Design of Steel Structures
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Compression Member
Module - 5
Lecture - 2
Design of Compression Member

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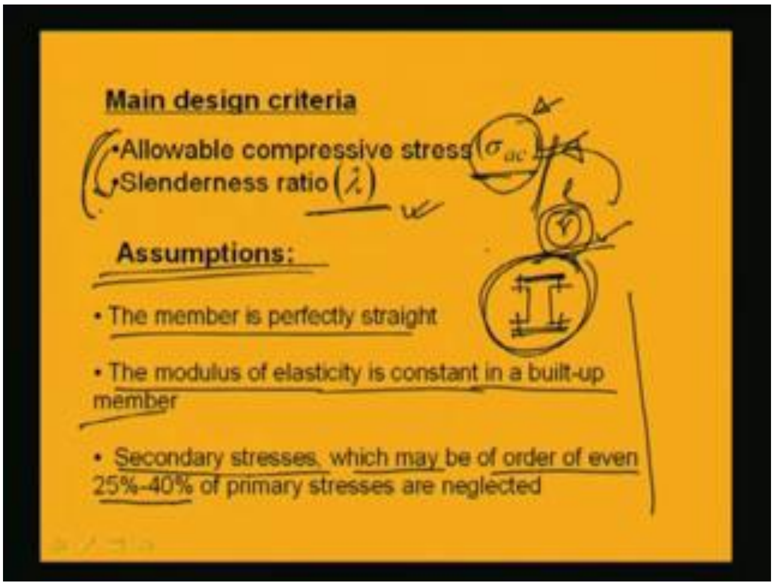

Today I am going to discuss about design aspects of compression member. So, main design criteria if we see, one is allowable compressive stress and another is slenderness ratio on which basis we have to start the design. Now, this allowable compressive stress sigma ac depends on the slenderness ratio. So, we have to know the slenderness ratio. That means, slenderness ratio means l by r. That means, we have to know the dimension of the member. So, it is an iterative process you can say because as we do not know allowable compressive stress, and as we do not know the dimension of the column, so we cannot find out straightforward.

So, what we have to do? Either we have to assume some compressive stress, allowable compressive stress on the basis of which we can find out some approximate dimension of the member. Then, we can find out the actual compressive stress which is coming for that particular member. Otherwise, we can assume some member. So, on this basis, we have to design and that is why this is called an iterative process.

Now, for designing, these are the certain assumptions which have been made. One is the member is perfectly straight. Another is the modulus of elasticity is constant in a built up member because in case of built up members, suppose there is a through channel and maybe with different materials, we can make the built up member. So, in this case, it will be difficult to design. That is why it is assumed that the whole built up section is with a constant elasticity. That means, same material whole section will be of same material. These are the assumptions on which basis the design has been made. Another is the secondary stresses which maybe of order of even 25 percent to 40 percent of primary stresses are also neglected. So, secondary stresses are going to be neglected through means, it maybe even order of this much also we are going to neglect.

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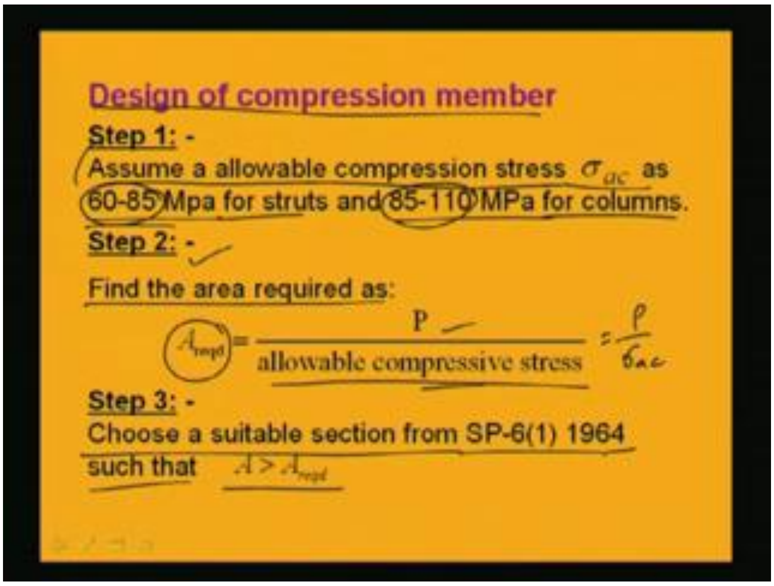

Now, we will see the design of compression member. What are the steps? So, first step what we will do is, we assume a allowable compressive stress sigma ac as 60 to 80 MPa for struts and 85 to 110 MPa for columns. What I told earlier that when we are going to design a column member or design a compression member, then what we have to do? We have to know the dimension of the compression member. Unless we know the dimension of the compression member, we will not be able to know the radius of gyration. That means, slenderness ratio sigma ac value, allowable compressive stress which has been given in IS 800-1984 in table 5.1 as I have discussed in earlier lecture, right.

