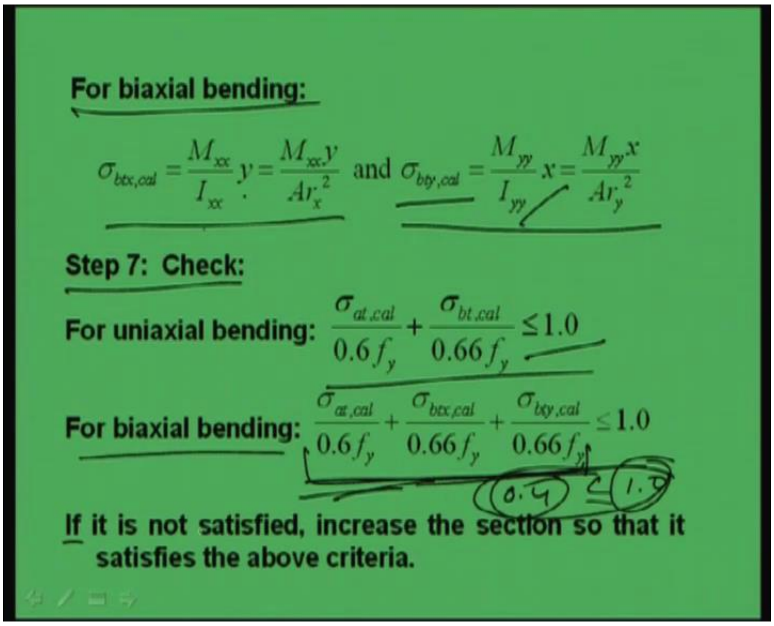

For biaxial bending, we have to calculate the two type of stresses sigma bt x calculated and sigma bt y calculated, right. Sigma bt x will be Mxx by Ixx into y and sigma bt y calculated will be Myy by Iyy into x. So, now we have to check the following condition. This is one condition for uniaxial moment that is sigma at calculated by 0.6fy plus sigma bt calculated by 0.66fy which should be less than or equal to 1 which we have discussed earlier.

Similarly, for biaxial bending we have to check this relation. What is this? That is sigma at calculated by 0.6fy plus sigma bt x calculated by 0.66fy plus sigma bt y calculated by 0.66fy which should be less than or equal to 1. So, now if it is satisfied, then the section is and if it is not satisfied, then you have to increase the section size accordingly, right. Now, at this starting point what section we will consider, it depends on the experience of the designer. Now, if we consider say suppose more than the required, then one can choose.

Suppose these values are coming after calculating all this, value is coming say 0.4. That means, it is much less than 1.0. In this case what we can do? We can reduce the section size and again we can check in similar way. That means it has to become closer to 1 to get economic design. Unnecessary we should not waste the material, right. If we chose a larger section, always it will be safer side, but wasting the material means it is economic in terms of cost, right. So, we have to think in that way also. If this becomes more than 1, then we have to in any case have to increase to satisfy this to make the section safe, right.

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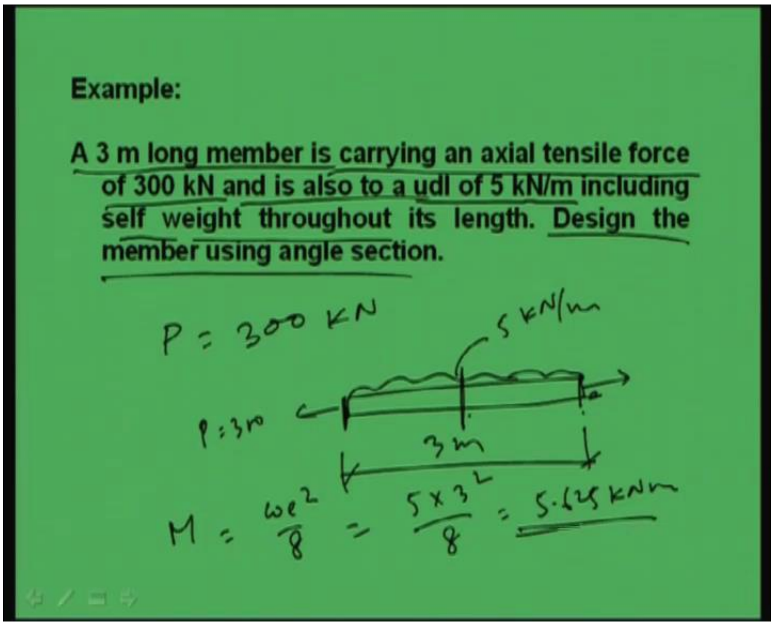

Now, with this discussion it will be easier if we go through one example. Then, we will see how to design and what are the aspects we have to consider and then, we will understand how simple it is to design an axial member. That means a member having axial force as well as bending. Question is a 3 meter long member is carrying an axial tensile force of 300 kilo Newton. So, force is 300 kilo Newton, and is also a UDL of 5 kilo Newton meter. That means, if the length is like this, then a UDL of 5 kilo Newton per meter is also there including self-weight throughout its length design the member using angle section design.

So, this length is 3 meter UDL load is given, right and this force is also axial force is given this P is equal to 300 kilo Newton. Now, we do not know the support condition here. So, let us assume the simple supported condition. Then, we can find out the maximum moment which is developing at the middle will be wl square by 8, right. So, let us design with the upper value. That means wl square by 8 which is the maximum. So, if we consider wl square by 8, this will become 5 into 3 square by 8, right. So, we can find out the value as 5.625 kilo Newton meter, right. So, the moment is coming 5.625 kilo Newton meter.

