Design of Steel Structures
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Compression Members

Module - 5
Lecture - 4
Built up compression members

Hello. Today our lecture will be focused on built up compression members. Built up members means basically combination of two or more members joining together, such that the whole member groups will act together to take the required amount of load. Now, why we will go for built up members? In simple words, we can say that when the required area is high, when the load is heavy, the amount of area required will be very high in case of heavy load. So, in that case the readymade section which are available in the IS code, that is SP: 6 1980, 1962, in that we see that higher section in case of say I member, it is ISMB 600.

Now, suppose the area required is more than the area available in ISMB 600. Then, what we have to do? We have to join some member or we have to arrange the members in such a way means more than one member, such a way that the cross-sectional area of the group will be more than the required area. So, in that case it will be able to carry that much load. That is why we have to choose the built up members in such a way that the required area will be less than the available area. Now, this is one reason why we go for built up members.

Another reason is, it is not only that if we increase the cross-sectional area, it will be safe or it will be means it has greater strength. Also, we have to see the slenderness ratio. Slenderness ratio, if is less than the strength as we know the allowable compressive stress of the member becomes high in case of lower slenderness ratio. So, we can do one another thing that the member will be means small members will be placed, will be arranged in such a way that the radius of gyration of the member in both the directions will be more. In that case, the strength of the member will become automatically more.

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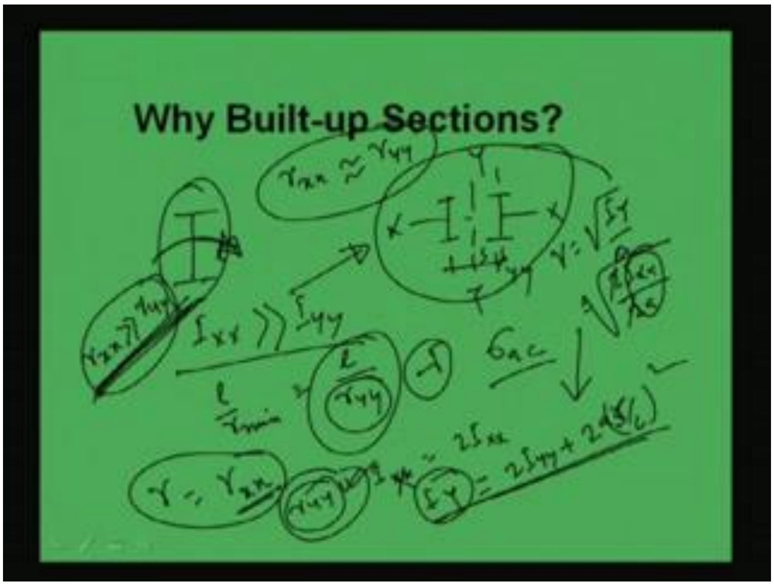

Suppose if I have I section, say suppose this. Now, if I add means here we see that if the moment is coming in this way or if it will be easily buckled. So, here Ixx is greater than Iyy. That is why the slenderness ratio l by r minimum will become, that means here it will be l by ryy and ryy is less. This will become more. Lambda will become more means the sigma ac value the allowable compressive stress will be less. So, we have to see that equal resistance is coming from both the sides. That means, from xx direction whatever resistance is coming, it should come from yy direction also same.

So, that can be made if we arrange in place of giving a heavier section, suppose we are arranging like this, then what will happen. Then, we will see the equivalent Ixx is simply 2 Ix, right. Sorry equivalent Ix will be simply 2 2 into Ixx, but equivalent Iy if this is x and if this is y and if this is yy direction equivalent, Iy will become how much. That will be 2 Iyy plus 2 into r square. R square means say if this is S, then I can write S by 2 whole square. So, in this way the value of Iyy magnitude of Iyy I am going to increase.

Now, what is radius of gyration? Radius of gyration is we know Iyy A or Ix by A. So, in case of x direction means 2 Ixx by A means 2 a. So, finally, this is Ixx by a. That means r will become finally rxx. So, with this combination rxx is not going to change, but iyy is going to change. So, the change means it is going to increase. That means, the radius of gyration in terms of ryy, we are going to increase. So, the strength of the member in terms of compressive stress will become more permissible. Compressive stress in the member will become more if ryy is becoming more. So, the built up member should be made in such a way that rxx will be almost nearer to ryy, rxx will be nearer to ryy. Whereas in a single section which is available that is rxx will be much greater than ryy that is not desirable.

So, this type of section is not desirable for compression member though we are using, but for small area and for small load, small magnitude of load this is, but for heavy load we must go for built up section. So, built up section is not only increasing the cross-sectional area, but also increasing the compressive stress, allowable compressive stress of the member by increasing the radius of gyration of the section or by reducing the slenderness ratio of the section because if we can decrease the slenderness ratio, then the permissible stress in compression can be increased.

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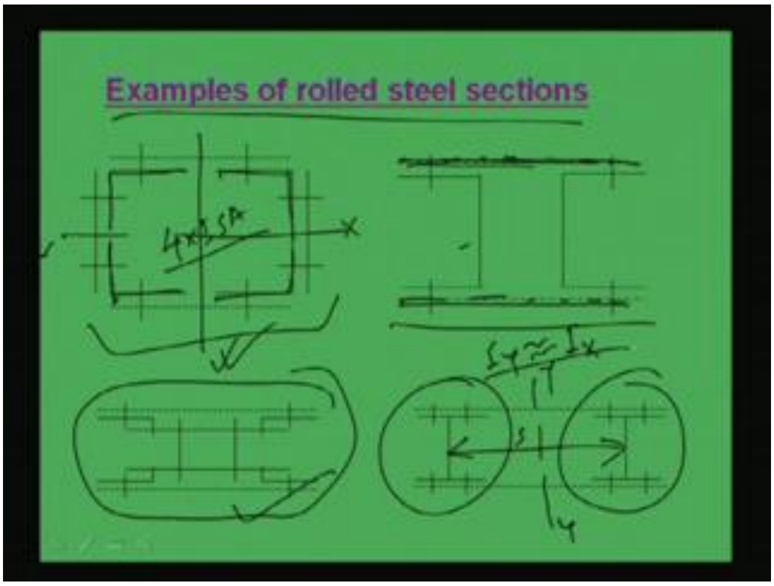

Now, some examples of rolled steel section with built up section. So, as we say suppose this is a angle section, this is another angle section, this is another angle section and this is another angle section. So, if we arrange four angle sections with box like things, then here Ixx and Iyy both will become very high. Ixx means in this direction X and Iyy means this direction. So, the radius of gyration will become more in this case. That is why this type of section is preferable.

Another way of making section is say two channel sections keeping back to back. This is one option which in general we use in case of design of compression member. Another case is say four angles can be met with like this and these dotted lines if you see, these are basically the member which is tying both the members, so that it act together. So, these are the tie which is called lacing or battening which we will be coming later. They are provided to make the two sections as a whole as one, so that it works as a whole. Another section say two I sections we can provide with some distance, so that the Iyy become more. So, that Iyy means Iy. If this is y direction, then Iy become more. That means we have to make that this spacing should be in such a way that Iy will become Ix. The moment of inertia of whole section about x direction and about y direction should come close together to get equal resistance from both the sides. That means to get the optimum placing of the sections, so that the maximum benefit we can get from the section.

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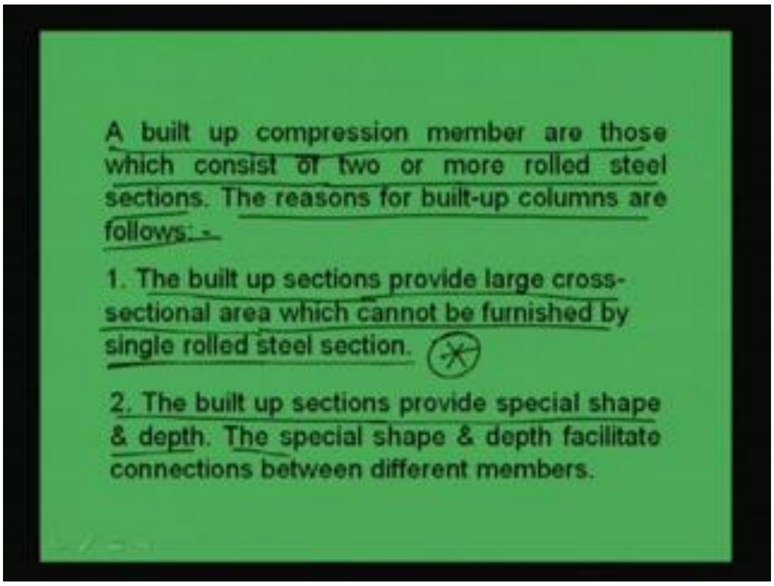

Now, whatever I was telling, let me summarize here that a built up compression member are those which consists of two or more rolled steel sections. The reasons of built up columns are follows. So, one by one I am just describing here. One is the built up sections provided large cross sectional area which cannot be furnished by single rolled steel section. In case of heavy load, large cross sectional area will be required which may not be provided by the single rolled steel section available in the market.

So, this is main reason means general reason, simple reason for which we generally make, but other reasons are there which I have discussed. Again I am writing here. So, another is the built up sections provides special shape and depth. The special shapes and depth facilitate connections between different members. So, because of different shapes and depths, we can make the connections at our own choice.

