Design of Steel Structures

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Module - 5
Lecture - 5
Compression Members
Design of Built Up Compression Member

Hello. Today our lecture will be focused on the design aspects of compression member with respect to built-up sections. In last few lectures, we have focused on design aspects of single compression member as well as the strength calculation of single compression member and the built-up compression member. Today we will finish first the remaining part of the last lecture. That means, how to calculate strength of a built-up section, then we will go the design aspects of built-up sections.

Built-up section design means we have to design the section in such a way that all the members will be acting as whole together. So, the members have to be tied properly, so that all members will be acting as a whole for carrying the compression load as well as we have to see that the compressive load are distributed properly to all the members as we want. Therefore, we have to design not only the main members properly, but also we have to focus on design on the other members like lacing or battening. What is lacing and is battening, I will come later. Basically the objective of providing all this extra type of plate is to connect the members each other, to tie the members each other, so that all members act together.

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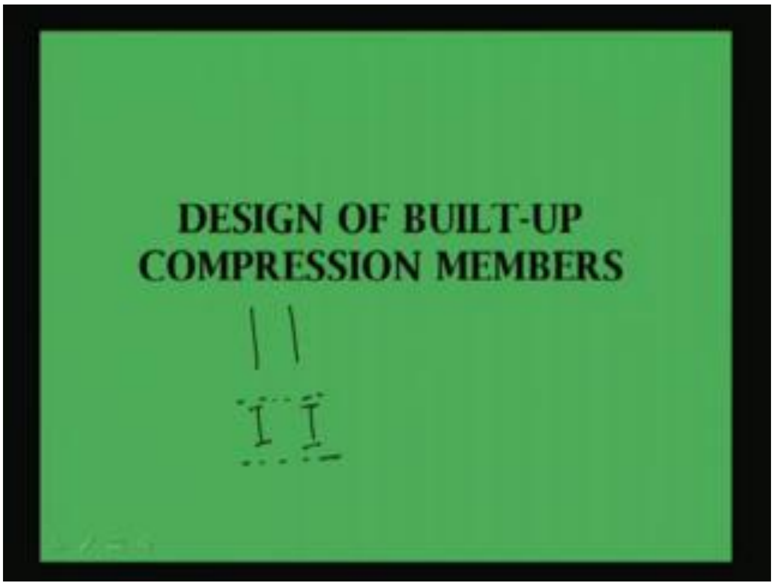

Suppose we have say two I sections. Then, we will see that this is a battening or lacing. Now, if we see in the elevation, we will see that this acting something like this. That means we will be having some sort of lacing like this. Then, this is called lacing system ((lattice)) members we have to provide. We will come to details later.

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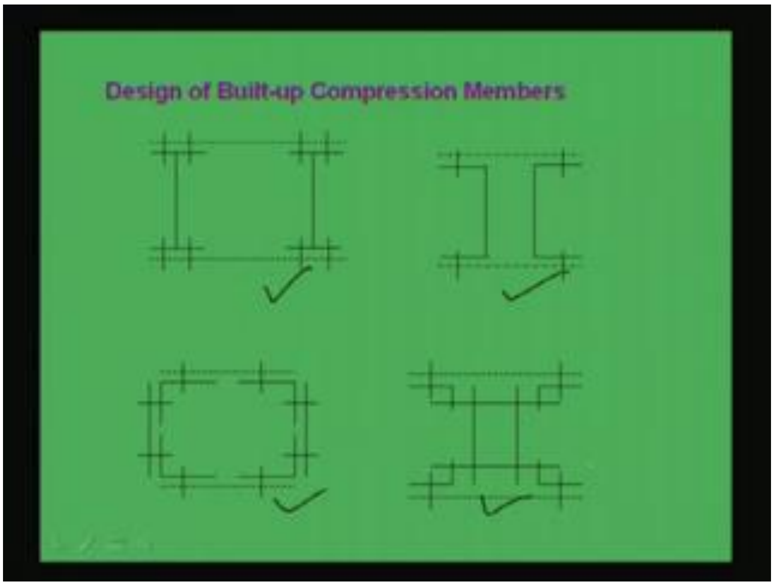

In continuation with the last lecture, we have seen that this type of members can be made with the use of individual members to find a built-up section, and the major objective of choosing the built-up section is that the radius of gyration in both the directions perpendicular to each other should be more or less equal. That means the radius of gyration in the weaker section we are going to increase, so that the strength of the member is going to increase.

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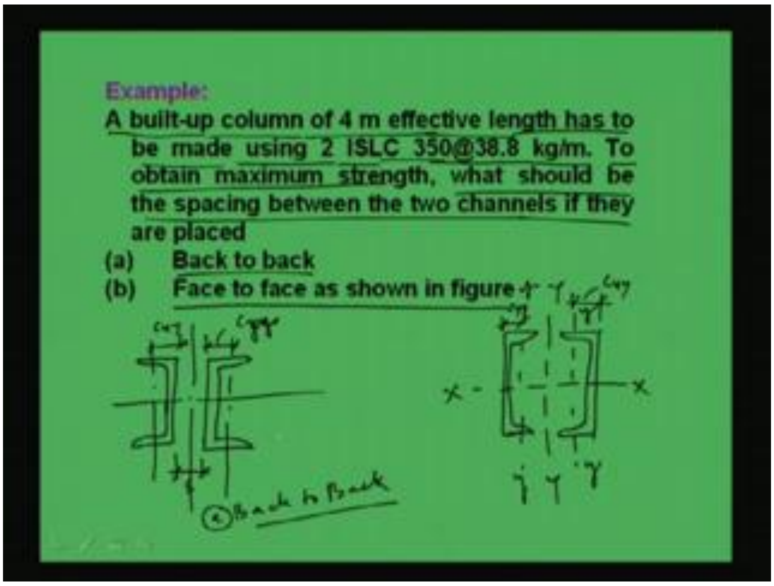

First I will discuss this problem as how to calculate the maximum strength of a particular system and then, I will go to the design aspect. So, let us consider this example that a built-up column of 4 meter effective length has to be made using 2 ISLC 350 at 38.8 kg per meter. To obtain maximum strength what should be the spacing between the two channels if they are placed back to back and face to face as shown in the figure? That means the two orientations we will give the two channels are placed back to back and two channels are placed face to face. If we make in this way, then what will be the strength and what should be the spacing we have to calculate.

Say first case is the channels are placed back to back. This is one channel, another channel is this. That means with same size this is called spacing s and as we know this is basically we call say cxx or cyy, this is called cyy. That means the cg of the channel, right and this is the center of the group section, this is back to back channels with back to back case. Another orientation is something like this. This is one channel; another channel is this which are placed face to face. So, x axis and y axis will be this and individual. This is y axis, individual y axis. This is basically we know cyy that a distance from face to the cg of the system.

So, now we have to find out what the strength of the system is if the channels are placed back to back and what is the strength of the same members if they are placed in face to face with some spacing. Now, here spacing means this one clear distance between two channels, all right. So, this spacing we have to find out. That means, spacing we have to find out means for maximum means for obtaining maximum strength, what should be the spacing with these two orientations that we have to find out.