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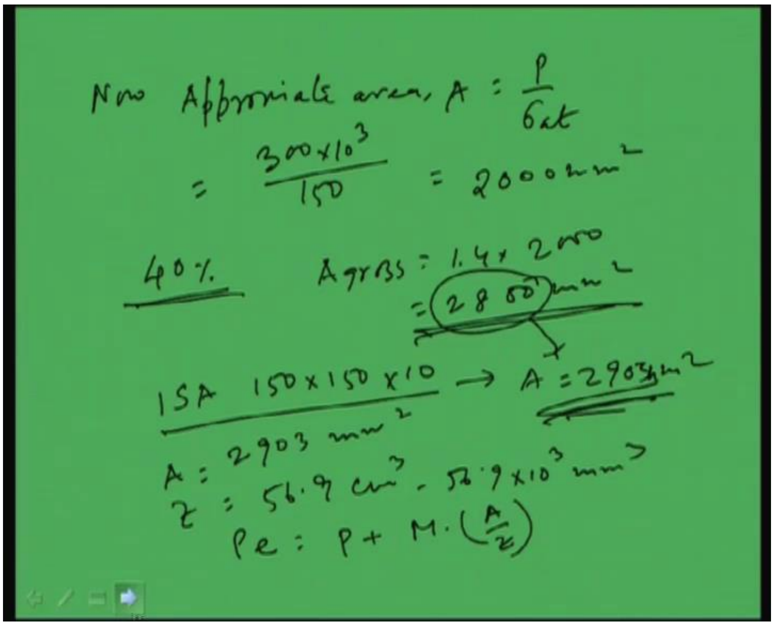

Now, approximate area, say first we have to find out some approximate area say this will become P by sigma at. So, this will be the load is 300 kilo Newton sigma at will be 150. So, this is coming 2000 millimeter square, right. Now, let us increase 40 percent of area, right. If we increase 40 percent extra, then A gross will become say 1.4 into 2000. So, this is becoming 2800 millimeter square. So, with this area now we have to find out a suitable section, right.

Now, from handbook of SP-6, we can find out a suitable section of say ISA 150 by 150 by 10 in which the area is becoming 2903 millimeter square, right. So, we have to find an appropriate section in which the area would be closer to this, but more than this. So, considering this aspect, we are getting a section of 150 by 150 by 10, right and from the table of SP-6 we are getting corresponding value of Z as 56.9 centimeter cube. That means 56.9 into millimeter cube, and area is 2903 millimeter square. So, we can now find out the value of Pe. Pe will be P plus M into A by Z.

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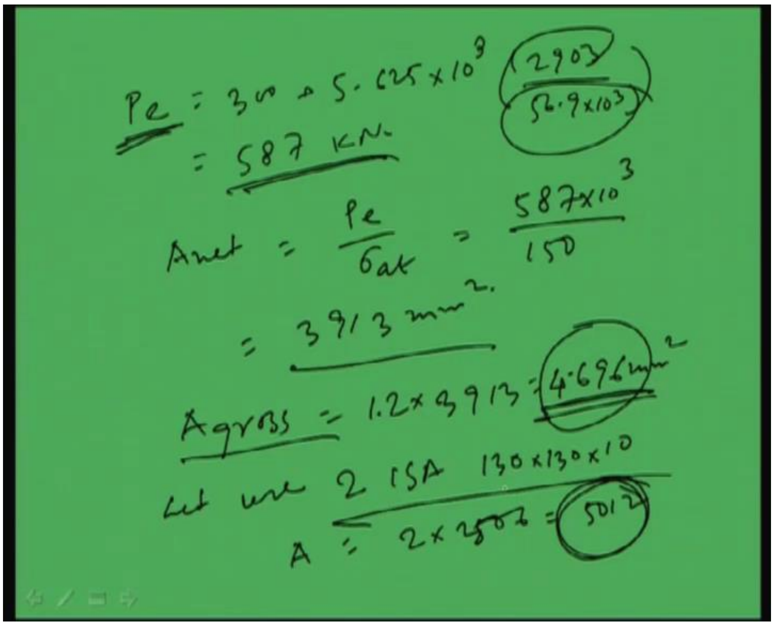

So, if we put the values of P and M by and M and A and Z we will get Pe is equal to P is 300; M is 5.625 kilo Newton meter. So, if I make millimeter 10 cube into 2903 by 56.9 into 10 cube, right. So, equivalent load we are going to get as 587 kilo Newton, right because you see first we have not considered means we have not calculated P because unless we know the A and Z, we will not be able to find out the equivalent load. So, first our objective is to start with we will consider some net means, some gross area. After finding out the net area considering only tensile force, then we are going to get the gross area and from that we are finding out some appropriate section. After finding out appropriate section, we will find out the equivalent load and then, again we can find an approximate section.

Now, from here A net will be Pe by sigma at. That means 587 by 150. That means net area required will be 3913 millimeter square, right. So, from equivalent load we are saying that we need an area of 3913 millimeter square net area. That means gross area will be required. Gross means because of deduction of whole etcetera, we have to increase little. So, may be 20 percent we can increase. So, if we increase this, we are this is getting 4696 millimeter square.

So, gross area we are going to get. So, with this now we have to find out a suitable section again because the earlier section will not be able to take care of that much load. So, let us say 2 ISA 130 by 130 by 10, right. Two angle sections we are going to use.

Then, area with this angle section will become 2 into 2506 that is 5012. So, in place of 4696, we are using 5012 as gross area with the use of two angle sections of 130 by 130 by 10, right.

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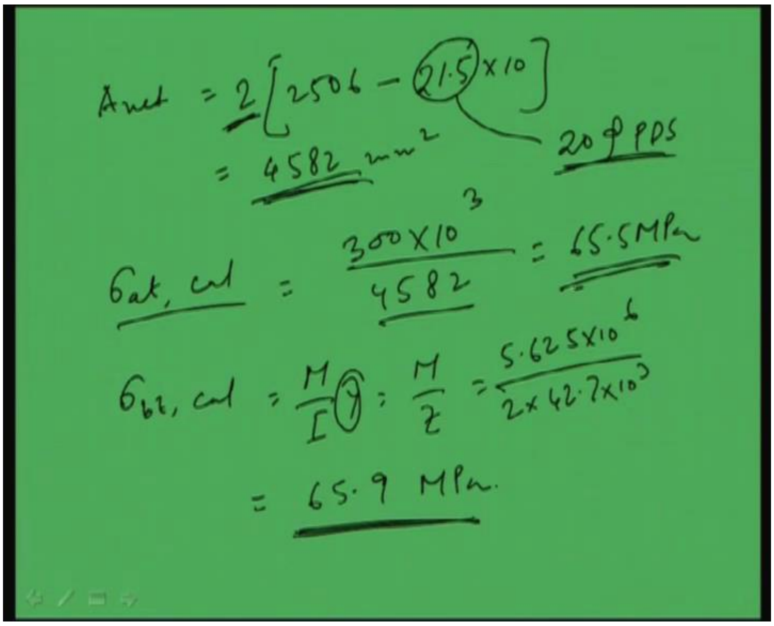

Now, we have to find out the net area. So, net area will become 2 into this is the area gross area, and we have to reduce the whole because of whole we have to reduce the area, right and two angle that is why we have multiplied with 2. So, this is becoming 4582 millimeter square. This 21.5 is the gross whole diameter using 25 power driven soft rivet. Let us use 25 power driven soft rivet, and then gross diameter will become 21.5 millimeter, right. So, the area is becoming 4582 millimeter square, right. Now, we can find out sigma at calculated because now we know the net area.