So, one thing is to know the appropriate dimension of the section for the compression member. Another thing is accordingly what the allowable stress is. So, both the cases are unknown. So, either we have to assume some allowable stress at the previous stress to find out some basis of area required for the compression member or straightforward. We can assume some dimension of the compression member and then, we can start finding what the allowable stress is for that particular compression member. Then, the given load which is been given is capable of carrying by that member or not that we will see.

So, here we have started in this way that first we will assume some allowable compressive stress and for strut members, this is 60 to 85 MPa and for columns, 85 to 110 Mpa. These assumptions we will start for the starting point. Next step is that find the area required. That means area required will be how much. The given load by the allowable compressive stress, that means P by allowable compressive stress. So, it is P by sigma ac, right.

Now, in next step what we will do? So, area required we know now choose a suitable section from SP 6-1964, such that A become greater than area required. That means, we have our handbook, IS handbook. So, from there if we have to choose a particular section say angle section or channel section or I section, first we will decide which section we are going to choose and then, we will see whichever is closer to area required. So, we will choose the section in such a way that the area whatever coming in the section should be little bit greater than the area required.

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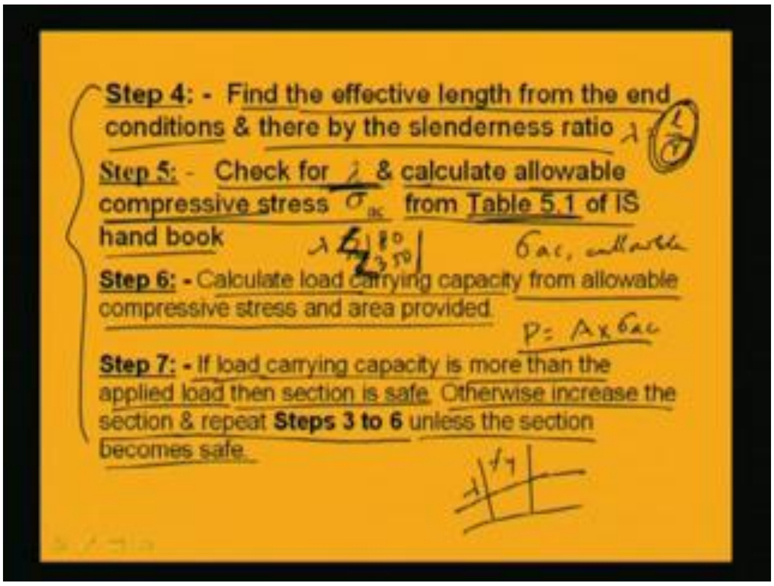

Next what we will do? Next we will find out the effective length from the end conditions because we know depending on the end conditions, the effective length will vary. It maybe 0.65l, it maybe 1.0l, or it may be 2.0l. So, it depends on the restraint condition of at the end of the member and thereby, we will find out the slenderness ratio. Slenderness ratio means that lambda which is called l by r. So, first we will find out the l value, the effective length of the member, then r r. We will find out from the given section whatever we have chosen that section. From that section, we can find out the radius of gyration or from that we can find out the slenderness ratio.

Next what we will do? Next we will check for lambda and calculate allowable compressive stress sigma ac from table 5.1 of IS handbook. First we will check whether lambda is greater than 180 or 350 as per the codal provisions or not. So, as per the codal provision, the value of lambda, sorry lambda is greater less than 3180 or 350. Value of lambda will be either less than 180 or less than 350 or 200 as per the codal provisions. So, we will check that.

The lambda calculated whichever we are getting, whether it is coming under the codal provisions or not that we will check. Then, we will calculate the allowable compressive stress which is given in table 5.1. In table 5.1, as I have told that for different grade of steel and for different lambda, the values are given. The allowable stress in compression has been given in the table 5.1. So, from that I can find out the sigma ac allowable, right.

Next, what we will do? Next calculate load carrying capacity from allowable compressive stress and area provided. So, we can find out the load carrying capacity. P is equal to the area we have provided for the section, and the allowable compressive stress. So, from this we can find out the load carrying capacity.