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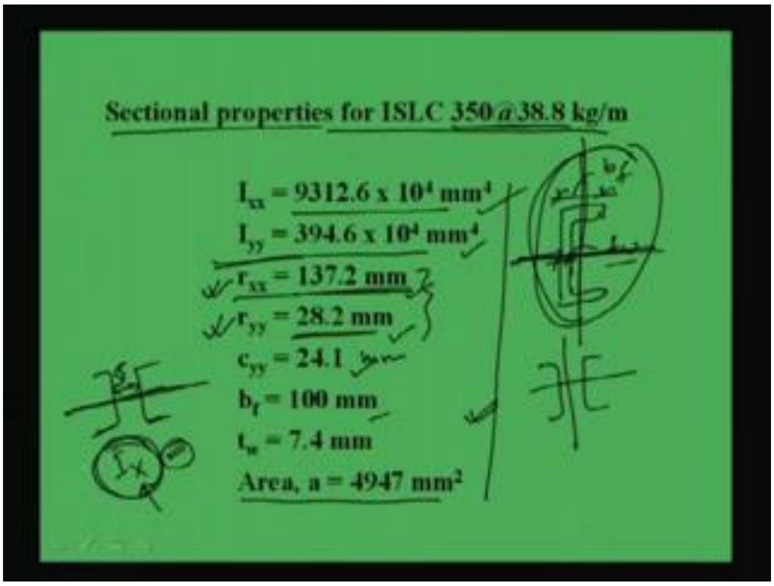

So, what we will do first? First we will find out the sectional properties for ISLC 350 at rate of 38.8 kg per meter. We know the sectional properties of a section which is given in IS code is available in SP: 6-1964, the structural handbook SP: 6, right. So, from there the properties of the channel section we can find out. Like the individual property of ISLC 350 has been given like the moment of inertia about x axis is 9312.6 into 10 to the power 4 millimeter to the power 4 which is obtained from structural handbook SP: 6.

Similarly, iyy is 394.6 into 10 to the power 4 millimeter to the power 4. Rxx is the radius of gyration is given 137.2 millimeters, Ryy is given 28.2 millimeters, Cyy is 24.1 millimeters. Bf is the width of the flange. Bf means if the channel is this, then we can say this is bf width of the flange is 100 mm. Tw is the thickness of web that is given 7.4 millimeter which will be required and area of the section is given 4947 millimeter square. Remember these properties of a single section have been given in the code which has been written here.

Now, if you see ixx is much greater than iyy or in other words also we can say that rxx is much greater than ryy. Rxx is 137.2 and ryy is 28.2. So, as we know the compressive strength of the member depends on the radius of gyration because if radius of gyration becomes less than l by r ratio, then that means slenderness ratio will increase. Slenderness ratio increasing means the allowable compressive stress of the member will decrease as because of buckling effect. So, to make the section economy to take the advantage of that, we can do what? We will place the channel section in such a way that this rxx will become ryy, right or ixx will become iyy, so that the resistance from both the directions will come same.

In a single section, resistance in this about this direction is very high compared to this direction. That is why though the member is very strong about this x axis, but weak about y axis. As a result, the member is weak because we have to see the strength from the weakest point of view because failure will happen first in the weaker section. So, if we can increase the radius of gyration by placing in a proper way, then what will happen is we can increase the strength of the built-up section. Now, suppose what we can do up to what we will increase because we know ixx is fixed whatever placing we are doing. Whatever s we are making ixx means ix combined ix is fixed that is the summation of these two individual ixx.

So, what we have to do? We have to increase the iyy up to what? We will increase up to ix because after that if we increase, again failure will start from ix point of view about x axis the failure will start. That is why what we will do is we will try to make equal. That means ix equal to iy. Unnecessarily if we increase the ryy value means ry value, that means radius of gyration about y axis then what will happen. Unnecessarily if we increase also, but strength will not increase after reaching rx value means ix because failure will start in about x direction and we cannot increase that one by placing of two channel section apart from each other, right. So, that is why for optimum we can make ix is equal to iy, right. So, that is what we will make it.

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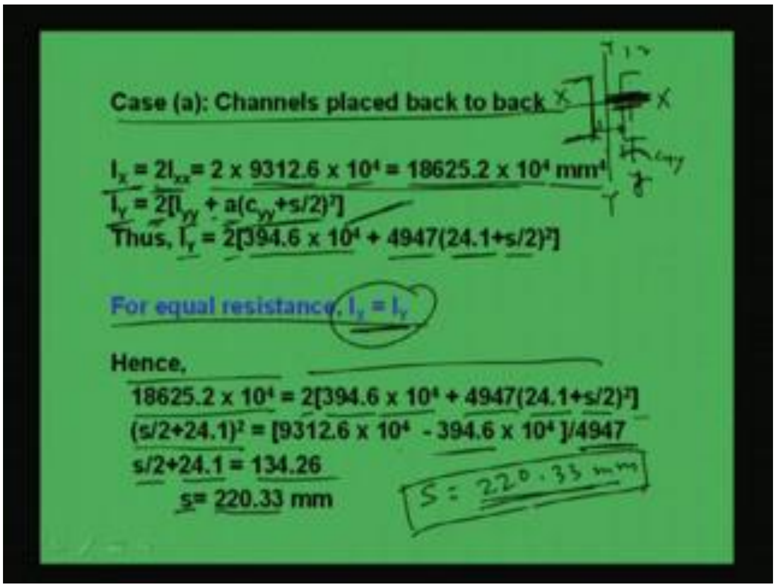

So, first let us consider case a. That means the channels placed back to back. That means, two channels are placed back to back. So, what we will do? First we will consider the equivalent ix for the built-up section. Ix means the moment of inertia about x axis of the built-up section. If this is x, then ix means 2 into ixx because ixx individual ixx we have here, right. So, 2 into ixx will be the moment of inertia about x axis of the built-up sections, right. So, ix we can find out 2 into ixx is equal to 2 into 9312.6 into 10 to the power 4 which will be equal to 18625.2 into 10 to the power 4 millimeter to the power 4. So, this will be the moment of inertia of the built-up section about x axis.

Similarly, I can find out the moment of inertia about y axis of the built-up section. When I am talking about y axis means this is the y axis, right. So, this will be what? This will be we have individual iyy, right. This is yy axis of the individual. So, what we will do? Iyy into means iyy is there plus that ar square, right. So, 2 into iyy plus a into r square. What is r value? R means this is cyy, the distance from the face to the cg of the section plus this is s. So, this will be s by 2. So, a into r square means a into cyy plus s by 2 whole square and into 2 yy we have made because of two sections, right. So, iyy we can find out from this expression.

Now, if you put the values of those, we will get iy is equal to 2 into 394.6 into 10 to the power 4 which is iyy value plus area is individual area of the section is 4947 millimeter square into this is the cg distance from the space 24.1 plus s by 2 whole square, and as we know for optimum utilization of the two members, what we have to make is ix equal to iyy. That means, we will place the sections in such a way that equal resistance will come from both the direction, right. So, if we make ix equal to iyy, what we will do? We will get this is ix that is 18625.2 into 10 to the power 4. Is equal to 2 into 394.6 into 10 to the power 4 plus 4947 into 24.1 plus s by 2 whole square. This is iyy and this is ixx, right.

Now, if we make equal, then what we will get? That is s by 2 plus 24.1 whole square will be equal to 9312.6 into 10 to the power 4 minus 394.6 into 10 to the power 4 by 4947. So, from this I can find out s by 2 plus 24.1 is equal to 134.26. That means s is equal to 220.33 millimeter. That means the spacing is equal to 220.33 millimeter. So, this is the spacing if we can make, then we will get equal resistance from both the side. That means, the ix will be equal to iy. So, that means I can find out the radius of gyration.