So, sigma at calculated will become the area. We have 4582 millimeter square load is 300 into 10 cube. So, if we make this, this is becoming 65.5 Mpa load by area, right. Similarly, sigma bt calculated here only uniaxial moment, we are considering only one direction moment. So, this will become M by I into y or M by Z we can write. So, M is 5.625 into 10 to the 6. This is the moment, and Z will become 2 into 42.7 into 10 cube. This is the Z which is given in the code. So, from this the value is coming 65.9 Mpa. So, bending stress due to moment is coming 65.9 Mpa. This is the maximum stress developing due to bending considering y as maximum, right. So, we have sigma at calculated and sigma bt calculated, right.

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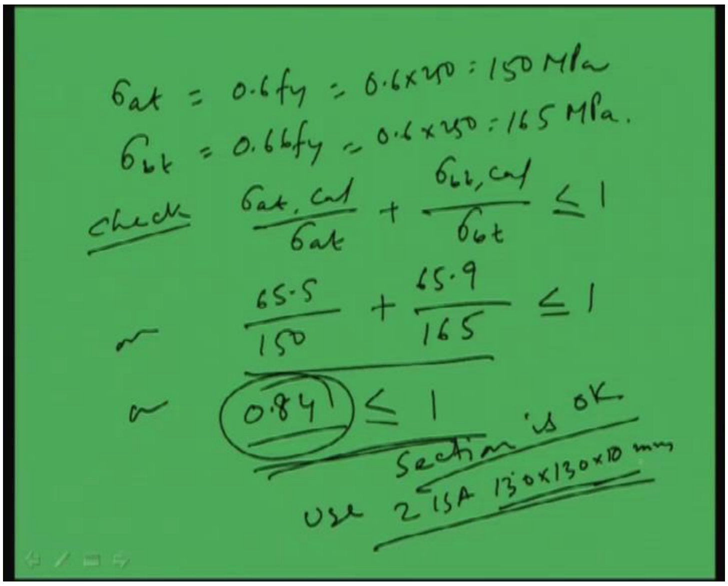

Now, the permissible value of sigma at we know that is 0.6fy, that is 0.6 into 250 means 150 Mpa and permissible value of sigma bt bending stress that will be 0.66fy. So, if we calculate this, this will become 165 Mpa. Now, we have to check whether this is or not, that is sigma at calculated by sigma at plus sigma bt calculated by sigma bt should be less than or equal to 1. So, if we see now what sigma at calculated is, we have that is 65.5 Mpa. So, 65.5 by sigma at value is 150 permissible stress and sigma bt calculated is 65.9 Mpa. So, 65.9 by 165 or if I calculate this, this is coming 0.84 which is less than or equal to 1. That means this value is coming less than 1. That means, the section whatever you have considered is complete.

Now, to make more economic we can reduce the size of the section one step below. Then, you can check whether it is or not, right. Otherwise, we can go for the section whichever we have considered, right. So, in this way if we consider this one, we can say that use 2 ISA 130 by 130 by 10 mm angle. So, using this we can make it, right.

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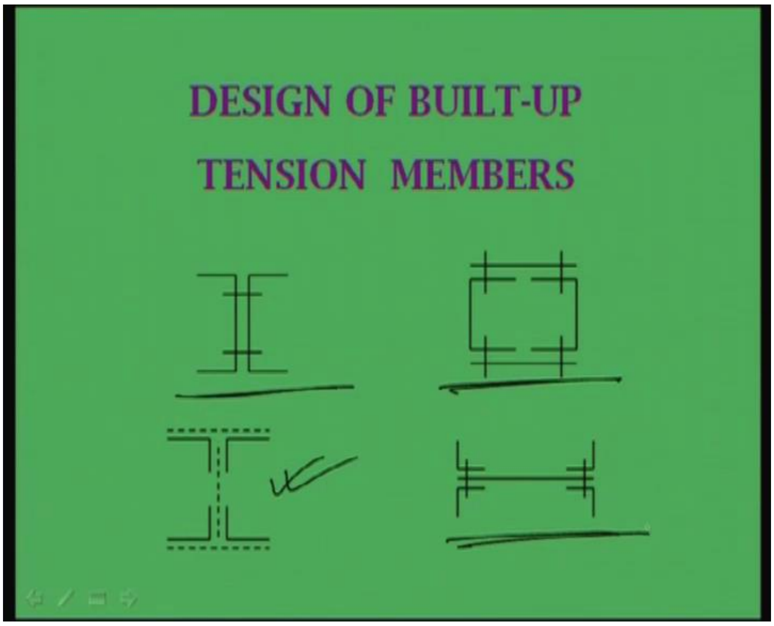

Now, we will go another thing that is design of built-up tension member, right. As we have discussed at the very beginning that if the load is very high or from architectural point of view, sometimes we have to go for built-up sections. Why we go for built-up sections? It is mainly because of large magnitude of the load which cannot be carried by the single section available. Single section is not able to carry that much load. In that case a suitable arrangement of built-up section is required. As we discussed earlier that arrangement can be made in different way say channel type of section two. Channel has been placed back to back or two channel sections have been placed front to front. Like this four angles has been provided. Like this it can be made four angles provided oriented in this way also.

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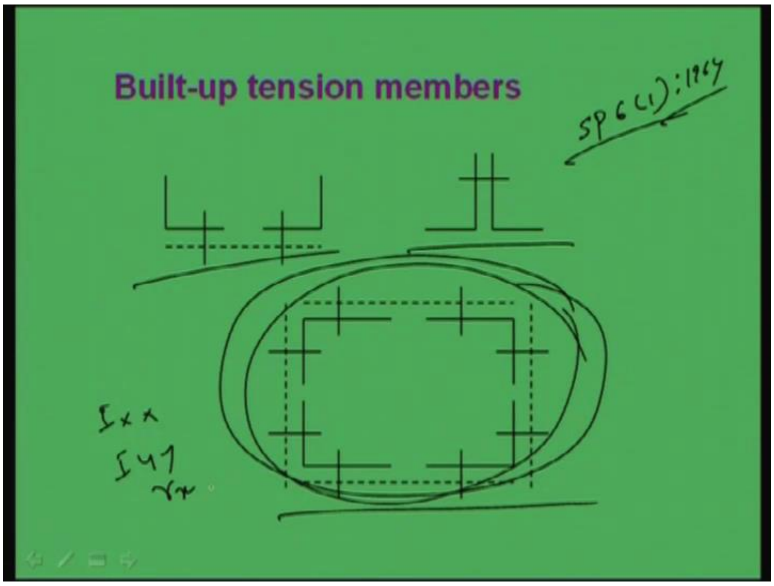

This is another built-up section. So, in different way we can make the built-up section. Now, I will discuss about how to design a built-up section, and before that also I like to just go through means inform you that when we are going for a built-up section, the calculation is tedious. That means if a single angle or single section is considered, then all the properties of that section is given in the SP6 handbook, SP6-1964. In this handbook, all the required property, sectional properties of different sections have been given, but if built-up sections are done, then similar properties has to be find out manually means you have calculate.