Next what we will do? Next we will check if load carrying capacity is more than the applied load, then section is safe. Otherwise, increase the section and repeat section 3 to 6 unless the section becomes safe. So, if load carrying capacity whatever we are getting, if it is more than the given load, then the section is quite. Otherwise, what we will do is we will increase the dimension of the section and then, again we will repeat the steps from 3 to 6. 3 to 6 means from here that sectional properties with a particular section, we will find out the sectional properties along with their area. Then, we will repeat these steps 4 to 7 unless the section becomes safe. So, these are the procedure through which we have to design a compression member.

Now, we will go through one example through which we will be clear that how to design a compression member. This example we will show in different way means that how it is becoming unsafe, and to make it safe how I am going to increase and how to make economic design. Those things we will demonstrate through this example. What is this example?

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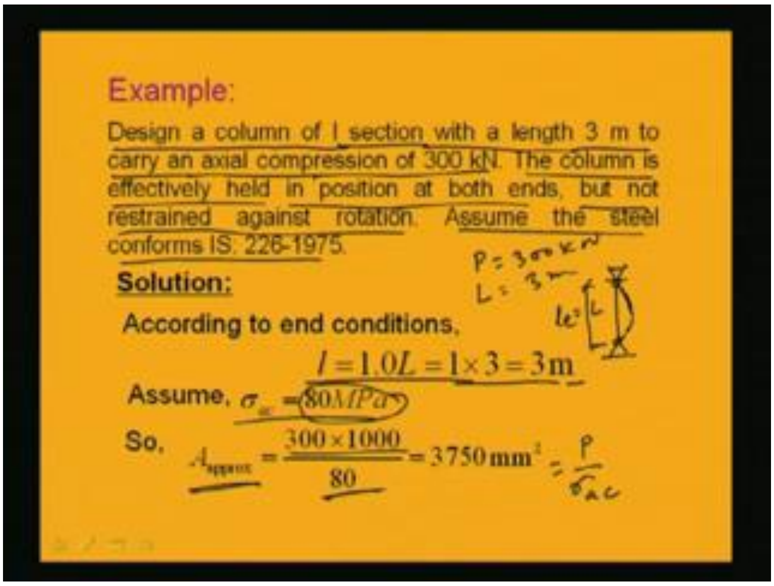

That design a column of I section with a length 3 meter to carry an axial compression of 300 kilo Newton. The column is effectively held in position at both ends, but not restraint against rotation. Assume the steel conforms IS 226-1975. So, first of all P is given 300 kilo Newton and total length is given 3 meter. What else? It is given that end condition is given that both ends are restraint in position, but not restraint against rotation. That means hinge. So, this is like this. That means, the buckling will be in this way. So, the effective length will be this one. That is the total length, right.

So, while we go for solution, we will find out first what the effective length is. So, in this case, effective length will be l is equal to 1.0 into L. That is 1 into 3 and that is 3 meters. Then, let us assume some allowable compressive stress in the member, so that we are assuming 80 MPa. So, let us try with 80 Mpa. Let us see what happens. Then, approximate area will be P by a, sorry P by sigma ac. So, P is given as 300 kilo Newton and sigma ac value is given 80 Newton per millimeter square. So, we are going to get as 3750 millimeter square. So, approximate area required to carry this much load is 3750 millimeter square. So, with this we will try to find out now the appropriate section.

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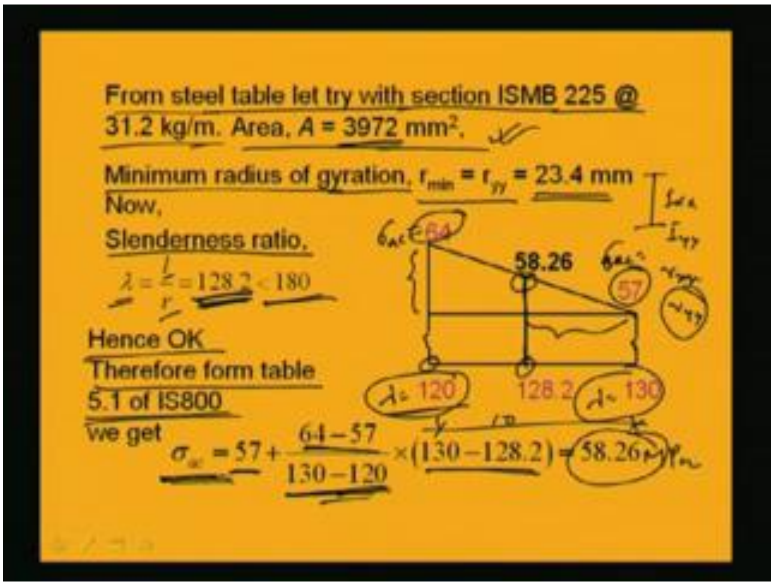

So, from steel table let us try with IS MB 225 of 31.2 kg per meter. So, for that particular section area is 3972 millimeter square. We need area 3750 millimeter square and we have area 3972 millimeter square. So, the moment we find out an appropriate section for the trial case, so what we will find. We will find out what the minimum radius of gyration is because we have to find out the maximum slenderness ratio. So, minimum radius of gyration from table, we will get which is given as 23.4 millimeter, right. Next minimum radius of gyration means actually in case of I section, it is given Ixx and Iyy. Similarly, rxx and ryy and this ryy will be minimum. So, that is given 23.4 millimeter, right.