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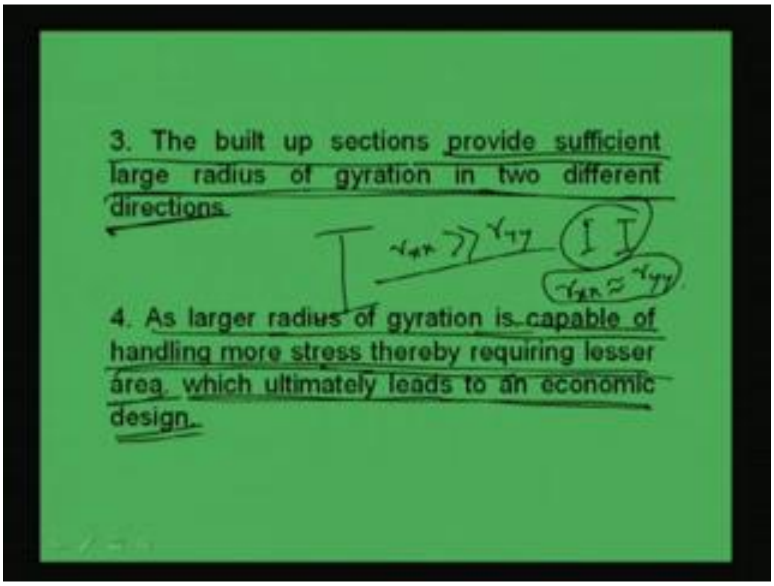

Another important reason of using built up section is that the built up sections provide sufficient large radius of gyration in two different directions and not only in one direction. As I told that in case of I sections say rxx is greater than ryy. That means much more greater than ryy, but built up sections can provide sufficient large radius of gyration in both the direction by using say suppose small two I sections. So, in this case or it will become rxx will become ryy because the permissible stress of the compression member depends on the minimum radius of gyration. So, from that only we can find out.

So, we will try to make the section in such a way that rxx is more or less closer to the ryy. As larger radius of gyration is capable of handling more stress, thereby requiring lesser area which ultimately leads to an economic design. This is important. I am repeating once again that as larger radius of gyration is capable of handling more stress, thereby requiring lesser area which ultimately leads to an economic design because final objective of our design is just to make it as much as possible economic.

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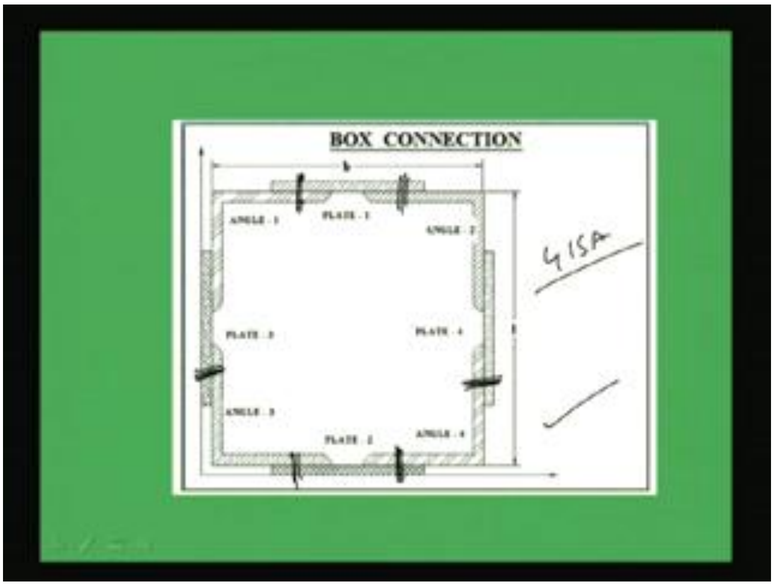

Now, different type of built up sections we can arrange, and we can make one common built up section which is used in industrial structure is this one box connection. That means box like section where four angles will be placed in such a way that as a whole it will work as a box section. So, here what will happen that these angles are connected through some plate, either we can connect through some plate or by the use of lacing or battening, we can make it. Lacing or battening we will come later. By the use of those also we can make it.

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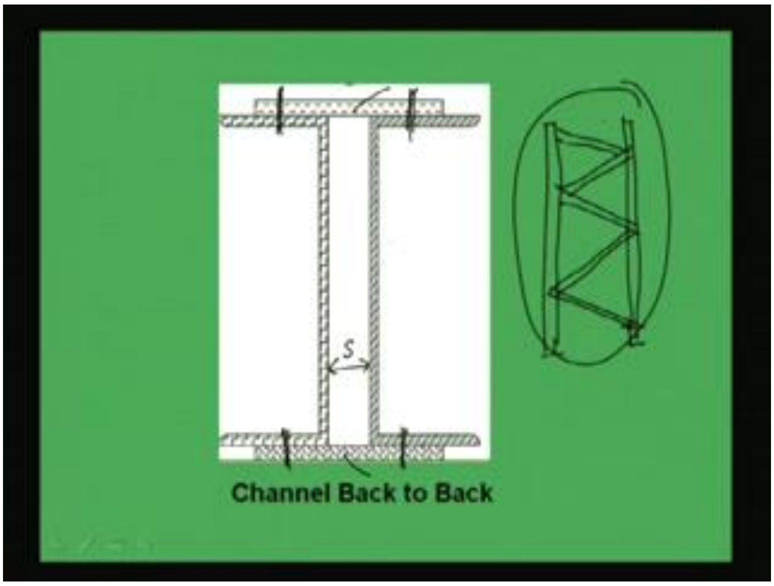

Another section which is commonly used is that two channel sections are placed back to back with certain spacing. This is called S spacing. Now, if we use lacing or battening say suppose this is lacing or battening which is helping the two channels to act together. So, if I see the view, how it will look like? Say this is one side, another side is this and this is another channel. So, we will be providing like this say lacing is providing like this. This is how this will be connected. How to design all these things, we will discuss in next lecture, but we should have some idea. So, this whole section is acting together, acting as a whole, right.

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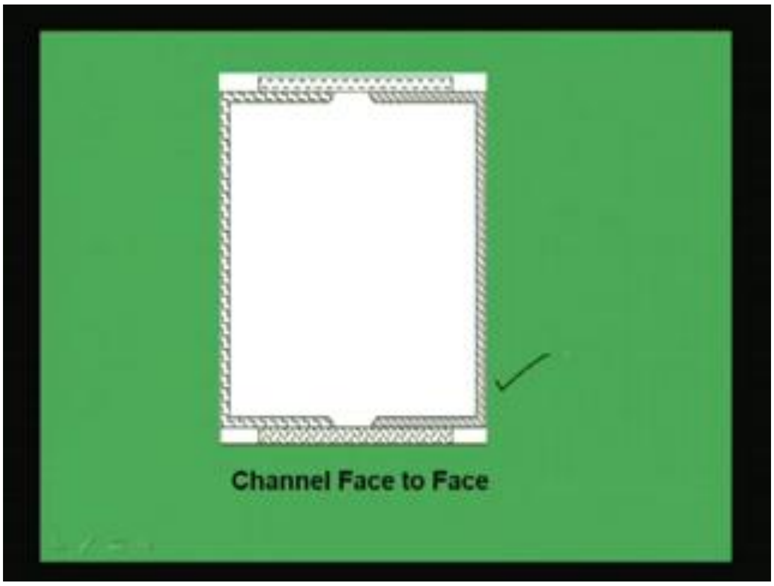

Another common section is the channel when comes face to face. We will see what is the advantage or disadvantages or which type of section we should go for a particular case of design. We will see later when we will go for designing.

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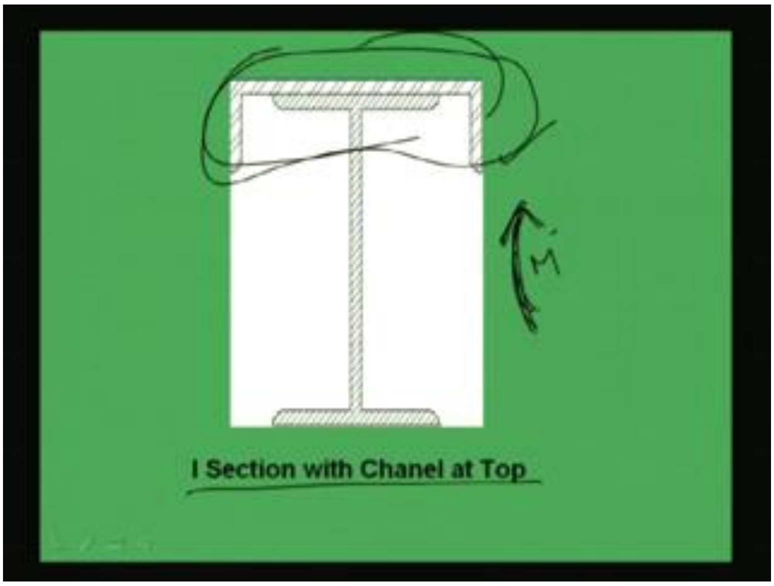

Another section available is that I sections with channel at top. If the stress is coming more here means in this side if moment is like this, moment is acting in this direction, then the compressive stress will be acting more here, coming more. So, in that case we may need some extra material which can be provided in terms of channel also. This is one section which is also commonly used in the industry.