Suppose if it is like this, then we have to find out what the Ixx value is, what Iyy value is and then, rxx ryy rxx minimum ryy minimum, sorry r minimum and other details has to be found out which is tedious. Then, again suppose design means in case of tension member design, we have seen that it is a iterative process. We have to start with some certain assumptions and then, we have to go with that section. Then, we have to check whether it is or not. If it is not, then we have to go for another higher section and we have to calculate again all these things. If it is, then fine or if you want to make economic, then again we have to reduce the section to make it optimize. So, in this way what we will see that we need lot of calculations in between that is very tedious and laborious.

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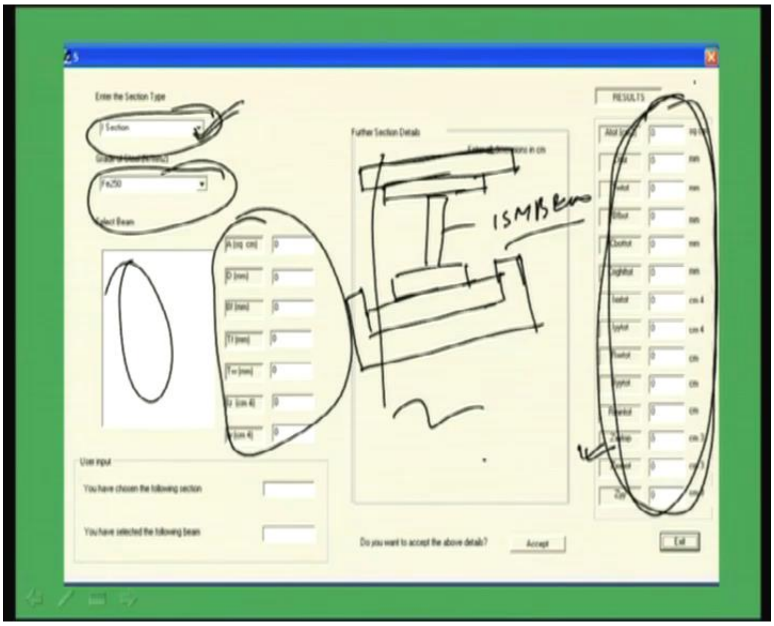

That is why if we can make certain software then we can use the software to find out the sectional properties of that. In fact, while teaching our students we have developed some sort of software with the help of students. In different way, you can also find out some software either from the internet or you can make some software at your own to use for this type of built-up section. In this case, if you see in this software say here one combo box is there where you can select different of section, where I section channel section or angle section whatever sections you want, you can and grade of steel also you can choose from this.

Then, when you are putting the particular I section, you will get all the values here, right. Area and Bf tf tw whatever you want, you can find out. Then, you have the option here. You can put additional members like suppose a I section is there, right. Now, you want say ISMB 200 is there. Now, because of heavy load in the member, you want some extra area in terms of plate. So, you can provide some plates here. Then, if you provide plate, what will be the equivalent sectional properties that can be found out from this software or you can provide some angle also. Here not only plate, some angle also you can provide. Then, what will be the properties that also you can find out from this, right. So, all the equivalent sectional properties will be displayed here.

So, once you make the program properly, in fact you can do at your own by the use of C plus program or by Java program you can make and then, you can find out the details of the sectional properties here. So, once you make it, it is very easy to use and it will be comprehensive and you can find out the economic, the best one which will fit to carry that much load, right.

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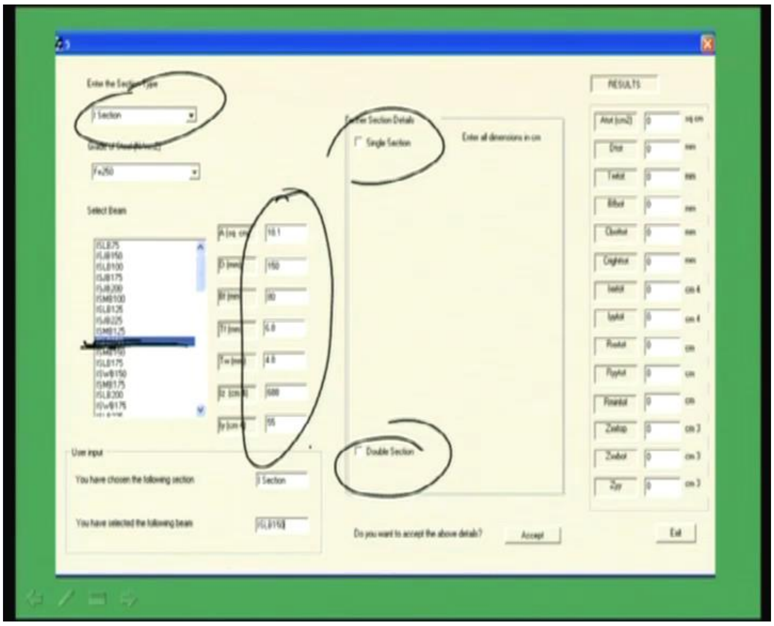

So, now if we see here, you see we have chosen I section of ISLB 150. Then, automatically it is giving the values of this. That means the sectional property of this, whichever is given in the SP 6 has been given here also in IS means in this software, right. Then, you have the option whether it is single section or double section. So, accordingly you can find out the values.