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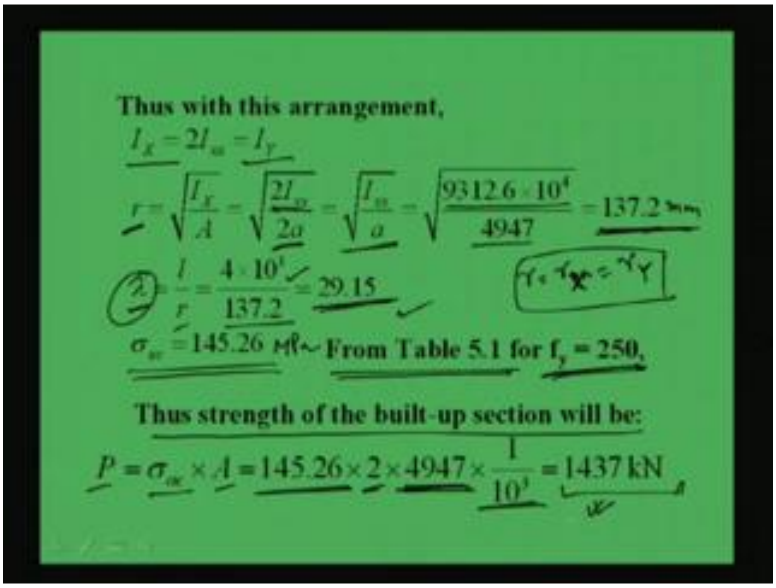

The ix value we know now radius of gyration. We know radius of gyration is ix by a or iy by a. So, ix means 2 ixx and a means area of the built-up section which is 2 into a where small a is the area of the individual section. Now, after equating we will see ixx by a. Now, if you put the value of ixx and the area of the individual section, we will get r as 137.2 millimeter, right and this is also directly we can find out from the SP6, right. So, lambda will become l by r.

Now, the effective length has been given as 4 into 10 to the power 3 millimeter means 4 meter, right. That means, 4000 millimeter by r radius of gyration. Radius of gyration is 137.2. This radiation gyration basically r means rxx we can say. Sorry rx we can say or ry also we can say. It will be same. So, lambda the slenderness ratio is becoming 29.15, right. So, now from this slenderness ratio value and for fy is equal to 250, if we assume the steel grade as 250, then from table 5.1 of IS 800, what we will get is sigma ac, the permissible compressive stress in the member. That is what we will get from table 5.1 and this is coming sigma ac as 145.26 Mpa, right. So, corresponding to lambda as 29.15 and fy as 250 from table 5.1 of IS 800, we can find out sigma ac as 145.26 Mpa. Thus, we can find out the strength of the built-up section which will be basically P is equal to sigma ac into a.

Now, sigma ac we have calculated that is 145.26 Mpa and area means 2 into cross sectional area of the individual section that is 4947. So, 2 into 4947 is coming in Newton. If we divide by 1000, we will get kilo Newton. So, finally, we will get 1437 kilo Newton, right. So, this is the way we can find out the maximum strength and this maximum strength we can find out if the spacing is becoming 220.33 millimeter. On these circumstances we can find out the maximum strength as this. That means 1437 kilo Newton.

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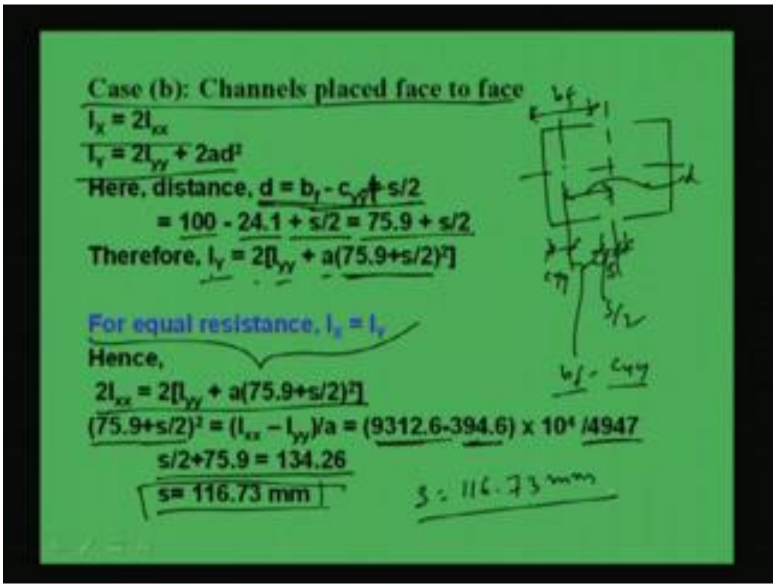

Now, let us come to the second case. Second case means channels placed face to face. That means if one channel is like this, another channel is placed like this, then what should be the spacing to get the maximum strength of the member, right. So, like previous cases we can find out ix as 2 ixx and similarly, iy as 2 iy plus 2 into a into d square. What is d? D is the distance which can be written as df minus cyy plus s by 2. This is plus s by 2, right. How we are getting that means we have to find out here, right. So, this is s by 2 and this we can find out s by 2 and this is bf and this is cyy, right. So, what we will get is this distance we will get bf minus cyy. So, the total distance from here to here we will get as d which we have written d will be bf minus cyy plus s by 2, right, so bf minus cyy plus s by 2.

So, bf is 100 mm, cyy is 24.1 and s by 2, we do not know as ac is the spacing which we have to find out. So, this is becoming this d. So, iy we can find out as iy is equal to 2 into iyy plus a into d square, where d is 75.9 plus s by 2, right. So, with the same concept that to get equal resistance from both the directions if we make equal ix is equal to iy, what will happen? We can find out the value of s. That means if we make ix equal to this, so we can find out that 75.9 plus s by 2 whole square is equal to ix minus iyy by a. That means this minus this. Ixx is 9312.6 and iyy is 394.6. So, by a is 4947 Newton square, right.

So, we can find out s by 2 as this one and s can be find out as 116.73 millimeter. So, the spacing whatever we are getting from this expression is that s is equal to 116.73 millimeter. If we make spacing of this magnitude, then the equal resistance from both the directions will be optimum, right.

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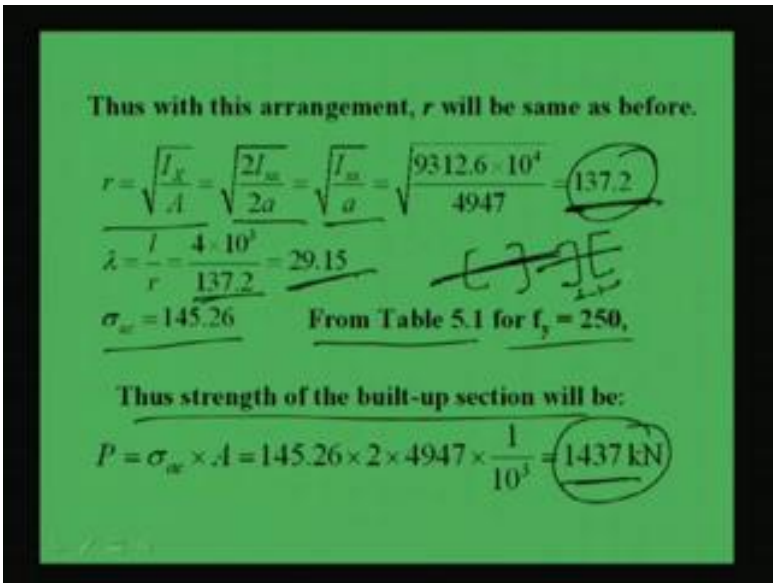

So, now the strength. How you calculate strength? In the similar process you can find out where r is equal to ix by a. That means, ixx by a means same thing. So, lambda will be similarly we can find out l by r, where l is the effective length which is given as 4 meter or 4000 millimeter and r we can find out that is 137.2. So, we can find out sigma ac value as 145.26 Mpa from table 5.1 of IS 800 for fy grade of 250 Mpa, right. So, in this way we can find out the strength of the built-up section as same that is 1437 kilo Newton. See here whatever combination we do means whether back to back or front to means, face to face ixx will be same for both the cases because ix will be 2 into ixx. So, the strength will be same means maximum strength can be attained this much.