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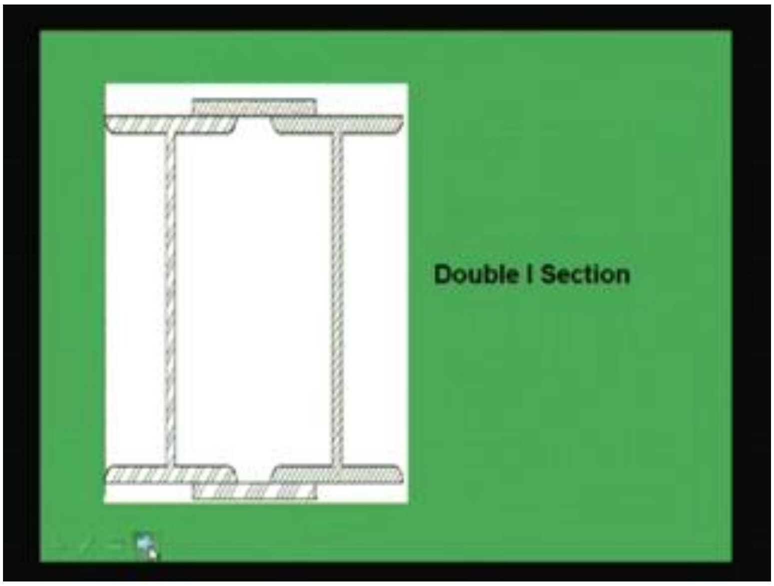

Another section which is commonly used as double I section as we have shown earlier. Double I section connecting through lacing or battening or some plate, right.

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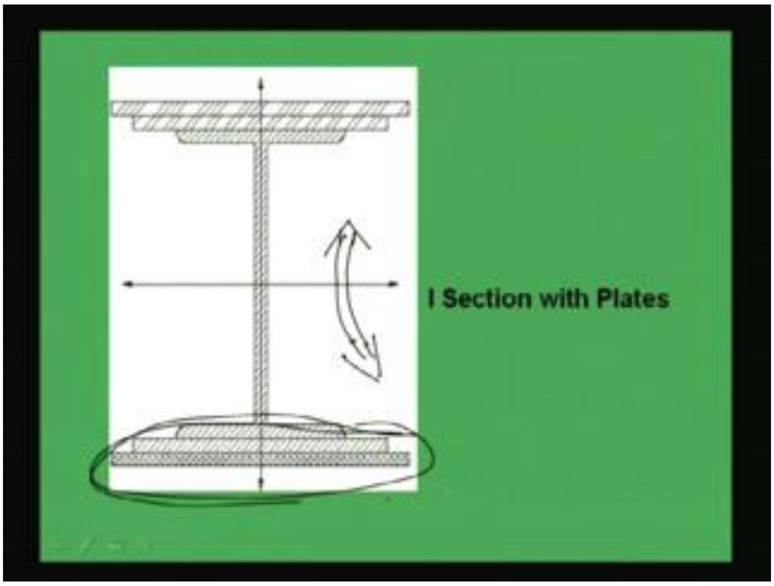

Next is another mostly used section when the moment is very high. In this direction, moment is very high and the reverse moment can happen also because of wind etcetera. So, in that case this single I section is not sufficient to take care that much moment. So, in that case we can add on plate maybe one plate or may be more than 1, 2, 3, whatever required. So, we may use. We will come in details when we will discuss about the design of plate girder. How we use those things, we will discuss there.

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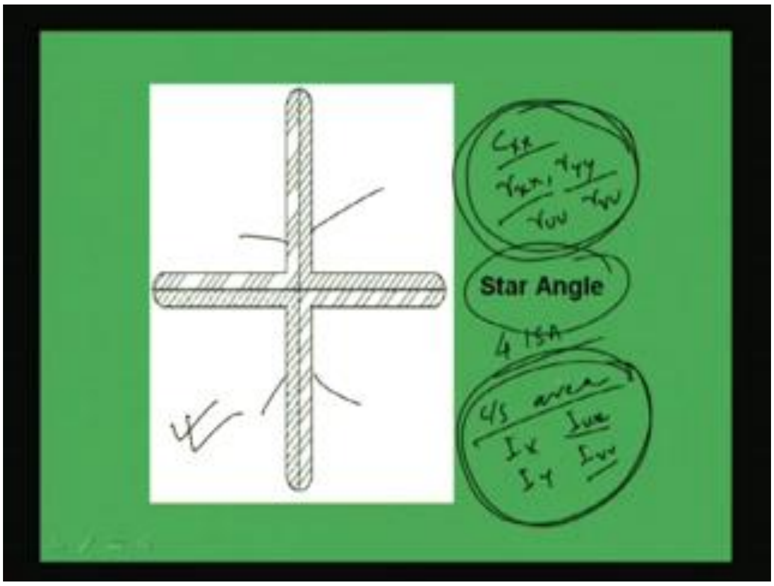

Another section is called star angle, where four angles are placed. Once I have shown that box type of connection where four angles are used. Another is this four angle is used. This is 1, 2, 3 and 4, four angles are placed in such a way that it makes star like angle. This is another section which is commonly used in the industry. Now, for using such type of built up sections, we have to know the area cross-sectional area of the built up section. Then, the total moment of inertia in x direction, total moment of inertia in y direction, again also the minimum means moment of inertia about major axis and moment of inertia about minor axis, those things have to also know.

Then the center of gravity of the built up section Cxx, then rxx ryy. That means the radius of gyration of the whole section in x direction, y direction, then about major axis and minor axis. So, all the properties have to be known and the difficulty is for built up section, we have to calculate all those properties. Now, when a designer is trying to design a built up section, first they have to choose some sort of combinations. Then, they have to find out the equivalent properties of the section. Then, what will they do? Then they will find out whether the design is or not. If it is not, again they have to change and they have to make or if it is over shaped means over design, then again here they have to reduce the size and they have to make.

So, it is a tedious job, it is an iterative job and it is a tedious job to make a suitable section. So, to overcome this problem we have developed some sort of software. In fact, many organizations are also developing their own software which is available in the market, commercial software. However, a student can develop his or her own software if they want.

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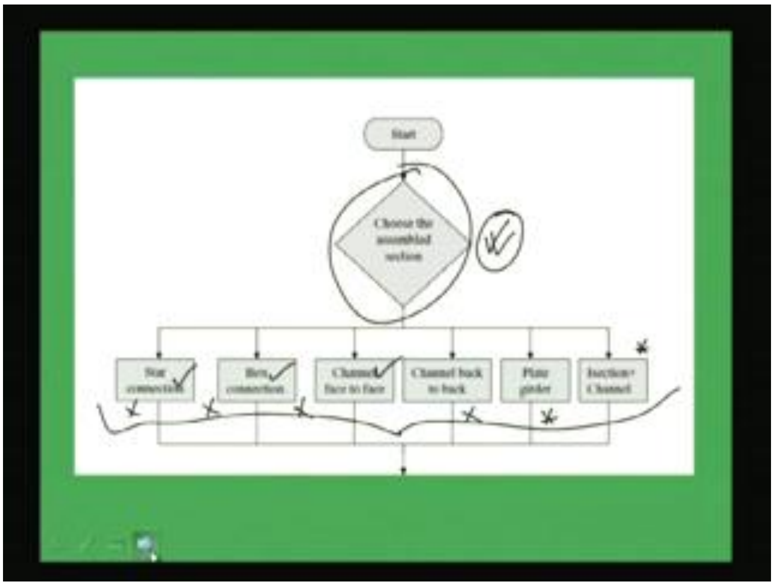

So, I am just showing the algorithm. Then, I will be showing one software, just two three phases, those GUI because then you can get some idea that how to use the software and how to develop the software and what is the algorithm. So, first we will find out an assembled section means we chose some assembled section. Assembled section in our software which has been developed by my students that which are available is one star connection. Another is box connection, then face to face channel section, back to back, then pate girder, then I section with channel. So, these six types of built up sections we have made in our software. However, n number of built up sections can be made out software as per our choice.

These are the six types of sections which have been chosen because of largely used in the industry. So, what will be the equivalent cross sectional area and other properties of the built up section, that can be find out from the software very easily. So, in algorithm what we will do first? We will give the option to the user that what type of sections he want, whether star connection or box connection channel, face to face. Whatever he wants, he can first choose that one.

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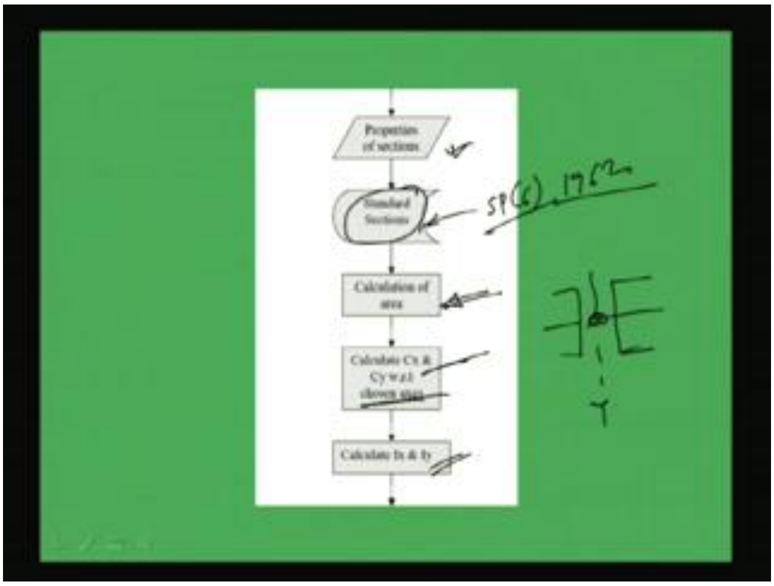

Then, what will they do? Then, they will find the properties of the standard section means properties of the individual sections. This is given in the IS means SP: 6-1962. This IS handbook from where they can find out the standard sections and their properties. Then, we will find out the area of the equivalent section area of the built up section, where we will find out other properties also like center of gravity with respect to chosen axis. Some axis is there. Suppose this is one section and this is another section. So, center of gravity can be found out Cxx and Cy with respect to that chosen axis. Then, again we can calculate the Ix and Iy equivalent moment of inertia about x direction and y direction. That also we can find out. Then what we will do?