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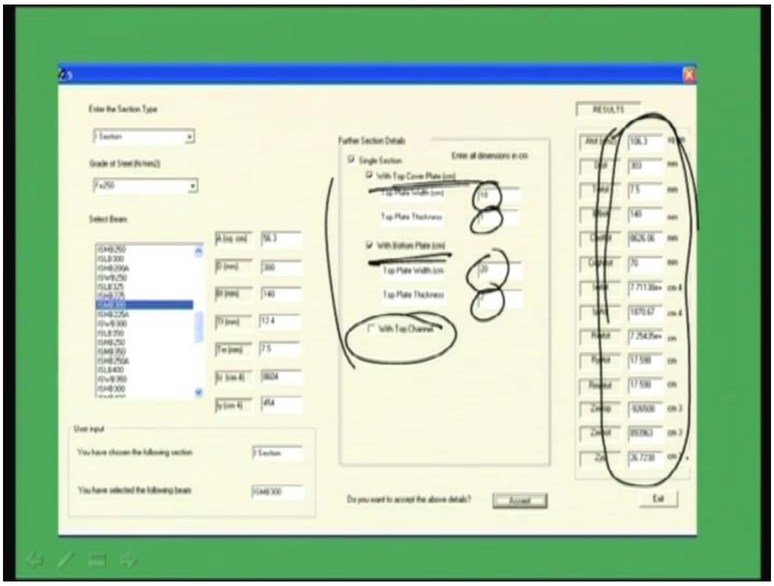

Suppose we are going for double section. Then, you see it has option with top cover plate with bottom cover plate. So, bottom cover plate thickness and width has been given top cover plate thickness and width has been given. Also, if you want channel to be added, with that channel also you can use by giving tick mark in the box. Then, you will get the results here. You see results have been printed here. What are those results? That ISMB 300 whatever we are, we have clicked here with those along with the plate, additional plate. What the moments of inertia are? What the radius of gyration is? What the equivalent area is? All the sectional properties have been displayed here. So, from this fraction of second, you can find out all the details and then you can find out.

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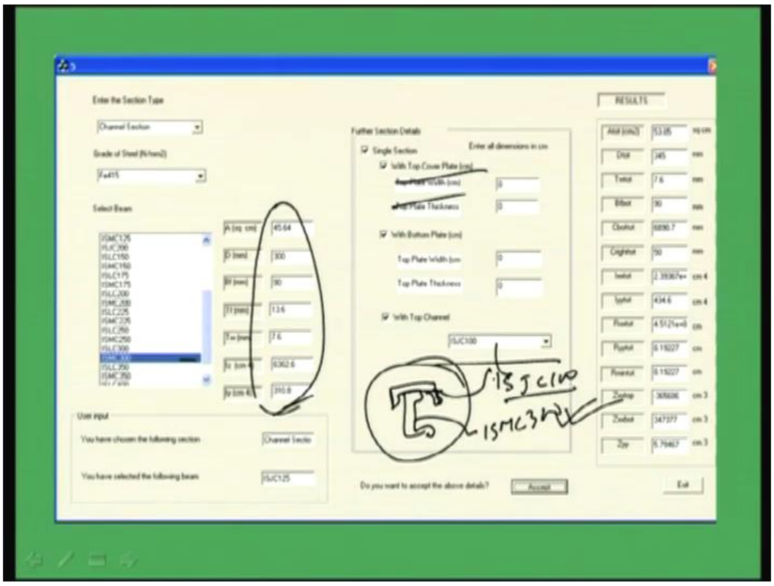

Similarly, for channel section also we have seen. If channel section is there, what is the individual sectional properties of that particular channel ISMC 300 that is been displayed here. Now, if you put say top cover bottom cover or if you put another channel, say channel section is there, right. Now, if you put another channel here, now what will be the properties of this means whole section that has been displayed here? This is given ISMC 300 and this plate is given ISJC 100. This top at the top one channel also has been placed. So, in this way we can find out.

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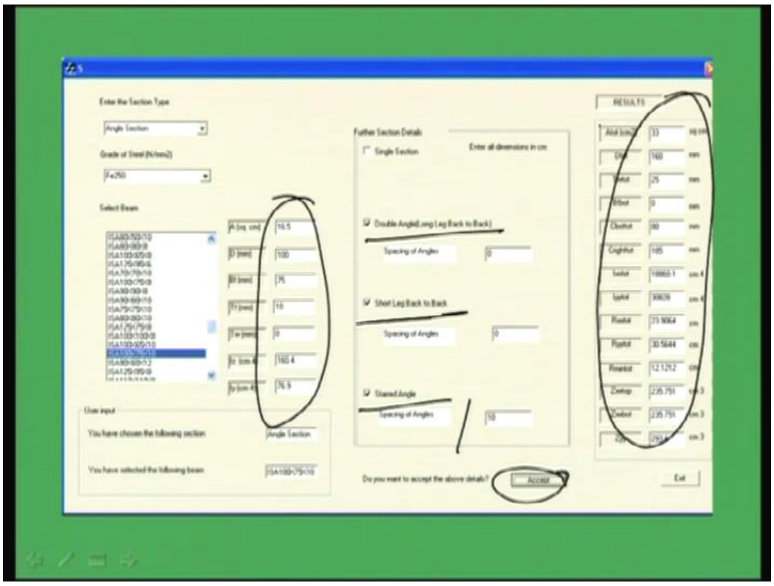

So, all the possible things it is showing the angle section, the individual properties of a particular angle. This is 100 by 75 by 110. The properties have been shown here. Now, whether it is double angle or means double angle, long leg back to back or short leg back to back or star angle, you have to define and you have to give the spacing. Then, accordingly if you accept, you will get the value. So, these are some ideas I am giving you, so that you can start making a program accordingly and you can use at your own. However, you can contact me through email, so that I can give you this software also if you need, right.

So, this is T section. Again in case of T section, we are providing some top cover plate and with some particular width and thickness, then we can find out the equivalent section, right. So, in this way you can make it. Now, we will go for a design of a built-up tensile member. Why we are going for designing? We will see how to design it and here also, we will see what the difficulty of calculating is. All this is very difficult to calculate. So, if we can find out some software like whatever I am showing, it will be very easy to calculate and to find out all details.