Now, if we increase the spacing, the strength about iyy means strength about y direction will be increasing, but failure will start in x direction, but we cannot increase the strength about x direction because that ix will be fixed that is 2 into ixx. So, to get maximum strength what we can do? That maximum radius of gyration rxx we can attain by increasing the spacing that s by calibrating the magnitude of the spacing because spacing if we increase much more, then it will not work. What will happen? The strength about y direction will be increasing, but strength about x direction as we cannot increase. So, failure will be happening on this strength 1437 kilo Newton, right.

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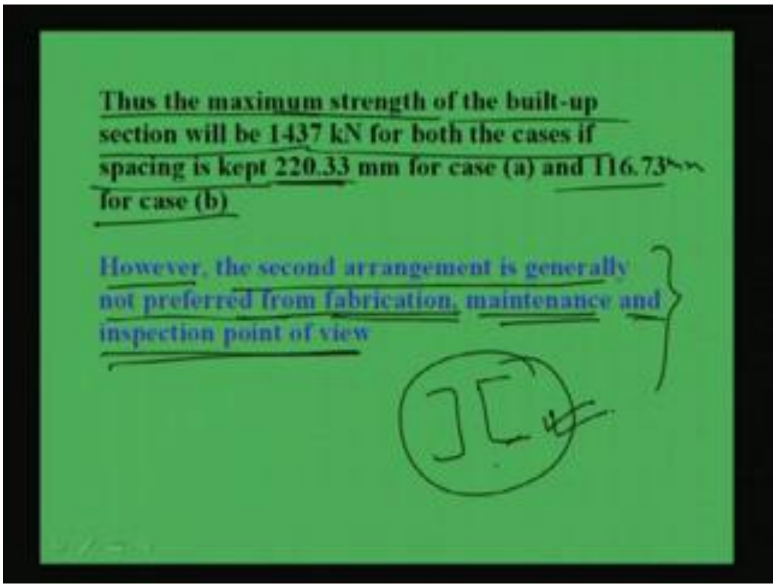

So, what we are getting? We are getting the maximum strength of the built-up section will be 1437 kilo Newton for both the cases. If spacing is kept 220.33 millimeter for case a, and 116.73 millimeter for case b, so which arrangement we should go we should think. However, the second arrangement is generally not preferred. Why? It is because of fabrication maintenance and inspection point of view. From these three points of view, the first case is preferable. So, generally we use to go first case that is channel back to back. So, in this way generally we use to design if we have to consider two channels. We now understood that how to find out strength of a built-up member.

Now, we will go for the design process that how to design a compression member having built-up sections. This is exactly same as we have done for individual member, right. So, similar process we will follow for getting the design aspects of built-up compression member. So, let us see how it happens.

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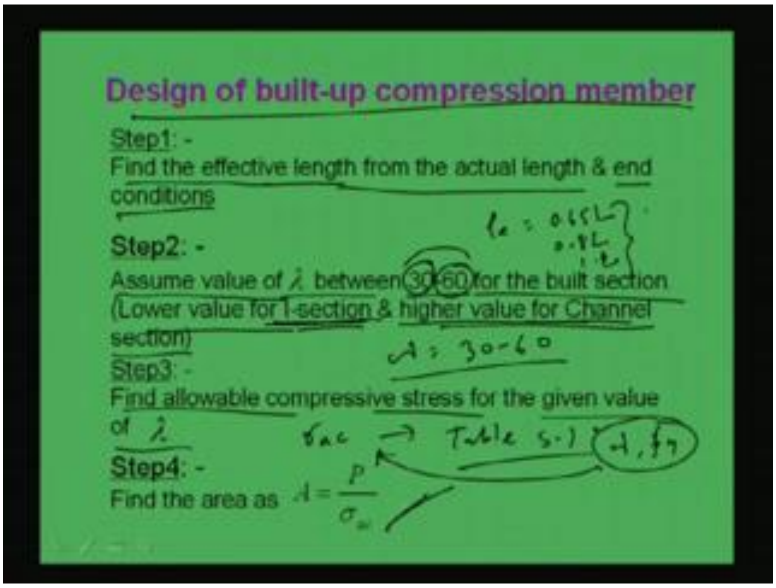

So, for design of built-up compression member, we will see what the steps we have to follow. In step 1, what we do that we can find out the effective length from the actual length and end conditions. That means what will be the effective length le whether this is 0.65 l or 0.8 l or 1 l. That means it depends on the boundary condition of the member whether it is restraint against both the directions or restraint against its rotation. So, all these things we have to see. Accordingly we have to find out the effective length.

Then, in step 2, what we can do? We can assume some value of lambda radius of gyration will be between 30 to 60 for the built-up section. You see lower value for I section and higher value for channel section. That means if I section we can consider 30 and if channel section we can consider 60, so in between 30 to 60 we can consider. One may ask why 30 to 60? Why not more? It is because in case of built-up section, we are taking the advantage of getting efficiency from both the section, both the side. That means the rxx will become ryy. So, maximum radius of gyration we are going to attain. That is why the compressive strength, allowable compressive strength will be more, right.

So, from the experience it is seen that if we consider built-up section, the radius of gyration varies from 30 to 60 in between near about. It is not exactly 30 to 60. It may be 70 or it may be 20 also. It depends on the type of arrangement whatever we are going to do, right. So, we have to first assume say lambda value say from 30 to 60. Something we have to assume on the basis of our experience or with this also for I section, we can go for lower value and for channel section, we can go for higher value, right. Then, what we will do? Then, we can find out the allowable compressive stress for the given value of lambda, right. For the assumed value of lambda, we can find out the allowable compressive stress that is sigma ac, right. From table 5.1 where from lambda and fy, we can find out the sigma ac value. After that what we will do? We can find out the area required that is the load by allowable compressive stress P by sigma ac. The required area can be find out in this way. Then what we will do?

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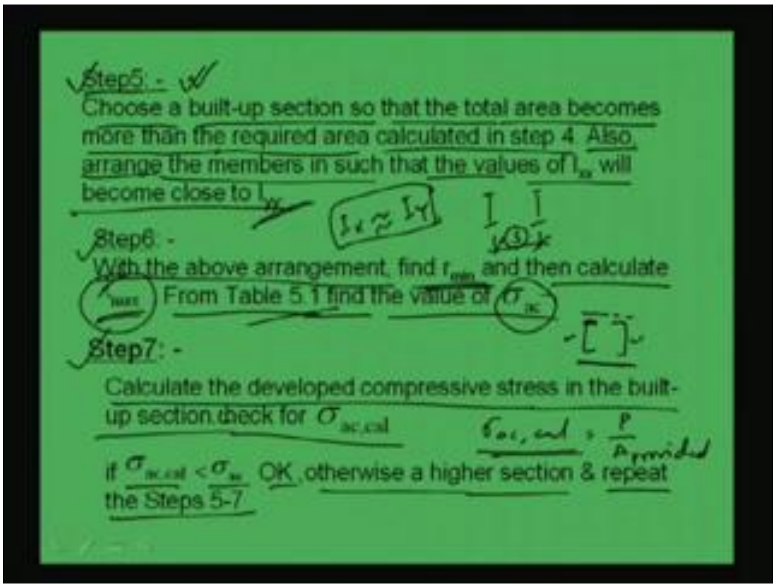

We will come to step 5. That means we know the required area. So, accordingly we can choose a built-up section, so that the total area becomes more than the required area calculated in step 4. That means the choosing area should be more than the calculated area which has been calculated in step 4. Then, also arrange the members in such a way that the values of ixx will become close to iyy. This is important. We have to arrange in such a way suppose we have two I sections. So, the distance between two sections will be in such a way that ixx will become close to iyy. So, ixx means ix will become close to iy of the built-up section that we have to make. Then what we will do? With the above arrangement, find r minimum r. Minimum is the radius of gyration.