Now, the slenderness ratio, maximum slenderness ratio lambda will become l by r minimum. So, that will be becoming l as given 3 meter and r minimum is given 23.4 millimeter. So, the ratio of l by r will become 128.2 which is less than 180. So, this is we can say, that means lambda as per the codal provisions lambda has to become less than 180. Now, in our case lambda is becoming 128.2 which is less than 180. So, the design means the section whatever we have chosen is from slenderness ratio point of view.

Now, what we will do? Now, we will find out the sigma ac from table 5.1 of IS 800, the value of sigma ac. Now, in the table 5.1, we will see the value is given for 120 lambda is equal to 120. Value is given sigma ac is given 64, and for lambda is equal to 130 value is given 57. These are the value given in the table. So, at lambda is equal to 130 values are given as 57 means that is sigma ac, and at lambda is equal to 120 sigma ac values are given as 64. Now, we have to find out for lambda is equal to 128.2. That means, here 128.2 and in this case, we will make linearly interpolation between two points. So, that is why we will be getting this point.

So, if we make linearly interpolation, sigma ac value will become 57 which is at 130 plus difference of sigma ac, that is 64 minus 57. This is the difference. By difference of lambda what is 10? So, 130 minus 20 that is 10 into 130 minus 128.2. This is the value 130 minus 128.2. So, after calculating this, the value of sigma ac we will be getting is 58.26 Mpa. I think now it is clear that how to find out the value of sigma ac from the table 5.1. For different value of lambda, that means for different value of slenderness ratio, the value of compressive stress has been given in table for different grade of steel. Here we are assuming the grade of steel as fy as 250. So, corresponding to that column, the values are given in the table for lambda is equal to 130 and for lambda is equal to 120.

Now, for lambda is equal to 128.2. The value of sigma ac can be found out from the linear interpolation. This is the process whatever I have mentioned here through which we can find out the value. Now, what we will do? Now, we can find out the safe load.

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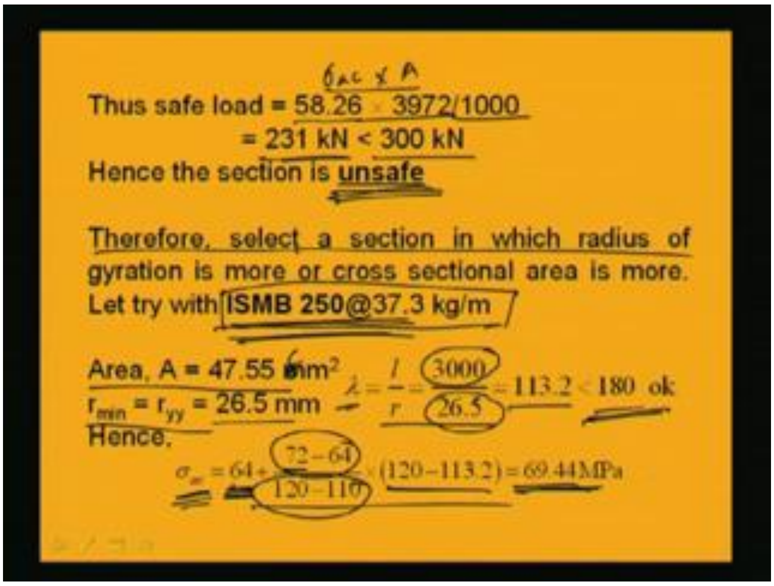

The safe load will be the value of sigma ac into area by 1000 for making kilo Newton. So, this is sigma ac and this is area from which I am getting 231 kilo Newton. So, the safe load we are going to get is 231 kilo Newton whereas the given load is 300 kilo Newton. That means the safe load is less than the given load. That means the section is unsafe. So, you see though we have maintained through proper process, still we are not going to get the safe load. That means, we are not going to get the safe cross-sectional dimension in which the given load will be safe. So, what we will do?