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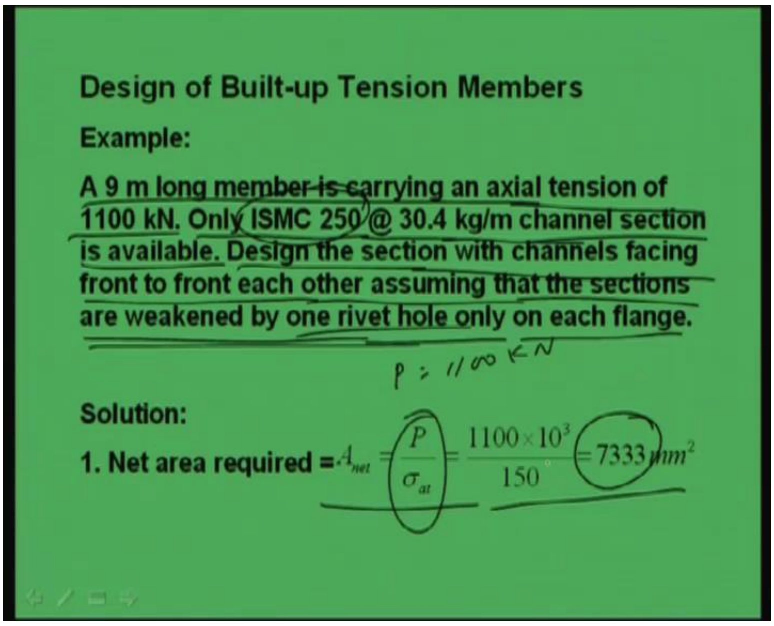

Now, question is that a 9 meter long member is carrying an axial tension of 1100 kilo Newton. Only ISMC 250 at 30.4 kg per meter channel section is available. Design the section with channel facing front to front each other assuming that the sections are we can by 1 rivet whole only on each flange. The assumption is that only one rivet has been used in the flange. So, the net area can be calculated accordingly. So, question is that P is given which is 1100 kilo Newton and section size is given ISMC 250, right and the riveted placed one rivet in each flange.

So, for designing, what we will do first? First we will do that net area how much it is required, we have to calculate. So, net area is required P by sigma at. So, from this 7300 and 33 millimeter square we are getting. So, this is the net area we need to provide.

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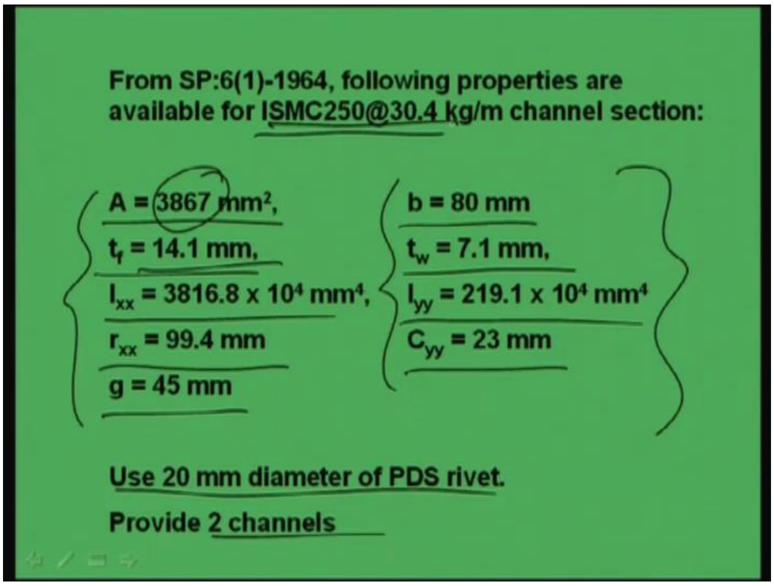

Now, what we will do? So, SP: 6-1964 handbooks for ISMC 250, the following properties, sectional properties are given which can be used. These are the properties. What are those? That cross-sectional area is 3867 millimeter square width is 80 mm thickness of flange is 14.1 mm thickness of web is 7.1mm. Moment of inertia in x direction is 3816.8 into 10 to power millimeter to power 4. Iyy is 219.1 into 10 to the 4 millimeter to the 4. Rxx is 99.4 millimeter. Cyy is 23 millimeter and g is 45 mm. These are all the details which will be required for our design which has been given in the SP: 6.

Now, using twenty mm diameter of power driven soft rivets and because of the required area is seven seven thousand three hundred thirty-three we need to provide two channels because area of channel is this is three thousand eight hundred sixty-seven

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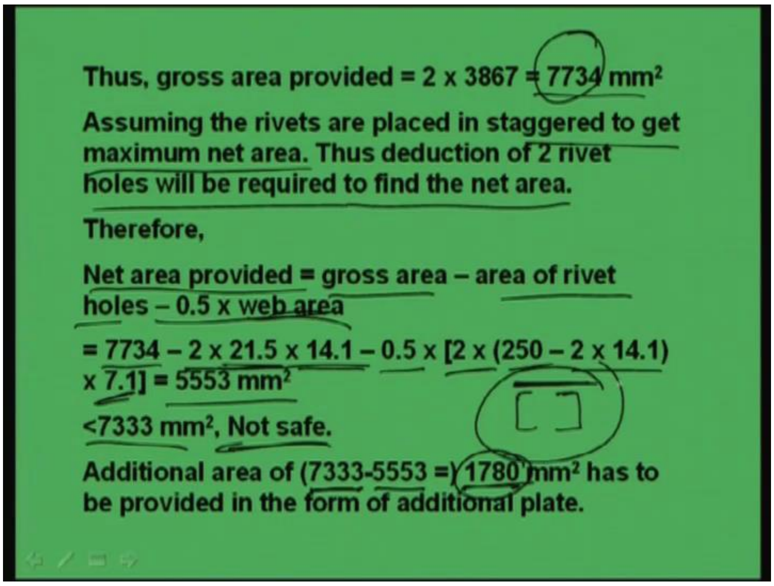

So, if we provide two channels, the total area will be even 1734, right. Now, assuming the rivets are placed in stagger to get maximum net area, so deduction of two rivets will be required to find that net area. So, we are using the maximum efficiency means we are distributing the rivet in a staggered way, so that maximum strength can be found. So, net area can be found gross area minus area of rivet whole minus 0.5 into web area as per the codal provision. So, net area provided is 7734 which is found here and two rivet whole.

So, two into rivet diameter is 21.5 and thickness is 14.1 means this flange thickness is 14.1. So, it is minus 0.5 into web area. Web area will be 250 minus 2 into 14.1 is the thickness into the thickness of the web that is 7.1 into 2 because two channels are used. So, this will become 5553 millimeter square which is less than 733 millimeter square. So, if we provide two channels, this is also not sufficient to take care of that much of load because this is not safe and we have been given that particular channel that is ISMC 250 channel is available only. So, what we have to do? We have to go for additional plate. What is the extra area required? That is 7733 minus 5553 which is becoming 1780 millimeter square. So, extra area of 1780 millimeter square has to be provided in the form of plate, additional plate, right.