Now, to get maximum efficiency means get maximum strength of the member, we will get rxx is equal to ry rx is equal to ry. However, if it is not possible, then we have to find out what the r minimum is and then, calculate lambda max r minimum means lambda max we will get. Then, again from table 5.1 you can find out the value of sigma ac. Sigma ac means the compressive stress, right. Now, calculate the developed compressive stress in the built-up section. How we will develop? That sigma ac calculated will be P by A. A means A provided, right. So, whatever area we are providing from the built-up sections, we can find out sigma ac calculated and before that we have already calculated the permissible stress from the actual slenderness ratio, and fy with the help of table 5.1, right.

So, now we will check if sigma ac calculated is less than sigma ac. Then, otherwise what we will do? Otherwise choose a higher section and repeat the steps 5 to 7. That means again we will choose a higher section and then will go to steps 5, then 6 and 7, right. So, this we will repeat till we are satisfied with this checking. That means, sigma ac calculated will be less than or equal to the permissible stress. So, this is the way of what we have to do. So, what are the differences we are getting from the design aspects of single section and from the built-up section? That is that we have to arrange the built-up section. We have to arrange the two or more individual sections in such a way that we will be getting approximately equal radius of gyration in both the directions to get maximum benefit from that orientation, right.

So, on that way we have to find out what will be the distribution of the members means what the arrangement of the members will be and then, what will be the spacing of the member. We have to find out and in that way we can find out the sectional properties of the built-up section as well as its spacing. Now, this is not the end of the design because when we say two channel sections, we are providing. Now, when we are providing two individual channel sections, it has to be tied up in such a way that it is acting as a whole. The section is acting as a whole as a group. So, by the use of lacing or battening members. So, that we will come later, but before that let us go through one example through which you will be seeing that how to design with these steps.

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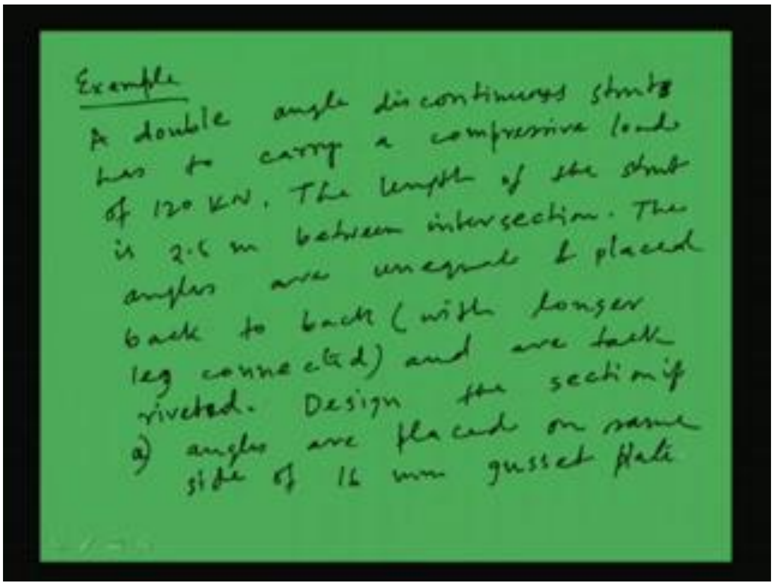

So, let us go through this example, that is, a double angle discontinuous strut has to carry a compressive load of 120 kilo Newton. The length of the strut is 2.5 meter between intersections. The angles are unequal and placed back to back with longer leg connected and are tack riveted, right. Design the section. If first case is say case a angles are placed on same side of 16 mm gusset plate, right. This is one.

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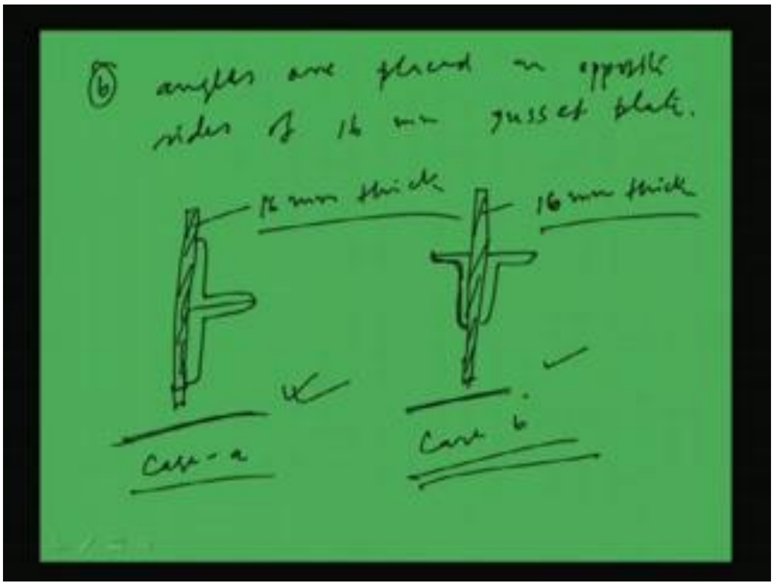

Second case angles are placed on opposite sides of 16 mm gusset plate, right. That means in first case say this is the gusset plate. Now, it is told that longer legs connected. So, this is one, another one is this, right. So, this is case a, right. This is the gusset plate and the orientation will be like this for case a. For case b, if this is the gusset plate, then remember that longer legs are connected with the gusset plate. So, this will be the longer, right. Now, these are 14, sorry 16 mm thick. These gusset plates are 16 mm thick. So, this is case b.

So, what we have seen here that the two unequal angles are connected with the use of gusset plate in two ways. One is in the same side; another is in the opposite side. Then, we have to design the angle section with these two arrangements and we have to see which one is better. We can see in fact which one will be means preferable, right.

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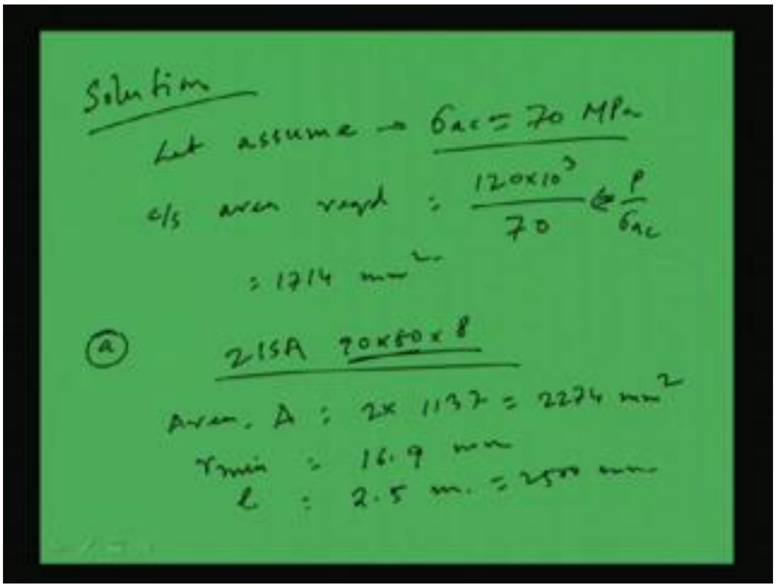

So, what we will do? See if we go for solution, so first what we will do is, we will assume either some radius of gyration or simply we can assume also sigma ac value say let me assume 70 Mpa, right. So, if we assume say allowable compressive stress as 70 Mpa, then we can find out cross sectional area required, right. That we can find out. P was 120 kilo Newton by sigma ac. This P by sigma ac we are making. So, from this we can find out 1714 millimeter square. Now, as unequal angle has to be chosen, so from the IS handbook we can find out that 2 ISA 90 by 60 by 8, right. Let us try with 2 ISA 90 by 60 by 8.