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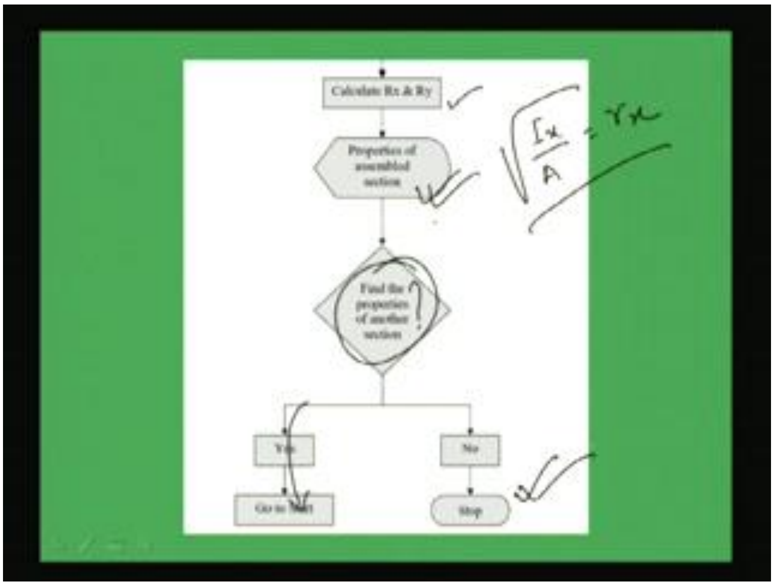

We will calculate rx and ry radius of gyration in x and y direction, which is Ix by A rx. So, in this way we can find out. So, the required properties can be found out from the equivalent section. So, all the properties we can find out. Then, what we will do whether we want properties of another section means form the properties we will understand whether it is or not. If we want with other section, then we can go to start. That means again we can start from here, choose some other sections or if the user is satisfied, then he can stop the program. By this way we have developed the software.

So, student can also make easily such type of algorithm at their own and can use for readily available because otherwise they have to calculate lot of steps. Then, they have to find out which is a very tedious and that is why now a days as computer is easily available, personal computer. So, one can make a small software and then they can use at their own. Now, here I will demonstrate, so that you can have some idea for developing your own software.

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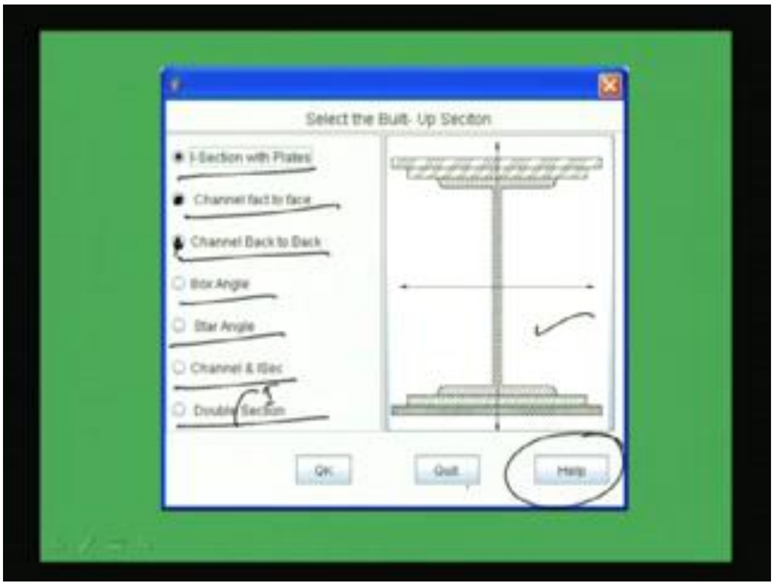

So, here as I told you that you have all these options whether you want I section with plate like this, or channel back to back, channel face to face, box angle say star angle channel and I section or double I section. Whatever the user want, he can just put, he can click the radio button and then he can go to, or if they want some help from this before using the software if they press the help button, they will find out the know-how.

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So, when we are clicking button, here we will get these types of pages where you can choose say I section, because we have clicked this one I section with plate. So, accordingly you will get such type of page. If you click other type of option, then other type pages will come which I am not going to show here. So, as we have chosen I section, so here I section is coming and what type of sections you want means what dimension like here it is shown IS will be 75. So, you have to choose a particular dimension of size of section. Then, you can choose the plate, you see plate. 1 plate, 2 plates, 3 plates, 4 because in our software we have kept option that one plate here, one plate here, one plate here and one plate here. So, four plates are there. Four plates may be equal width, equal thickness or may be different.

So, these plate properties have to be given here thickness and width. So, you have selected one plate and then you have to give thickness and width of that plate, right. Here also option is there. You can provide some channel also here. So, here if you want some channel you want to provide, you can have that option also from clicking here, say IS LC 75. Then, when you will put, you will get results of this. Results means, Ixx Iyy Cxx Cyy rxx. All the properties of that built up sections you will get. After that Cxx Cyy, you will get another is rxx ryy and area here the scroll button is there from which you will get all the required properties, right.

Now, when I am clicking I am getting the individual properties say here I have given ISMP 300. So, for that what is Ixx Iyy Cxx Cyy? So, all the properties are given here. Now, with the help of plate means with providing plate, we are going to get these results, that is, the Ixx Iyy means equivalent Ixx equivalent Iyy Cxx Cyy rxx like this. We will get ryy and cross sectional area. All the things we will be getting for the different plate. Thickness has been given for different plates. So, in this way very quickly we can find out the equivalent properties of the built up section. So, this is the advantage of using such software, where user can find out the equivalent properties of the built up section required equivalent properties of the built up section at a moment. Here we will demonstrate some example through which you will be able to find out that what type of orientation should be made, and how the strength of the member is going to increase by changing the orientation.

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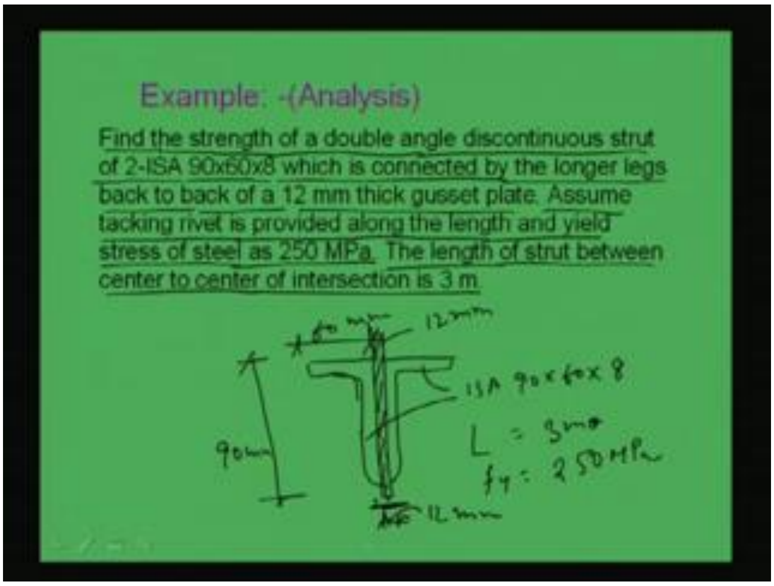

First example is find the strength of a double angle discontinuous strut of 2-ISA 90 by 60 by 8 which is connected by the longer legs back to back of a 12 mm thick gusset plate. Assume tacking rivet is provided along the length and yield stress of steel as 250 Mpa. The length for strut between center to center intersections is 3 meter. That means the two angles are provided like this which is connected through the longer legs back to back. So, this is one angle and may be this is longer leg. This is how it is connected back to back. This is the gusset plate and the thickness of this gusset plate is 12 mm and the section is ISA-90 by 60 by 8. This section is also 90 by 60 by 8. Now, length is 3 meter and grade of steel is 250. That means, fy is given as 250 Mpa. So, these are the given thing. So, this length is 90 mm because longer length and this length is 60 mm. Now, we have to find out the strength of this built-up section.