Now, we will go for another increased dimension. That means we can select next step dimension which is given in the handbook. After IS 225, it is given IS MB 250 at 37.3 kg per meter, right. So, now let us show this is the next dimension in the handbook after IS 225 ISMB 250. So, now let us try with this IS MB 250 at 37.3 kg per meter. So, as per the handbook area is given which is 47.55 centimeter square, this is centimeter square and ryy is equal to r minimum which is given 26.5 millimeter. Now, lambda we can find out lambda will be l by r, where r is 26.5 and l is the effective length which is given as 3000 millimeter. So, this is coming 113.2 which is less than 180. So, from slenderness point of view, it is so this check we did.

Now, what we will do? Now, we will find out the value of sigma ac, the allowable compressive stress in compression member. So, sigma ac value we will get the value is given for 110. This is given 64 and sorry, for 120 this is given 64, and for 110 this is given 72. So, by linear interpolation as we have done in earlier case, we are going to get the value of sigma ac as 69.44 MPa. So, value of sigma ac we are getting 64 plus 72 minus 64. This is the difference of the sigma ac value and this is the difference of the lambda value, and this is the difference between the lambda values. So, by the linear interpolation, we are getting sigma ac value as 69.44 MPa.

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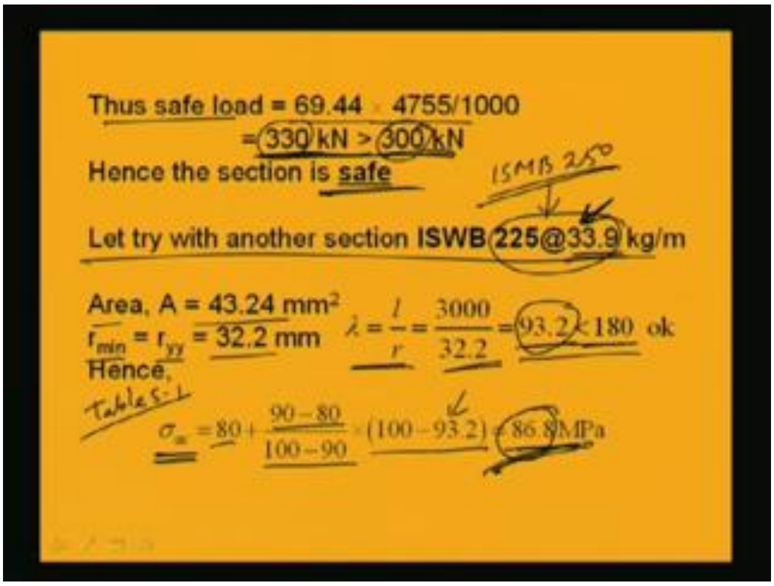

Thus, the safe load can be found out now that the area into this. So, if we calculate this is you are going to get as 330 kilo Newton, right. So, the area we will be getting as 330 kilo Newton which is greater than the given load which is 300 kilo Newton. So, we can say that the section is safe. So, what we have seen that if we choose ISMB 250 section, then the section can carry the given load which is 300 kilo Newton. In fact, the load carrying capacity of that section is 330 kilo Newton.

Now, let us try with another section just to have some experience that is ISWB 225. ISWB 225 at 33.9 kg per meter. That means, here the weight of the section will be lesser than the ISMB 250. So, if we choose let us see because if we see that this means this is safe, then definitely these sections will be better than these. Better means economic than ISMB 250, right. So, in this case what we are seeing that area is becoming 43.24

millimeter square, and r minimum which is ryy is 32.2 millimeter, right. So, lambda we can find out. Similarly, l by r is equal to 3000 by 32.2 which is coming 93.2 which is less than 180. So, the member is from slenderness ratio point of view l by r is less than 180.

Now, what we will do is the allowable sigma ac from table 5.1, I can find out the allowable sigma ac value is coming 80 plus these are the value 90 minus 80 by 100 minus 90 into 100 minus 93.2 because we have to find out the sigma ac value on 93.2. So, this we are getting 86.8 MPa. Now, if we remember the earlier cases that here with ISMB 225, the lambda value is coming 128. Therefore, the sigma ac value is coming 58, whereas here the lambda value is coming very less. In place of 128, it is 93. That is why the sigma ac value is becoming more. The allowable compressive stress in the member is becoming more. So, definitely it can carry more loads.