Now, from this section we can find out the corresponding areas and other details like say area we can find out say total area will become 2 into individual area is 1137 for this section ISA 90 by 60 by 8. So, this is coming 2274 millimeter square. Now, r minimum of the individual section is given 16.9 mm, right and the effective length that will become as per the codal provision as equal to the length between the intersections, that is 2.5 meter. That means 2500 millimeter.

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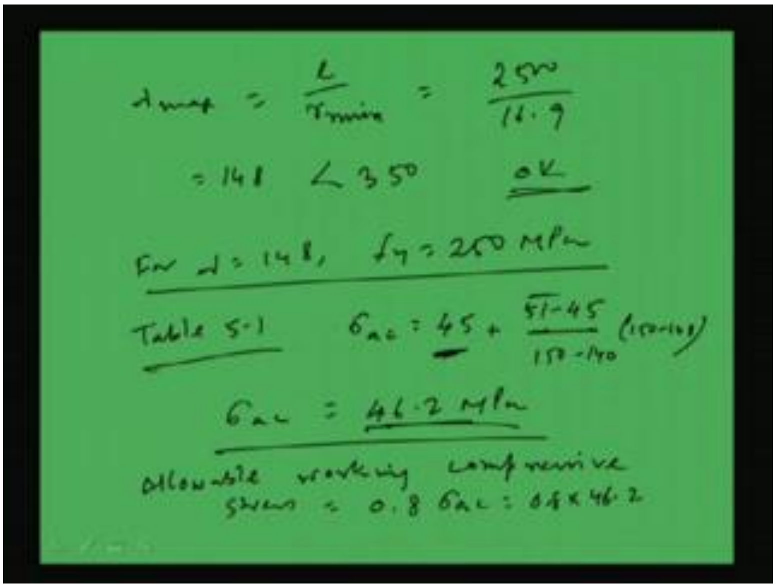

So, the lambda max will become l by r minimum, so that we will get 2500 by 16.9 which is coming 148 and this is less than 350. So, we can say from the slenderness point of view, it is now we have to find out the strength. So far lambda is equal to 148 and assuming fy is equal to 250 Mpa, we can find out the sigma ac value from table 5.1, we can find out sigma ac. That will become 45 which is at 150 plus 51 minus 45. Sorry this is at 140 and this at 150. Sorry this is 150, this is 140 by 150 minus 140 into 150 minus 148, right. So, from the interpolation we can find out the value as 46.2 Mpa. So, sigma ac value for lambda is equal to 148. We are getting as 46.2 Mpa, right. So, now we can find out the allowable working compressive stress that will be 0.8 times of sigma ac. So, 0.8 into 46.2, right.

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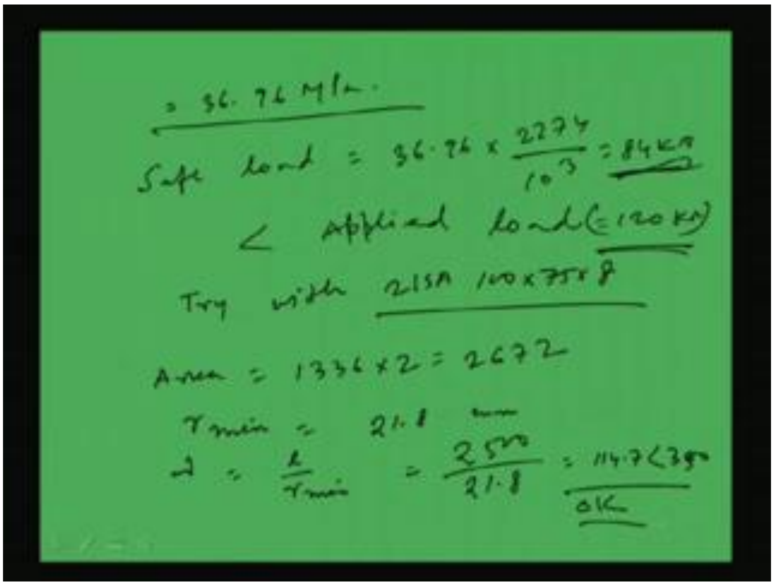

This will become 0.8 into 46.2 will become 36.96 Mpa, right. So, this is the allowable working compressive stress. Now, safe load will become area into the allowable working compressive stress. Allowable working compressive stress is 36.96 and area is 2274, and I am making kilo Newton. So, I am dividing 1000 which is coming 84 kilo Newton, right which is less than the applied load.

What is applied load? Applied load was 120 kilo Newton. So, what we have seen the assumed compressive stress was not and for what we are getting the safe load which is less than the applied load, right. Now, let me see once again that here we are getting that required cross- section area is 1714, right and we are providing 2274. That means 2274 we are providing and 1714 is required. So, we are providing more. Still it is not safe that is because we have considered the allowable compressive stress little high. Now, we have to change it, right. So, as the design is not satisfactory, so we can increase the section.

So, let us try with say 2 ISA say 100 by 75.8. So, now the area will be from the structural handbook, we can find out area that will be 1336 into 2 which will become 2672 and r minimum will be 21.8 millimeter, right. So, lambda we can find out l by r minimum that is l is 2500 r. Minimum is 21.8. So, this is becoming 114.7 which is less than 350. So, from slenderness point of view this is (( )).

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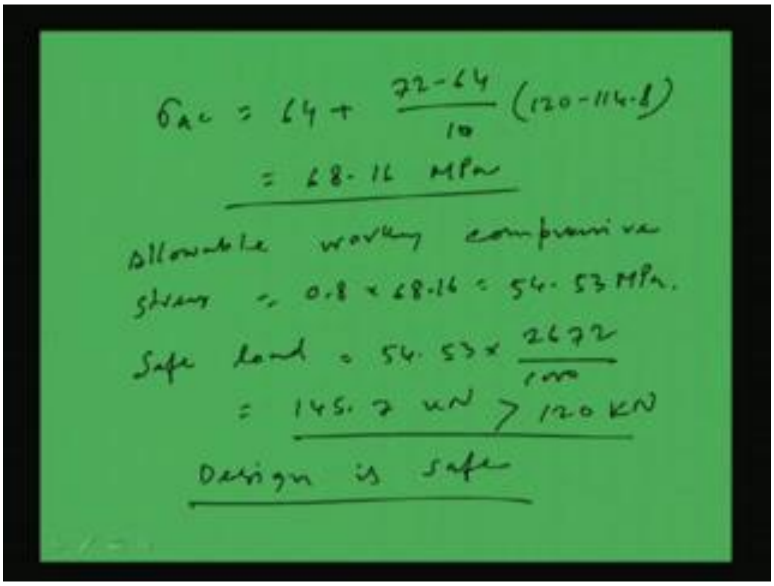

Now, with this we can find out the sigma ac value. Sigma ac value will be from table 5.1. We can find out as this 64 plus 72 minus 64 by 10 into 120 minus 114.8, right. So, after calculation we will get 68.16 Mpa. So, the allowable compressive stress for this particular section we are going to get as 68.16 Mpa. So, allowable working compressive stress will be 0.8 times of that. So, 0.8 times of 68.16, this is becoming 54.53 Mpa, right. So, safe load will be going to get safe load as 54.53 into area. Area of the combined section is 2672, and now I am making into kilo Newton. So, this is becoming 145.7 kilo Newton which is greater than 120 kilo Newton, right. So, we can say design is safe.