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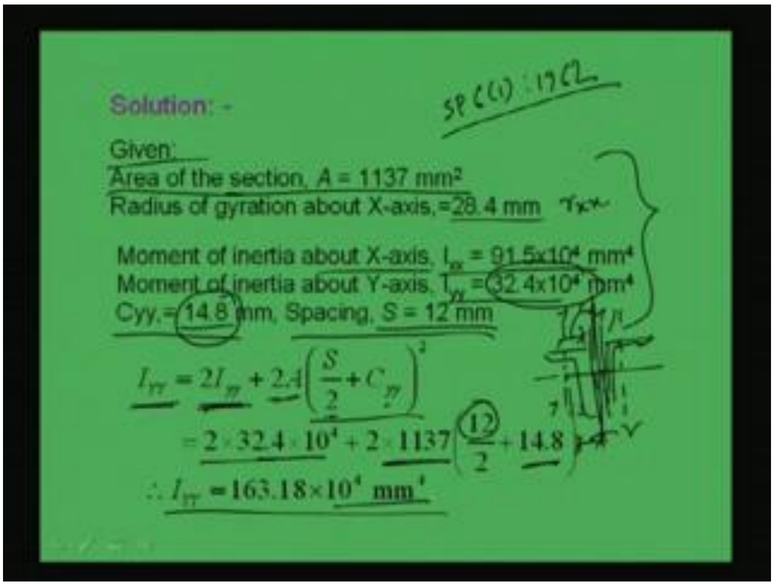

So, what we will do first? We will see what are given is the area of the section is given, that is area of the individual section is given 1137 millimeter square. This property we will find from SP: 6-1962. The structural handbook from which we will get the area and the radius of gyration is also given. This is basically we can say rxx. Rxx is given 28.4 and moment of inertia Ixx about x axis is given 91.5 into 10 to 4 millimeter to the 4. Moment of inertia about y axis is Iyy which is given as 32.4 into 10 to the 4 millimeter to the 4 and this is the Cyy distance from one face that is given 14.8 millimeter, and spacing is 12 mm because the gusset plate thickness is 12. This is 12. So, spacing is 12 mm.

So, these are the required properties which will be useful for the calculation of the equivalent sectional properties. So, now we will find out the Iyy. Iyy will be basically that as you see this is one section, another section is this. So, we will see Iyy will be this one and Ixx will be here. So, Iyy will be 2 Iyy. 2 Iyy, because the moment of inertia about y axis at its own will be this one. This is Iyy plus this Ar square if this is r. So, 2 Iyy plus 2 into area Ar square r is Cyy. This is Cyy and this is S by 2 here. It will be clear.

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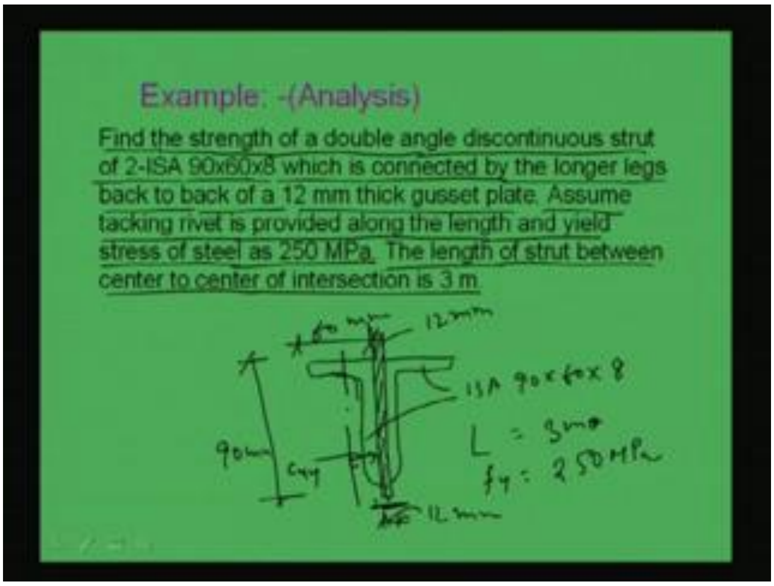

So, this is called Cyy and S is this one, right. So, 2 A into S by 2 plus Cyy whole square Ar square. So, if we put those values, because Iyy is 32.4 into 10 to the 4 millimeter to the 4 which is given here, and area is 1137 millimeter square for individual section and S is 12 mm spacing which is the thickness of the gusset plate, and Cyy is given as 14.8 millimeter. So, from the calculation we can find out Iyy as 163.18 into 10 to the power 4 millimeter to the 4. So, this is how we can find out the Iyy.

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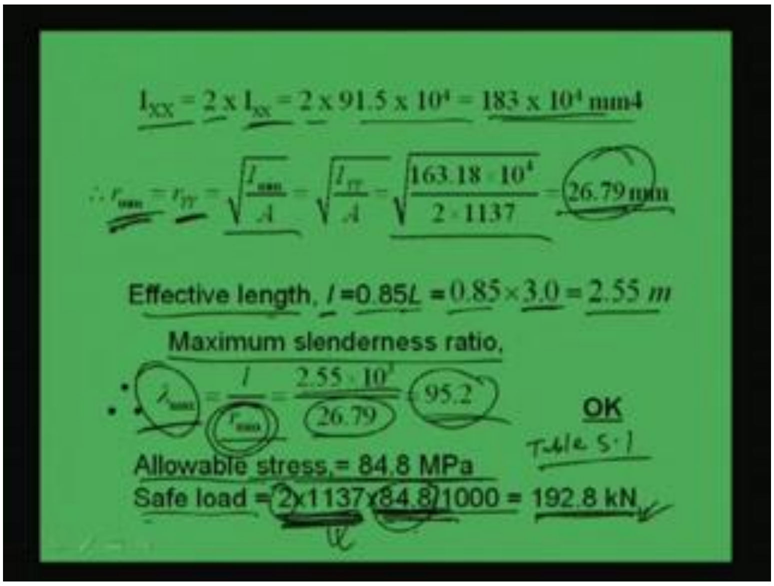

Next we find out Ixx. Ixx will be simply 2 into Ixx because the xx thus xx is not going to change about x. So, 2 Ixx. So, 2 into this is becoming. Now, I have to find out the minimum radius of gyration for getting maximum slenderness ratio. So, minimum radius of gyration is r minimum is equal to ryy in yy direction minimum. It will be because Iyy is becoming 163.18 and Ixs is coming 183 into 10 to the 4. So, I can find out ryy as square root of Iyy by area is equal to 163.18 into 10 to the 4 by 2 into 1137. So, this will be coming 26.79 millimeter, right.

Now, effective length as per the codal provision, the effective length will be 0.85 into L. So, 0.85 into L was 3 meter. So, this is coming 2.55 meter. The maximum slenderness ratio has become lambda max as l by r minimum, where L is 2.55 meter effective length and minimum radius of gyration is 26.79 millimeter which is calculated here, right. So, lambda max is becoming 95.2. Why I am finding out maximum lambda is to get minimum permissible stress. So, allowable stress for this lambda is equal to 95.2 is becoming 84.8 MPa which is obtained from table 5.1 of IS-800. So, allowable stress I am going to get as 84.8 Mpa. So, the safe load can be found out from here. Area means 2 into this total area into the allowable stress. So, this coming 192.8 Kilo Newton. So, in this way I can find out.

Now, what we have seen here that if we increase the area, if we increase the number of section, that means if we increase the area, then the strength is going to increase because strength is allowable into area. So, area I am making double. So, strength is becoming double. Not only this one, but also this allowable stress is increasing because the r is becoming high now. This r minimum is coming 26.79 whereas, for individual case r minimum was quite less. So, we can find out the allowable load means we can increase the allowable load by decreasing the slenderness ratio or by increasing the radius of gyration in both the directions. That means minimum radius of gyration can be increased by the use of built-up section.

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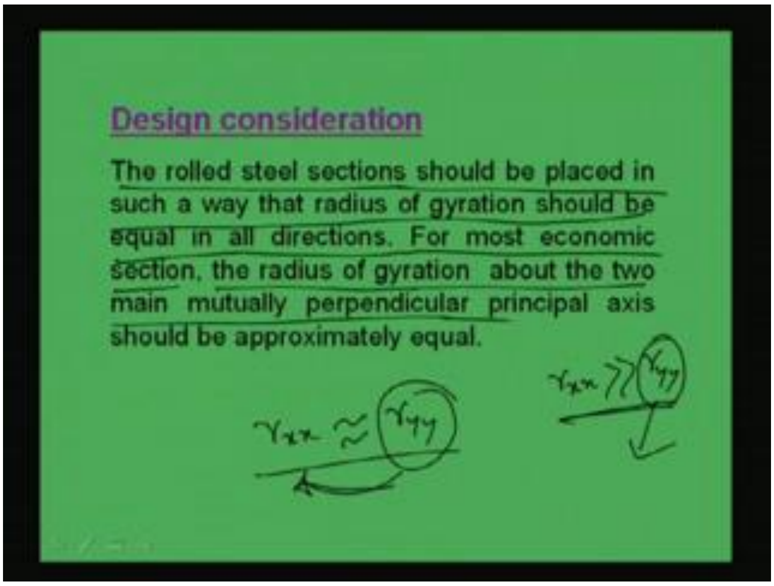

Now, we will discuss about the design consideration. Design consideration means as I told earlier that we have to make the section in such a way that the radius of gyration in both the direction will come close together as much as possible. That means rxx should become ryy. For individual section, generally rxx become much greater than ryy and the strength is calculated on the basis of ryy minimum. So, if we can increase the value of ryy to rxx near to rxx, then we can find out the allowable compressive stress as a higher value and allowable compressive stress becomes high, then definitely we will be going to get more strength.

That is what I have written here also that the rolled steel sections should be placed in such a way that the radius of gyration should be equal in all directions. For most economic sections, the radius of gyration about the two main mutually perpendicular principal axes should be approximately equal. Sometimes it may not be possible to make exactly equal, but we should try as much as close as possible. So, the radius of gyration in principal direction should be approximately equal. Let us find out some optimum spacing through which we can make equal resistance. That means, the radius of gyration in both the direction will be equal.