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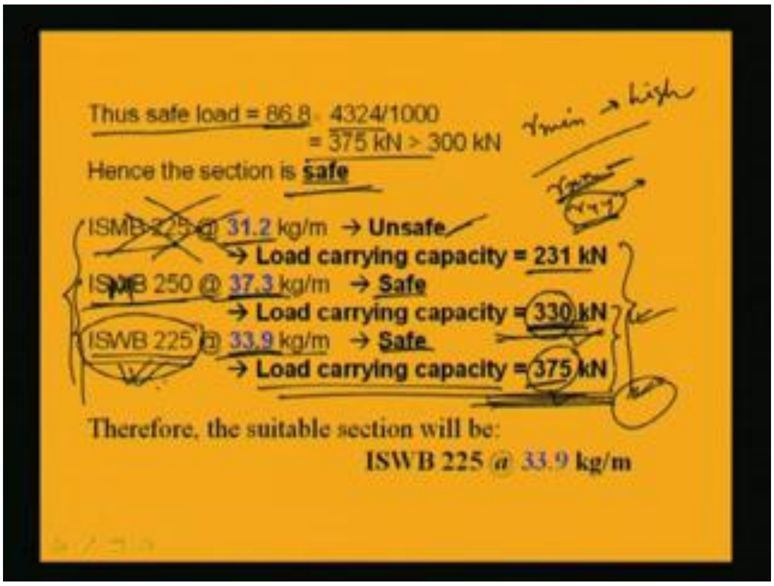

That is why the safe load will become the area into the allowable compressive stress. Then, we will get 375 kilo Newton which is greater than 300 kilo Newton. So, we can say that the section is safe. So, what we have seen from these three sections is that ISMB 225 with 31.2 kg per meter, this is unsafe and load carrying capacity is coming 231 kilo Newton. Similarly, ISWB 250 at 37.3 kg per meter is safe where this is coming 330. This is ISMB, not WB ISMB 250. So, ISMB 250 at 37.3 kg meter, this section is safe and its carrying capacity, load carrying capacity will be 330 kilo Newton, and if I choose ISWB

225 at 33.9 kg meter, this is also safe whereas, load carrying capacity is 37.5 kilo Newton.

So, out of these, what we have seen that this member is not safe. So, this we can reduce. Now, out of these two we are seeing here the weight of the member is 37.3 whereas, weight of the member is 33.9. So, this will definitely be economy in terms of steel weighted in terms of cost of steel. So, definitely we should go for ISWB 225. Even if we see ISMB 250 and ISWB 225, the load carrying capacity will be more for this and less for this one. Here, it is 375 kilo Newton; there it is 330 kilo Newton. So, load carrying capacity is more with less weight as ISWB 225. So, in this way we have to find out that what will be the suitable section. The sections maybe safe, a particular section may become safe for a particular load, but we have to see what the economic section is which will be most economical.

Available sections are there and in the IS handbook, their properties are given. So, what we have to see that which one if we choose will be giving the less material. That means weight of the member will be less. That is why cost of the member will be less as well as the member will be safe. Here, why it is much stronger than this because the radius of gyration is not very less here or minimum compared to this one. So, if r minimum is not less, then lambda will be less and lambda is less means sigma ac value will be more. The allowable compressive stress will be more if radius of gyration is, sorry slenderness ratio is less. That means if radius of gyration is more, so we have to choose the section where r minimum is high.

Rxx ryy is given. Now, suppose rxx is high, ryy is very less. This member will not be suitable, but if we see rxx is high and ryy is also nearer to rxx, then this member will be suitable for compressive load. In fact, not for moment we have to check again, right. So, in this way we can find out a suitable section, and in this case the suitable section will be ISWB 225 at 33.9 kg per meter. Another example we will go through which we will see how the load carrying capacity is going to increase with the increase of number of rivets. That means, the same member if we connect with different number of rivets, then we will see the load carrying capacity is going to increase or in other sense, we can say that lesser dimension can be used for same load.

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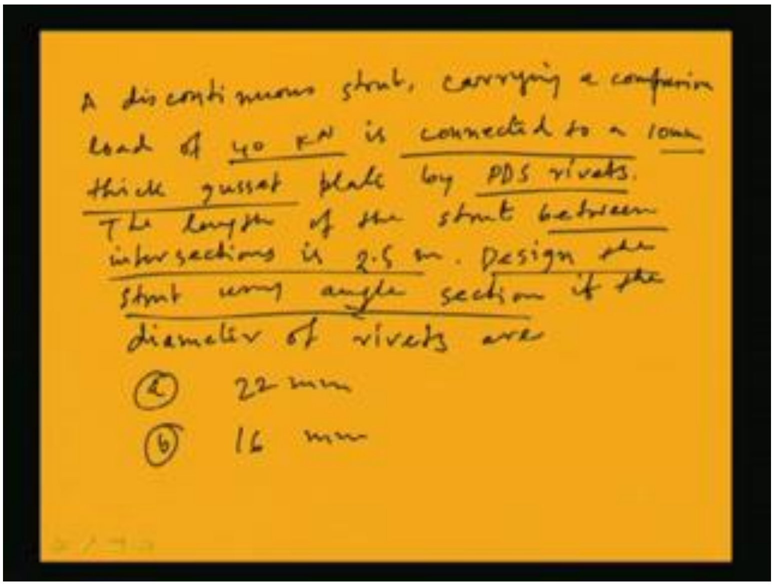