So, we have the applied load was 120 kilo Newton and the section can carry 145.7 kilo Newton. So, in this way it is safe. So, this is how we can find out the cross-sectional property means the section, the required section we can find out from this way.

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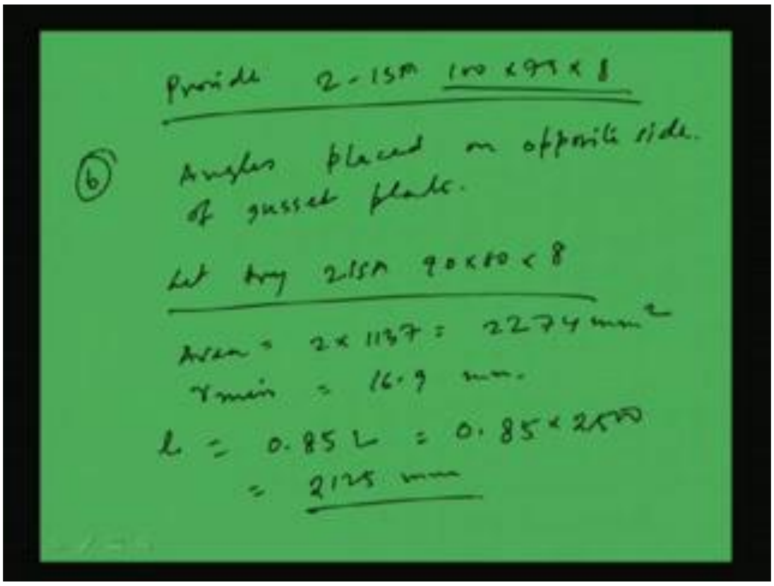

So, finally what we can say is that provide 2 ISA 100 by 75 by 8 angles. For case a, we can provide 2 ISA 100 by 75 by 8 angle. Now, let us come to the second case. In second case, what is there is that angles placed on opposite side of gusset plates. So, what we will do? Now, for this case let us try with the earlier section say 2 ISA 90 by 60 by 8. Let us try with this first. So, area is becoming 2 into 1137 which is 2274 millimeter square and r minimum is for this case 16.9, right and l for this arrangement where the angles are placed opposite side of the gusset plate, l will become the effective length will become as per codal provision 0.85 l. So, this will become 0.85 into 2500. So, this is coming to 2125 millimeter. So, the effective length is becoming this.

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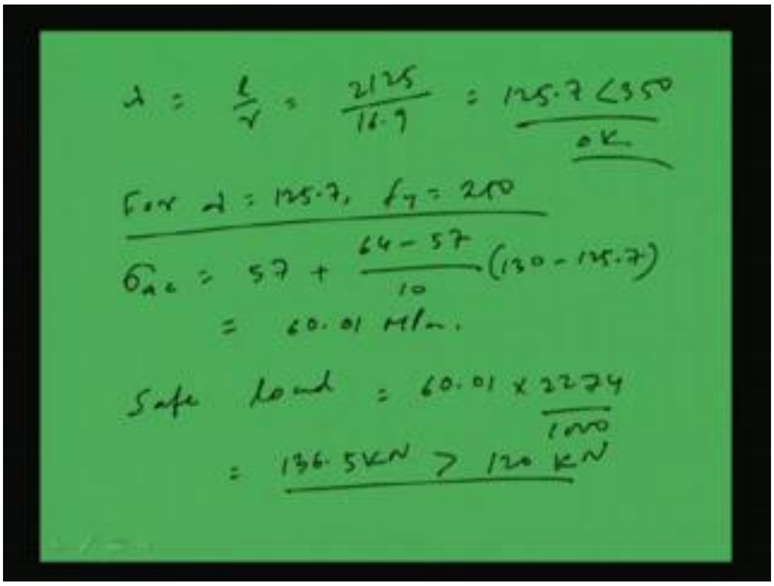

Thus, the lambda will become l by r. That means, 2125 by 16.9, this is coming 125.7 which is the less than 350. So, we can say right. Now, from table 5.1 for lambda is equal to 125.7 and fy is equal to 250. We can find out the allowable compressive stress sigma ac. That will become as per table 57 plus 64 minus 57 by 10 into 130 minus 125.7. So, from this I can find out this as 60.01 Mpa, right. So, safe load will be this will become 60.01 into 2274 by 1000 per kilo Newton. So, this is coming 136.5 kilo Newton which is greater than 120 kilo Newton. That means the design is safe, right.

So, what we have seen that when the angle are placed opposite side of the gusset plate, the strength is increasing. Strength of the built-up section is going to increase because if they are placed opposite to the gusset plate, then the effective length is going to increase by 0.85 times of the total length. That is why the effective length decreases means the buckling effective will be less. That means the slenderness ratio will be less. That means the allowable compressive stress of the section will be more. If allowable compressive stress of the section becomes more, then definitely the strength will be more. So, with lower section we can provide.

So, what we have seen to carry 120 kilo Newton load if we choose the second case with a lower section, the design will be safe whereas, if we choose the case a, the first case, then we have to go for higher section because in that case we see that the length is means effective length is equal to the clear distance between two points. So, effective length is not going to reduce. That means the slenderness ratio is not going to reduce. That means the stress is going to decrease. Allowable stress is less and as a result the sectional property has to be more. That means, dimension has to be more, cross-sectional area has to be more to carry that much load.

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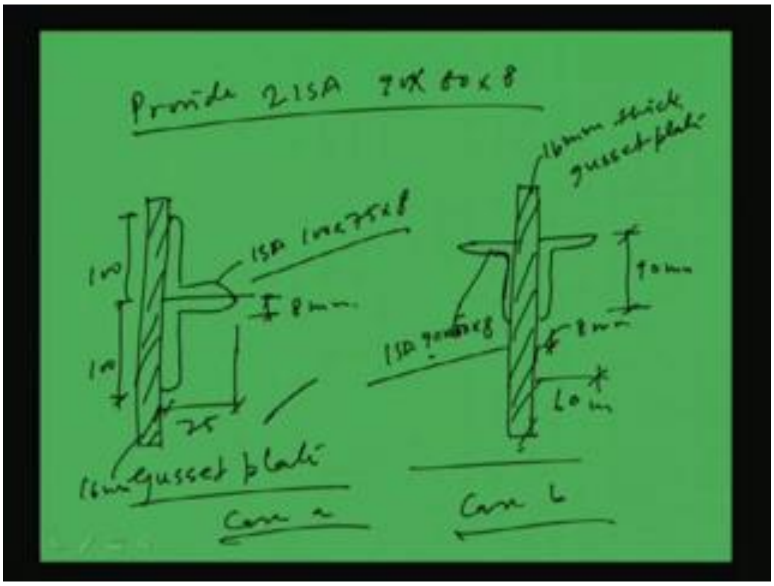

So, we can provide 2 ISA 90 by 60 by 8. So, this we can provide. So, what we have seen that if the angles are placed in case of first case, in this way say this is the thing then. This will become 100. This is 100 and this is 75 and this is the gusset plate, right. So, this is ISA 100 by 75 by 8. This is 8 mm and this is 16 mm gusset plate. So, case a, and in second case, what we have seen that the angles are placed to the opposite sides of the gusset plate, right. So, if we place like this, this is 16 mm thick gusset plate, this is 8 mm and this is basically 60 mm, this is 90 mm. The section is ISA 90 by 60 by 8 case b.