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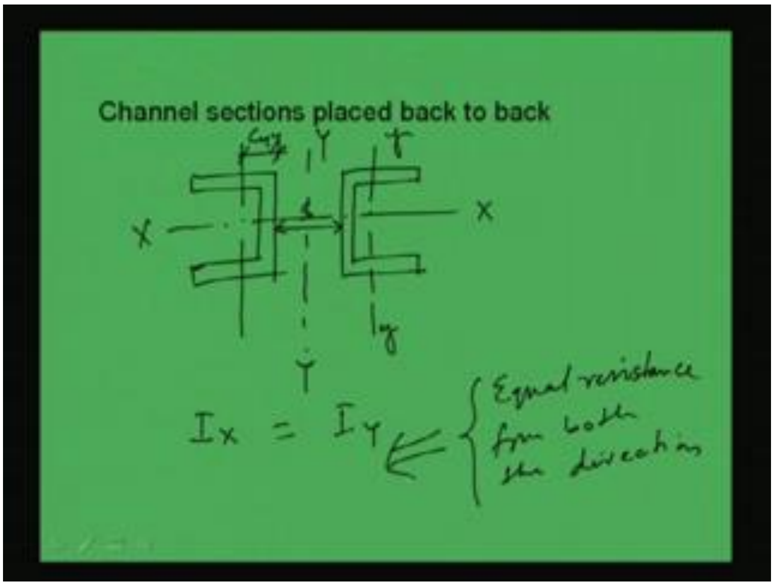

So, suppose for this type of case say channel section, if two channel sections are placed back to back what will happen? Say two channel sections are placed here. This one is another channel section, right and placed back to back with a distance of S. So, what should be value of S to get most economic design? So, this is the CG of individual section, right. So, we can say this is Cyy, this is y and this is x and this is also y direction. So, what we will do? Here first we have to find out the required sectional properties, so that we can find out the equivalent sectional properties. For equal resistance from both the direction if we want, what will happen? If moment of inertia about x axis and about y axis become equal, then we can say that equal resistance from both the directions. So, this can be possible if Ix become Iy equivalent moment of inertia of the system about x and y direction.

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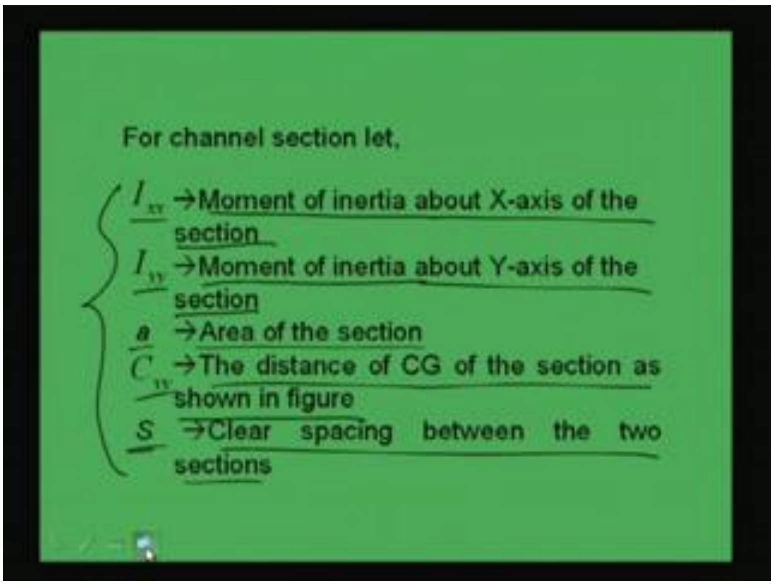

So, for channel section if we denote Ixx as moment of inertia about X axis of the section and similarly Iyy is the moment of inertia about Y axis of the individual section. Let a is the area of the individual section, and Cyy is the distance of CG of the section as shown in the figure means as I have shown here, this is Cy. Then, S is the clear spacing between the two sections; S is this one clear spacing between two sections. This is s. So, these properties we have to know to find out the equivalent properties of the section.

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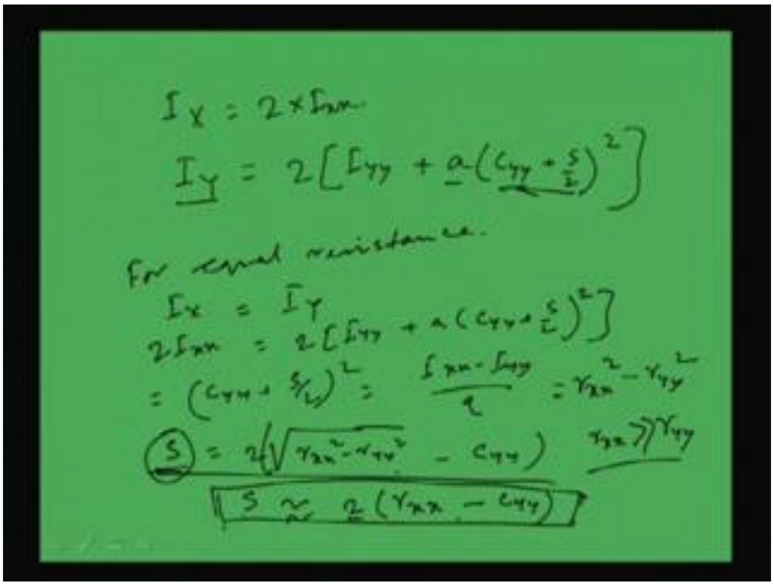

So, now we can find out the other details. That means, we can write Ix will be 2 into Ixx and Iy will become because Ix will be here Ixx one here, another one here. So, 2 into Ixx. Similarly, Iy will be 2 into Iyy plus area into Cyy plus S by 2 whole square. 2 Iyy 2 Iyy, Iyy is this about this axis, then plus a r square a into r means S by 2 plus Cyy. So, a plus a into Cyy plus S by 2 whole square. So, Iyy Iy will be this one. So, for equal resistance what we can do is that Ix will be equal to Iy. That means, we can write 2 Ixx Ix means 2 Ixx is equal to 2 Iyy plus a into Cyy plus S by 2 whole square. So, from this I can write that Cyy plus S by 2 whole square is equal to Ixx minus Iyy by a or Ixx by a is nothing, but rxx square minus ryy square.

So, from this I can find out S is equal to 2 into root over rxx square minus ryy square minus Cyy, right. So, the spacing has to become this or getting the economic size, the spacing should become with that configuration as 2 into rxx minus ryy whole square minus Cyy. Now, for channel section as we know rxx is much greater than ryy. So, we can make S as simply 2 into rxx minus Cyy. So, this is the final expression which we can use for the design. What is the final expression? That the spacing of the channel section which is placed back to back will become approximately 2 into rxx minus Cyy.

If we make the spacing from this equation, then it means that rxx will become ryy. That means, the column or compression member will give equivalent resistance from both the direction that hears we are making use of the material in an optimum way in an economic way, so that the maximum strength can be available for that section.

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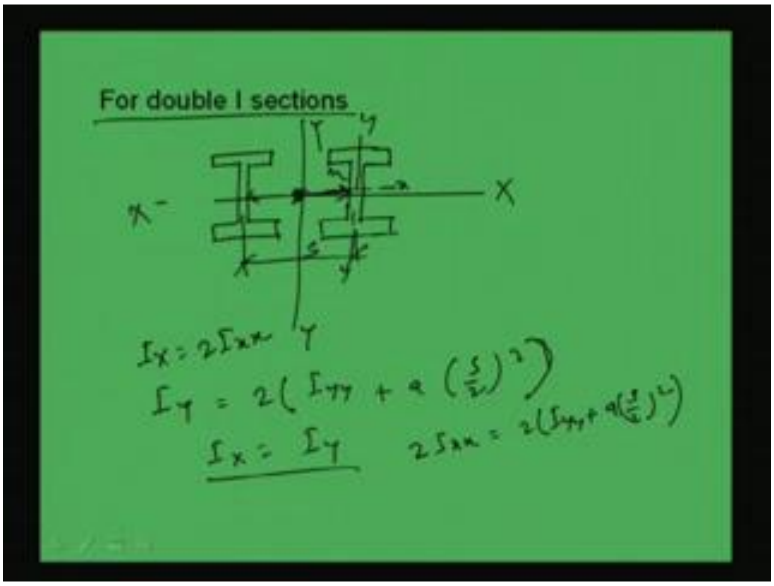

Similar spacing can be obtained for double I section also. Let us see if we use the double I section, how the spacing should be and how it is calculated. Say we have two I section, 2 equal I section are placed like this with a distance of S. So, this is yy and this is xx and for this, this is Y capital Y and capital X. Now, let us make S as not this one say center to center distance, we are making S as center to center distance. So, what we can make that Ix. What will be Ix? It will be simply 2 into Ixx and Iy will become 2 into Iyy plus a into s by 2 whole square, and for equal resistance from both the side if we want, then we have to make Ix is equal to Iy. That means, 2 Ixx will be equal to 2 into Iyy plus a into S by 2 whole square. So, from this I can find out.