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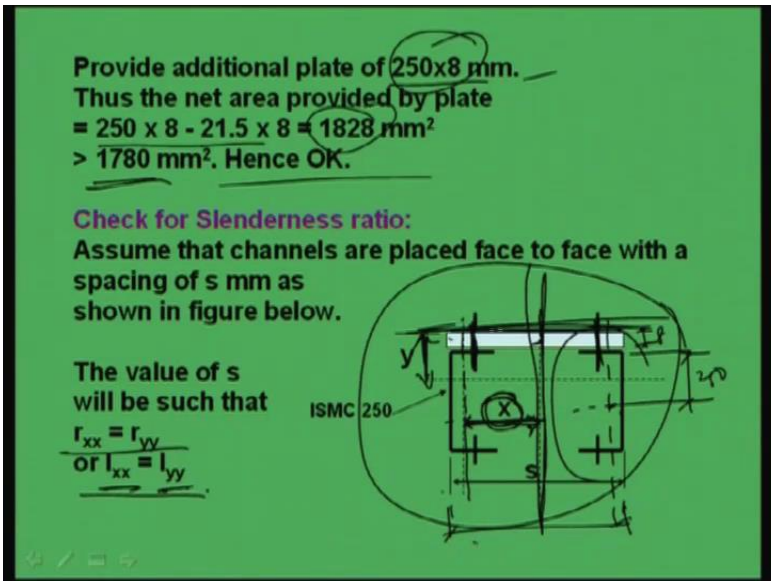

So, we have to provide some plate. So, we are providing plate here say of 2550 by 8 millimeter plate. Now, if we provide this plate, then net area can be found because rivet joint has to be made. If we make rivet here, then we will see that 215 to 8 minus 21.5 into 8, this will be becoming net area which is greater than the required one. So, providing this much plate is sufficient to take care the load.

Now, we have to go for the checking of slenderness ratio. What we have seen so far that we can use a plate of 250 by 8 with channel section placed like this which can take the required amount of load which has been decided, but again the thing is we have to the check slenderness ratio, right. So, for checking slenderness ratio what we have to do? We have to place in this way and then, we will find out rxx or ryy. Now, channel sections has to place in such a way that rxx will become ryy for maximum efficiency means rxx and ryy will become same. Then, we can find out this. This will be the optimum orientation. That means rxx equal to ryy means Ixx has to become Iyy, right. So, we have to find out Ixx and Iyy. If we can make equal, we can find out the value of S, this distance between two channels. So, distance between two channels has to be placed in such a way that Ixx become Iyy, right.

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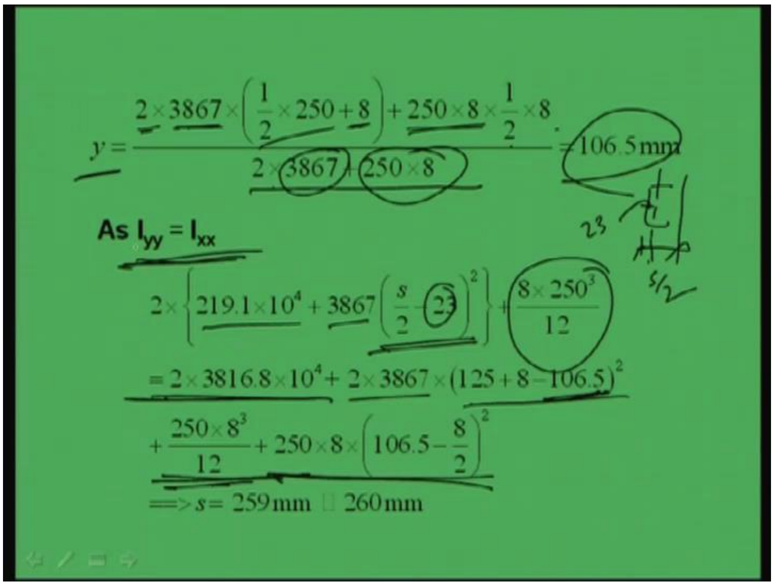

So, if we make this, so for finding Ixx and Iyy, first we have to find out the y y. That means the center of means cg distance from top. If this is y, then let us find out y value and x value and it will be simply half of S. So, x value we can find out. It is at the center of these two. So, the cg of individual, this is the cg of individual channel. So, x is we denoting distance between cg of one channel to the cg of the whole section. Now, y we can find out. Now, y will become what?

Now, if we take moment, about this moment is this say face, then what will happen. Y into total area will become this into this area plus this into channel area plus this into channel area. So, that is what we are making here, right. This is the total area 2 into this area is the individual area, and this is the plate area 2 into 3867 plus 215 to 8, right. This is the channel area 2 into channel area into half of the resistance plus thickness of the plate 250 by 2 plus 8 because this is 8 and this will be 250 by 2, the cg distance of individual member. So, from this and this is the plate 250 into 8 into half of 8. So, we are getting y as 106 millimeter, right.

Similarly, y we have to need to calculate for getting the value of Iyy and Ixx. Now, I can find out Iyy and Ixx, right. So, Iyy if I make Iyy means about this. So, individual moment of inertia into ar square to shift this means ar square r will be x. Individual moment for inertia into a into x square for this plus bd cube by 12 of this plate. So, individual moment of inertia plus a into r square r square is nothing but s by 2 minus this cg distance 23. If plate and the channel is this, this is 23 and this is S by 2. So, S by 2 minus 23 ar square plus bd cube by 12 for the plate, this is Iyy, and similarly Ixx will be Ixx about it own axis plus A into r square r will be 128 plus 8, where cg is placing minus this y plus the plates at its own axis, then ar square. Now, if we make equal of Iyy and Ixx, we will get value of S as 260 mm, right. So, we are going to get the value.