Now, let us go through that example through which it will be clear. Say a discontinuous strut carrying a compressive load 40 kilo Newton connected 10 mm thick gusset plate by power driven soft rivets. The length of the strut between intersections is 2.5 meter. Design strut using angle section is the diameter of rivet is 22 mm and by 16 mm. So, here we will see the member is carrying 40 kilo Newton load, a member is carrying 40 kilo Newton load and it is connected to a 10 mm thick gusset plate by power driven soft rivets.

Now, the length of the strut between intersections is 2.5 meter which is given. Now, design the strut using angle section angle section, it has told. So, we will use angle section if the diameter of the rivet is used as 22 millimeter 16 millimeter. That means, the sections we will going to design using 22 mm power driven soft rivets for end connections and again 16 mm power driven soft rivets for the end connections. So, both the cases we will see how it varies.

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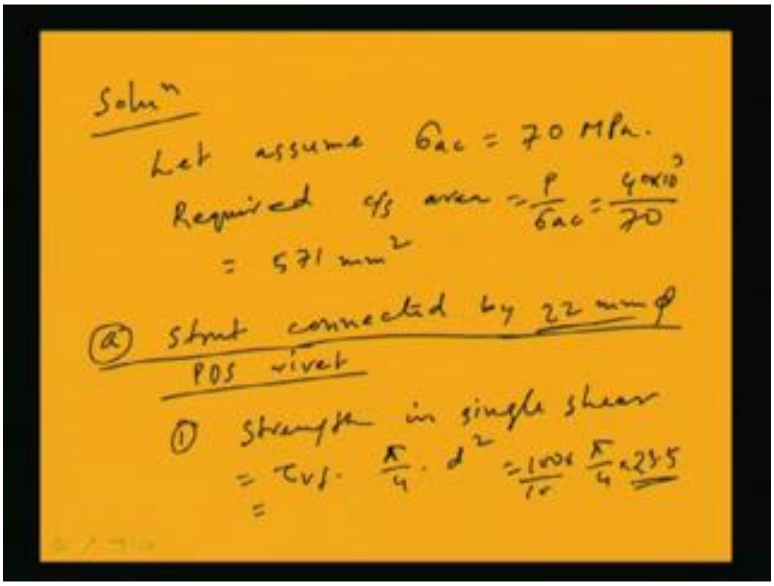

So, if we go for solution, so first what we will do is we will assume some allowable compressive stress which is sigma ac say for strut, let us assume 70 MPa. So, required cross-sectional area will be P by sigma ac and that will be 40 kilo Newton by this. So, this is coming 571 millimeter square. Now, let us start the design with strut connected by say 22 mm 5 PDS rivet. Now, let us first design the member using 22 mm diameter of power driven soft rivets for the connections. So, for this we know for 22 mm PDS, the strength in shear here it will be single shear.

So, strength in single shear will be tau vf into phi by 4 into d square. That will become 100 phi by 4 into d will become 23.5 because 1.5 will be the tolerance for the whole. So, that will become 1000 which will be in kilo Newton. So, this will become 43.4 kilo Newton. So, strength in single shear of 22 mm 5 PDS rivet will be 43.4 kilo Newton.

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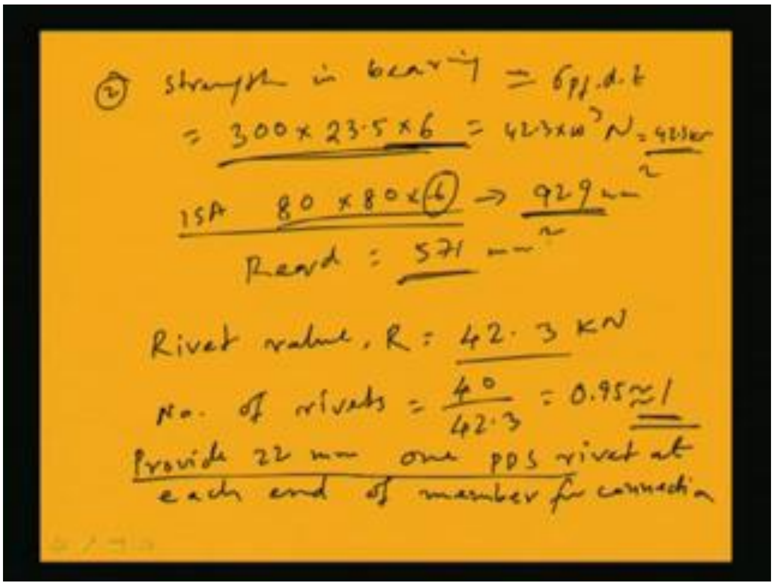