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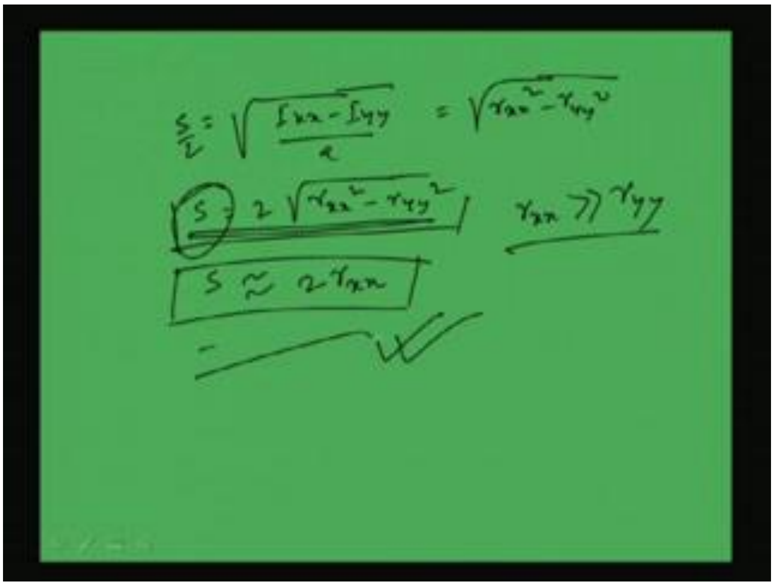

S is equal to say S by 2 is equal to Ixx minus Iyy by a, or I can write rxx square minus ryy square. That means S will be simply 2 into rxx square minus ryy square. So, the spacing between two I sections should be more or less equal to like this for a convenient design. If it is exactly same with this expression, then the most economic design we can have. Now, if rxx is much greater than ryy, then further simplifications can be made by reducing the term ryy. So, S will become 2 into rxx. So, the spacing will become approximately 2 into rxx. So, this is how we can find out the optimum orientation for the compression member.

Of course remember this is for explicitly compression member means there should not be any moment. If moment is there, then again we will have to see which we cannot generalize. We have to find out accordingly in terms of the magnitude of the moment.

If the load is (()) acting, then that means only compressive force is coming. Then, we can find out the optimum spacing which will be making the built up sections most economic that can be found out through this.

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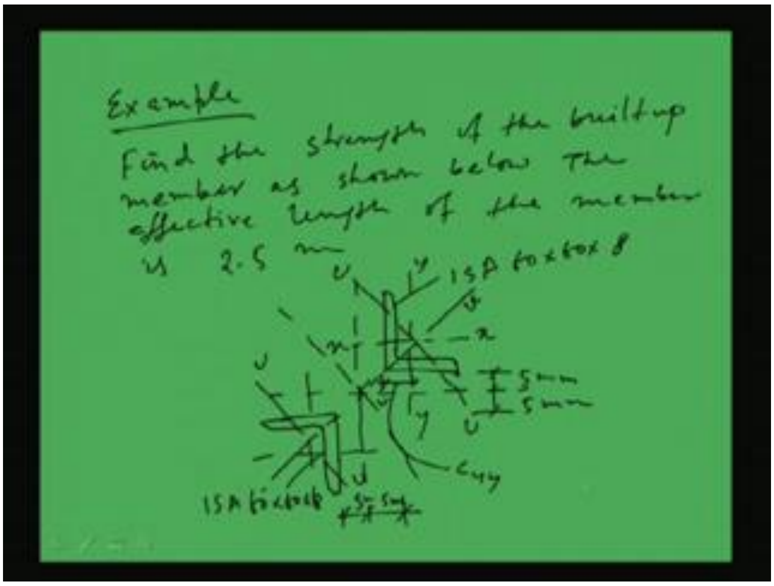

Here we will go through one example to demonstrate how to find out the strength of a built up section, say find the strength of the built up member as shown below. The effective length of the member is say 2.5 meter. Now, the sections are placed in this way. This is one angle, this is another angle. This angle size is ISA 60 by 60 by 8, and this spacing is 10 meters. That means, 5 meter I am sorry 5 millimeter and 5 millimeter. Similarly, in this direction also spacing is 5 millimeter and 5 millimeter, right. This is also ISA 60 by 60 by 8. Now, we have to find out the strength of the member. So, for individual properties we know this is called x direction and this is y direction.

Similarly, here also we have. So, this is Cyy and of course, we have another scope of buckling in this direction and in this direction. This is for individually you can say major-minor axis. This is v and in this direction, it will be major axis u. So, this will be u and u, right. So, these are the possible chances where we have to calculate the radius of gyration for calculating the strength that is in x direction as a whole in y direction as a whole about major axis about minor axis. So, in four directions we have to find out the radius of gyration and minimum one, we have to consider for the calculation of the strength because the permissible stress will be calculated on the basis of minimum radius of gyration or maximum slenderness ratio.

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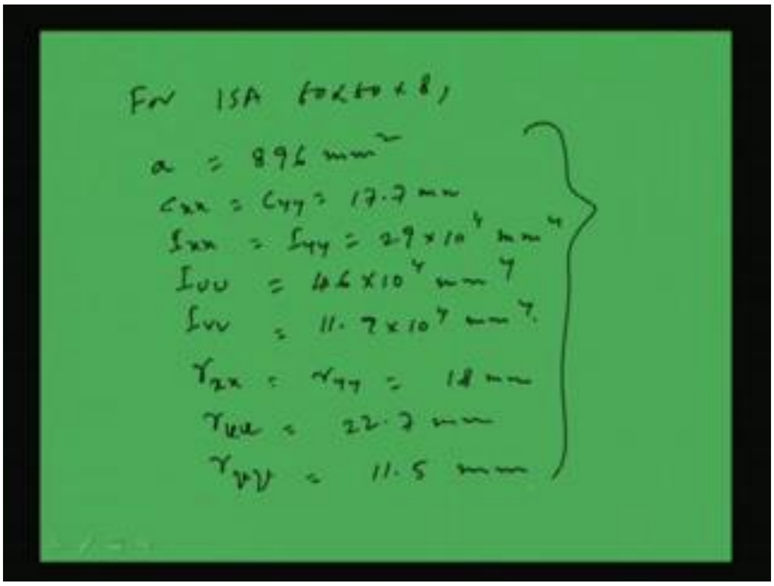

So, for ISA 60 by 60 by 8 sections, the sectional properties can be written as a equal to 896 millimeter square. This is the individual sectional properties. The CG distance Cxx and Cyy will be equal that is 17.7 millimeter. Ixx will be equal to Iyy. The individual moment of inertia about xx and yy direction that is 29 into 10 to the 4 millimeter to the 4. All these properties can be found from the structural book SP 6. So, Iuu that is moment of inertia about major axis will be 46 into 10 to the 4, and Ivv will be equal to 11.9 into 10 to the power 4.

Similarly, I can find out other properties like rxx. The radius of gyration in x direction and in y direction is 18 millimeter, and ruu will be 22.7 millimeter, and rvv is equal to 11.5 millimeter. So, these are the required properties which will be helpful for calculating the equivalent sectional properties of the member.

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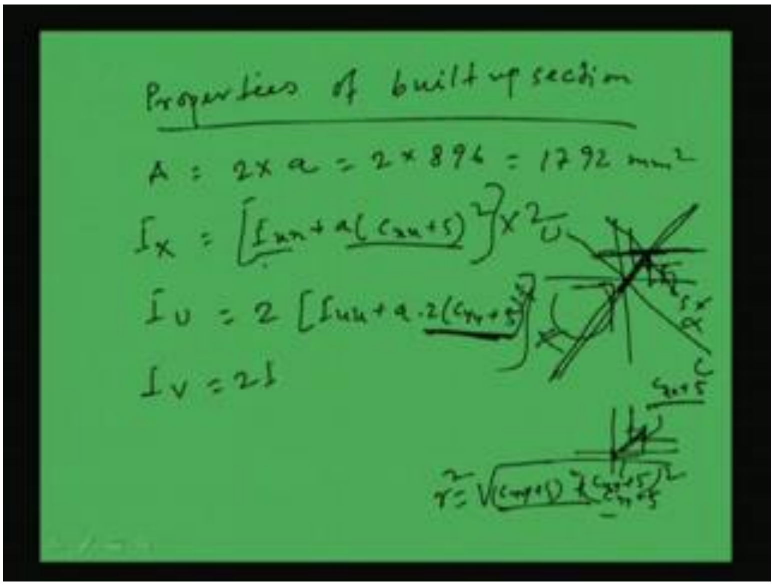

Now, we can calculate the properties of the built-up section. So, what will be the cross-sectional area of the built up section? That will be simply 2 into a 2 into area of the individual properties. So, that is 2 into 896. So, this is coming 1792 millimeter square. Similarly, we can find out the Ix. If we see say one is given here, another is given here, right. Now, So, Ix will be simply that Ix in this direction it is there. So, Ix will be simply this Ixx about this, then ar square. So, that will be Ixx plus a into r square. R square means this is 5 millimeter and this is Cyy or Cxx. That means, this should be Cxx plus 5 millimeter. So, Ixx plus ar square and into 2 because two members are there. Here one member, another member here. So, Ix will be this.