So, for case b we can use 90 by 60 by 82 angle of 90 by 60 by 8 to carry 120 kilo Newton load whereas, for this arrangement we need ISA 100 by 75 by 8 to carry the same amount of load. So, this is the way how we have to design a compression member with using built-up sections. How to design? We have gone through one example from which we can understand. Now, this is not the end of the design of a built-up sections because so far whatever we have done is that the design of the main members of the built-up sections.

Now, as we told that built-up section that means the sections consisting of more than one has to be tied in such way of that the whole sections working means acting as a group. All the components are working means are acting as a whole. So, that is why we need to tie the members, the individual components. So, those tying can be done through lacing or battening which will be discussed now shortly. That means as we do not have much time, so just I will give today some overview of the lacing and battening system and next day I will discuss more about this, right.

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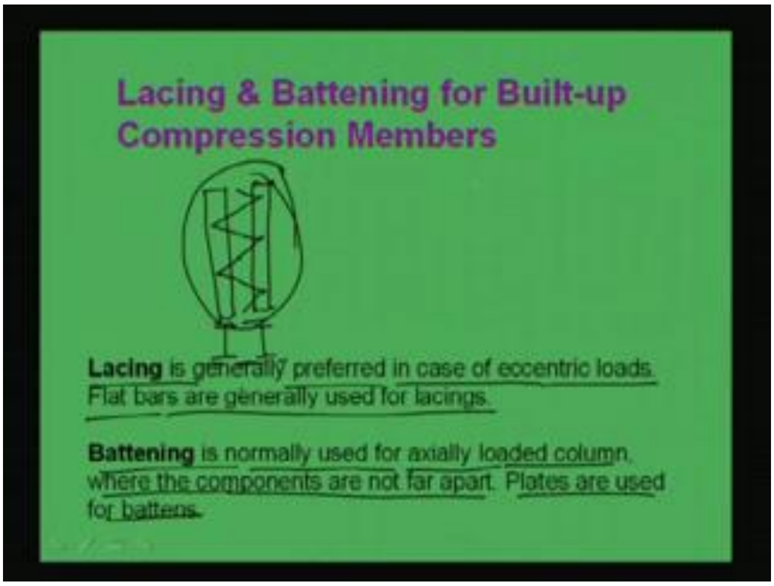

So, that means suppose there is two I sections, right say I section are there and here it is. Now, if you see the elevation of this section, you will see like this, right. So, this is one I section, this is another I section. Now, it has to be tied in such a way maybe this is called generally the lacing system. So, it is tying in such a way that the whole systems are working together, right. That is why we call this as a lacing. This member is called as a lacing. So, lacing is generally preferred in case of eccentric loads. Flat bars are generally used for lacings. This is the lacing and battening is normally used for axially loaded column, where the components are not far apart. Plates are used for battens.

So, in case battening what we will see if it is something like this, say 2 I sections are provided, then you will see that battening is done like this, right. So, here one battening like this it will go on. So, this is the battening. Some plates we are providing here, right.

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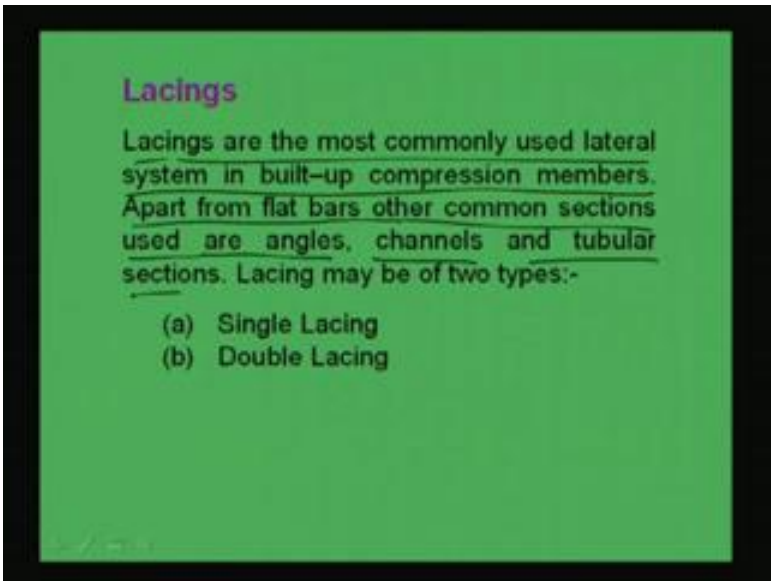

So, we can see that lacings are most commonly used lateral system in built-up compression members. Apart from flat bars, other common sections used are angles channels and tubular sections. So, for lacing, generally we use flat bars. Other than that we use also channels, tubular section or angle sections. Now, lacing can be divided into two types. One is called single lacing, another is called double lacing.

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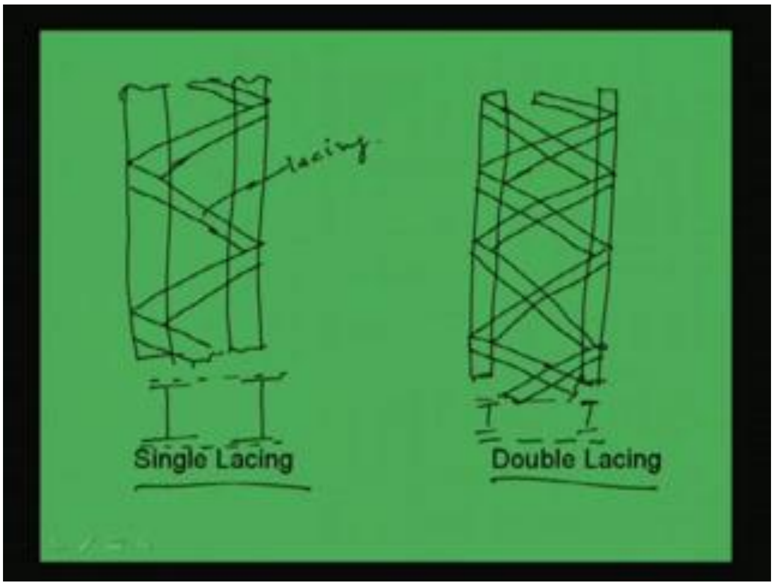

What is single lacing? Let us see. Single lacing if you see say two I section is there, right. Suppose these are the two I sections. Now, the lacing is provided here. So, if the elevation, this is one I section, this is another I section, right. So, what we will do? So, this is how lacings are placed. This is called single lacing. This is the lacing and in case of double lacing, what will happen.

Suppose this is one I section, another one I section is here, right. So, this is one I section, this is another I section and these are placed in this way. So, here we will see say suppose it is going on like this in one way, right. So, you can see this is one, right and another one will come. Similar way from this side say like this just crossing each other, right. So, this is another lacing system which is called double lacing. Now, whether we will go for single lacing or double lacing, it depends on the type of problem. How much load is coming, what are the type of load is coming, whether it is an eccentric load, horizontal load is there or not. So, all these things you have to see and what are the sections you are going to take.

Basically design engineers can means from their experience can choose whether it should be double means, whether we should go for double lacing system or single lacing system, right. So, this is the way of lacing system. So, now because of shortage of time, I will like to finish our lecture today here and the unfinished things means the starting things whatever we have started now, that is the lacing we will discuss in next class.

So, in today’s lecture what we have seen that how to design a compression member with built-up section, using built-up section basically that we have focused here, and for design of built-up sections, we need to design also the lacing system which is tying the individual members to make them act together, right. So, in next class we will discuss in details about lacing. Now, today with this I like to conclude here.

Thank you very much.