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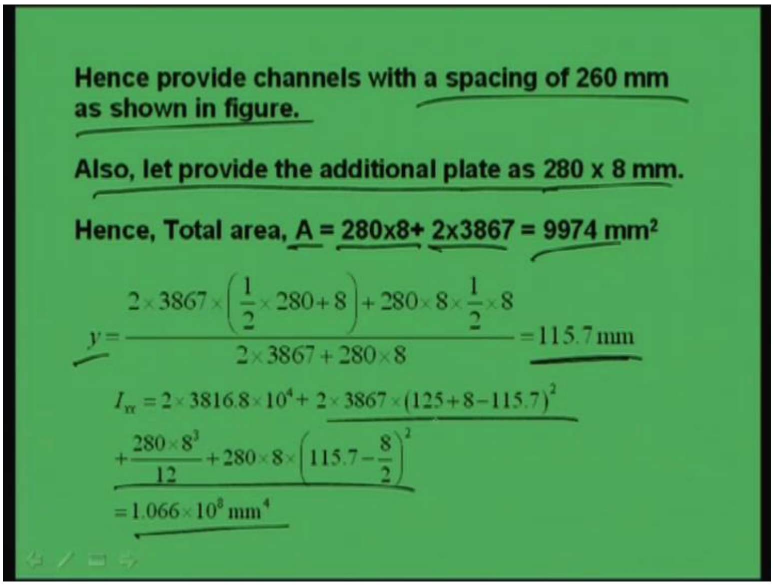

That means, hence we provide channels with a spacing of 260 millimeter as shown in the figure. So, figure means this one. So, this will become 260 millimeter, right. So, what we will do now? Now, let us provide the additional plate as 280 by 8 millimeter and then what will happen. Total area will become 280 by 8 into this which is becoming this one. Then, y is becoming this one. Similar way, Ixx I can find out. So, what we are seeing here that lot of calculations we have to go for to find out the sectional properties. However, this calculation can be omitted if we have the software, if we have the programming things.

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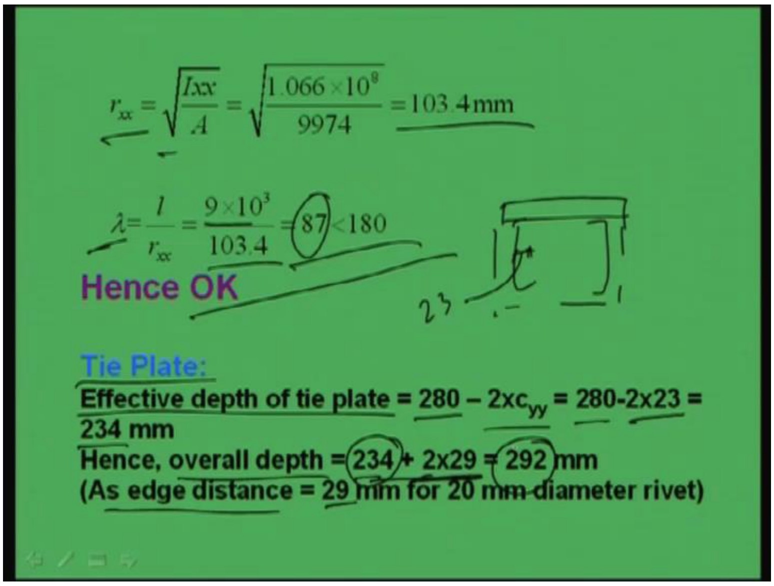

So, now we will find out the rxx which is nothing, but Ixx by A or Iyy by A. So, this is becoming Ixx by A is becoming 103.4 radius of gyration, and the slenderness ratio is nothing, but l by rxx. So, length is given 9 meter and radius of gyration is 103.4. So, this is becoming 87 which is less than 180 as per the codal provision if it is less than 180. So, from the slenderness ratio point of view also, the assumed section is to take care of that much of load, right. So, this is fine.

Now, the tie plate means we have two channels. We have given some plate. Now, we are giving some tie plate, right. Now, effective depth of tie-plate will become how much? It is 280 minus 2 into Cyy, right. This is the distance Cyy. This is 23. So, 280mm we have considered here plate width. So, it is 280 minus 2 into 23. So, effective depth will become 234 millimeter. Therefore, the overall depth will become 234 plus 2 into S distance. Now, S distance is 29 millimeter for 20 mm diameter of rivet. From the codal provisions, we can find out the minimum S distance for 20 mm diameter of rivet as 29 millimeter. So, overall depth will become effective depth plus 2 into S distance. So, after calculating this, we are going to get 292 millimeter, right.

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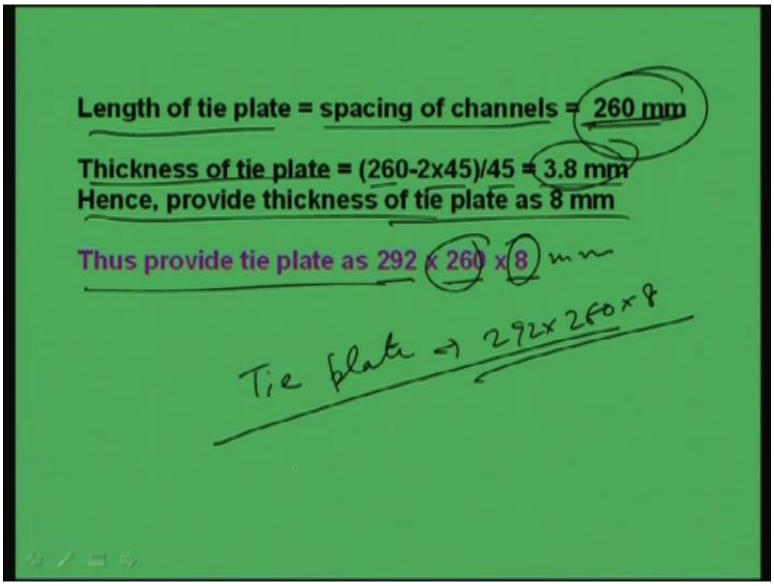

So, what we will do now? So, length of tie can be made as spacing of channels which was calculated as 260 millimeter, right. So, length of tie can be found as 260 millimeter means basically we are providing as spacing, right and thickness of tie-plate will be 260 minus 2 into 45 by 45, right which will become 3.8 millimeter. Hence, we can provide some plate thickness means this is the tie-plate thickness you can make. However, we are providing 8 millimeter with some standard plate thickness. So, thus we can provide plate as 292 by 260 into 8 millimeter. 292 we are getting here overall depth and 260 is the length and 8 millimeter as spacing. So, tie-plate will be 292 into 260 into 8. So, with this means, this is the way to calculate the built-up sections, sectional properties and the design procedures.

Now, I think we have some idea about designing of tension members. In the last 4 lectures, we have discussed about details of the tension members starting from the connections of the tension members to the tension member with only axial tension force, tension member with axial tensile force, and bending moment and also, some additional members like gusset plate, lug angle and tension splices. So, with all this, I would like to conclude this lecture design of tension members as a whole.

Thank you.