Similarly, I can find out as these are. So, Ix will be totally means this into 2. So, Iu is basically in this direction. So, Iu will simply 2 into Iuu plus a into 2 into Cyy plus 5 square. If this is u, so this can be found out 2 Iu means Iu plus this one. Here ar square r square I am getting 2 into Cy plus 5 square. How? It is because if this is a, I mean center of axis if this is one angle, so here is the Cyy and Cxx. So, this distance I have to find out. This distance will be basically this plus this whole square plus this square. That means, this is Cyy plus 5 and this is Cxx plus 5 and Cxx and Cyy is same. So, this r if I say r will be basically Cyy plus 5 whole square plus Cyy plus 5 whole square. That means, 2 into r square will be 2 into Cyy plus 5 whole square. That is why we have written this and Iv will be Iv is basically in this direction. So, simply 2 into Ivv. So, in this way we can find out. Now, I will find out rx and now Ix will be Iy.

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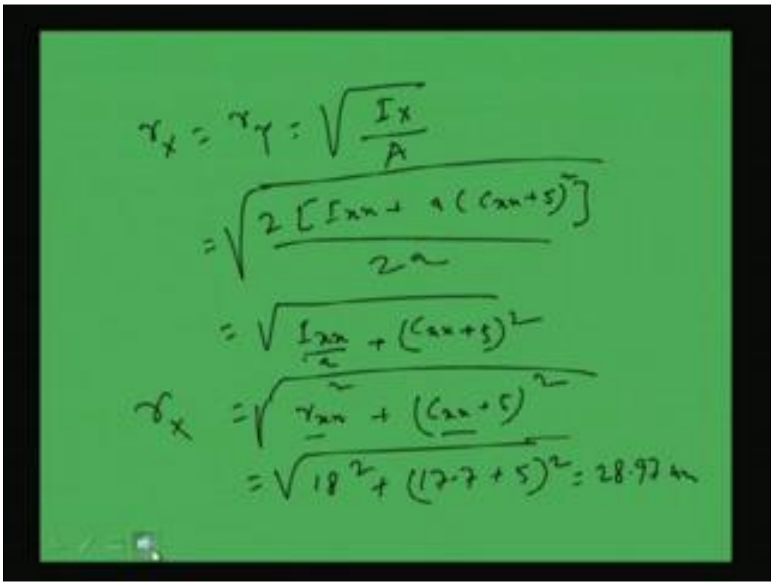

So, rx will be equal to ry which can be find out rx is equal to ry is nothing, but Ix by A. That means Ix is given as 2 into Ixx plus a into Cxx plus 5 whole square into 2 by area means 2 into a. So, now this will become Ixx by a plus Cxx plus 5 whole square. That means rxx square plus Cx plus 5 whole square. So, this is rx, right. Now, if you put the values of individual properties, that mean rx and C rxx and Cxx, we can find out the value rxx is 18 and Cxx is 17.7. So, if you put all these values, we will get rx as 28.97 millimeter.

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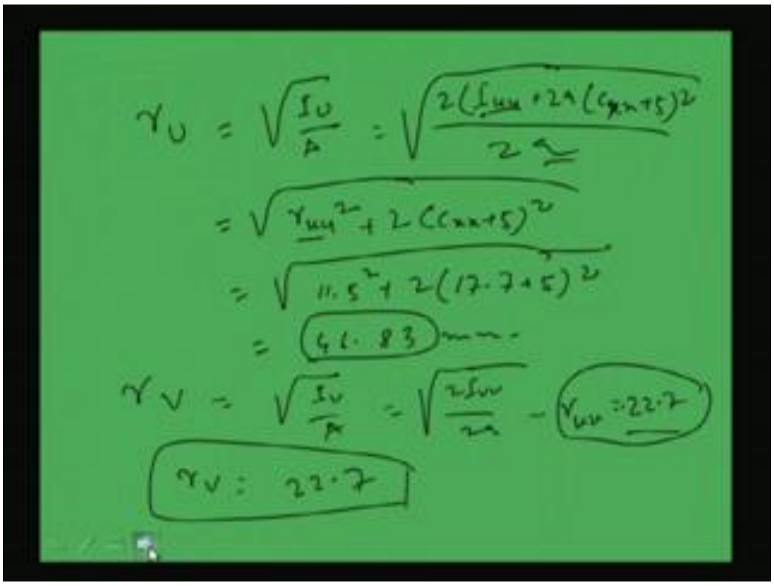

Similarly, I can find out ru that will be Iu by A. That means, it will be 2 into Iuu plus 2 a in to Cxx plus 5 whole square by 2 into a. So, similar way this will become ruu square plus 2 into Cxx plus 5 square, where ruu will be Iuu by a will become ru square. So, now if we put those values, we will get this is 11.5 square plus 2 into 17.7 plus 5 square. So, this is becoming 47.83 and rv will become simply Iv by A. That means, 2 Ivv by 2 a. That means rvv which is given as 22.7. So, what we see that rvv means rv is becoming 22.7, ru is 46.83 and rx is 28.97. So, the minimum is this one that is, rv is 22.7.

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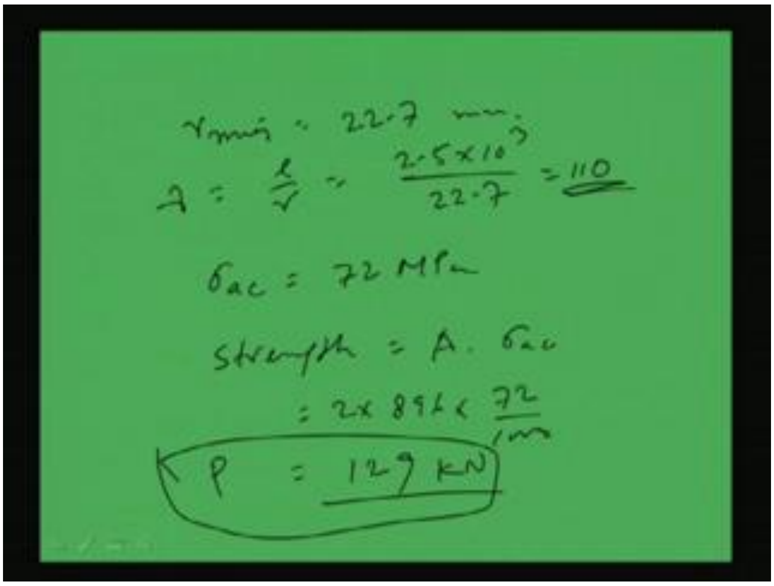

So, r min is becoming 22.7 millimeter. So, we can find out lambda which is l by r. So, l is 2.5 meter. So, this is coming 110. So, from table 5.1, we can find out sigma ac value for A 5250 as 72 MPa for lambda is equal to 110. So, the strength will become A into sigma ac that 2 into 896 into 72 by this is becoming 129 Kilo Newton. So, the strength of the section will become 129 kilo Newton, and it is interesting to note that the strength has been calculated on the basis of rvv in this.

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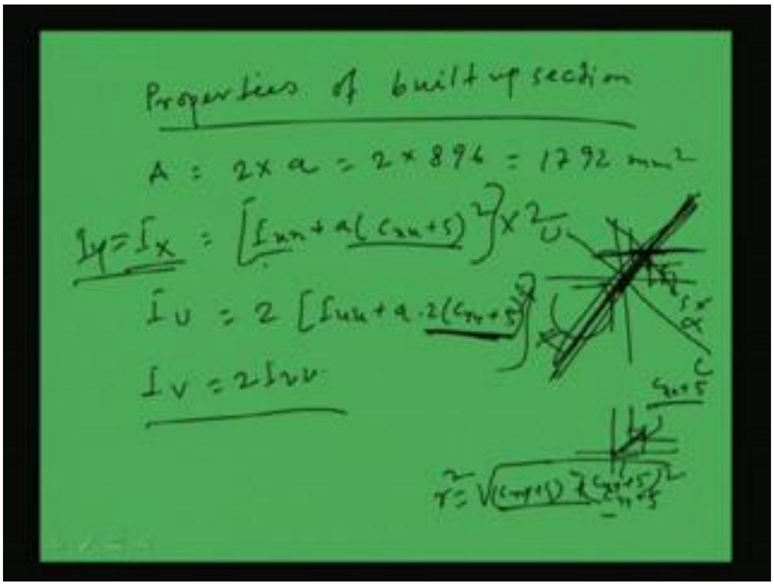

So, the failure will be about this axis, not xx or yy, because xx and yy is same and that is the radius of gyration about xx and about yy direction is more. That is why we have to see what the minimum radius of gyration is considering major axis, minor axis and other. So, along minor axis means for equivalent section we have to find out what the radius of gyration is about minor axis through which it will and the strength has to be calculated accordingly. So, I guess you have some idea about finding the equivalent area and equivalent radius of gyration of the built-up section through which we can find out the strength of the built-up section.

As I told the basic reason of using built-up section is to increase the strength of the member whereas, the increase in material will not be much compared to the increase in the strength. If we use an individual readymade section, if we go on increasing the size of section also, we may not be able to get much more strength because the radius of gyration about y axis that r minimum is not going to increase that much for a single section, but if we use the built-up section, then that means if we use several members with a proper arrangement, so that the radius of gyration becomes more in both the direction. Then, we can find out the compressive stress, allowable compressive stress from table 5.1 much more as the radius of gyration is becoming much more as the slenderness ratio is becoming much more, much less.

So, our target will be to reduce slenderness ratio as less as possible or to increase the radius of gyration as much as possible, and that is possible by increasing the material or by changing the arrangement. Simply if we change the arrangement, it is possible to increase the strength of the member. In next class, we will discuss about the design aspects of compression member.