Similarly, strength in bearing will be sigma pf into d into t. So, for power driven soft rivets sigma pf value will be 300. Here d is 23.5 and t is the thickness. So, for thickness, the plate thickness we have to make, sorry the member thickness. So, let us assume member. Before that we have to assume a member say ISA 80 into 80 into 6. Let us assume this because to take care of the required area was given as 571 millimeter and this area is given as 929 millimeter.

So, required area is 571. Let us use 929 millimeter square of area where the section is 80 into 80 into 6. So, the angle thickness is given 6 millimeter. So, if we use 6 millimeter, then we can find out the load. So, this will become 42.3 into 10 cube Newton. That means 43.2 kilo Newton. So, strength in bearing is 42.3 kilo Newton and strength in shearing is 43.4 kilo Newton. So, the rivet value will become lesser of these two rivet values. R will become lesser of these two and that will become 42.3 kilo Newton. So, number of rivets will be required total load was 40 kilo Newton and rivet value is 42.3 is equal to 0.95. That means at least one rivet will be required. So, number of rivet will be required is 1.

So, we can say provide 22 mm 1 power driven soft rivet at each end of member for connection. So, we will provide 22 mm power driven soft rivet 122 mm power driven soft rivet at each end of the member for connections, right. Now, we will go for the design of the member whether the member is able to carry that much load or not that we have to see. So, what we will see? First we will see effective length.

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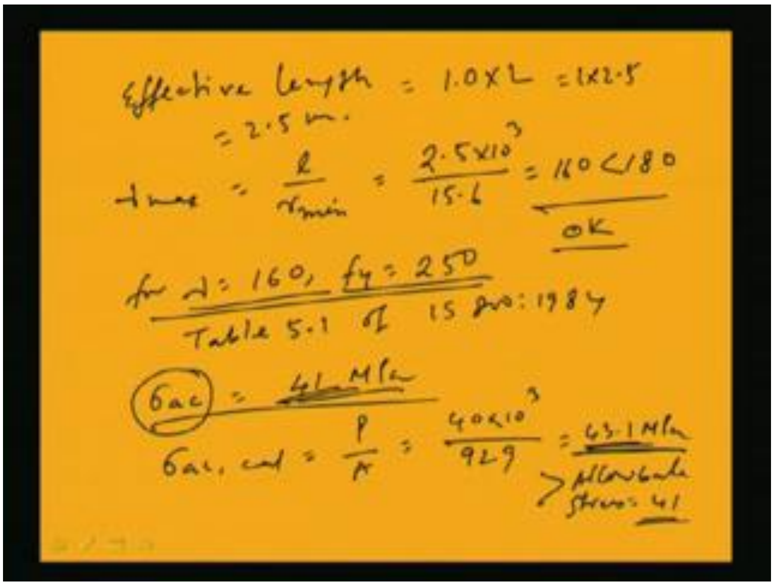

Here effective length will be 1.0 into L. So, that will be 1.25. So, 2.5 meter. So, lambda max will be l by r minimum. So, 2.5 meter I am making millimeter by r minimum is 15.6. For this section that 80 by 80 by 6 angle section. So, this is coming 160 which is less than 180. So, from slenderness ratio point of view, this is the section. Now, for lambda is equal to 160, and let us use the steel grade of fy is equal to 250. Then, from table 5.1 of IS 800-1984, we will get the value of sigma ac as 41 Mpa, right.

So, allowable compressive stress in the member sigma ac will become 41 MPa for lambda is equal to 160, and fy is equal to 250 from table 5.1 of IS 800-1984, right. So, allowable stress we have now let us find out the calculated stress sigma ac calculated means the developed stress and that will become basically P by A. So, P is 40 into 10 cube. This is 40 kilo Newton and area is given 929. So, that will become 43.1 MPa. Now, calculated stress or developed stress is 43.1 MPa and allowable stress is 41 MPa. That means this is greater than the allowable stress. So, the design is unsafe because allowable stress is given 41 and developed stress is coming 43.1 MPa. So, that design is unsafe. That means the section which we have chosen is not correct. We have to increase the dimension of the section. We have chosen ISA 80 by 80 by 6.

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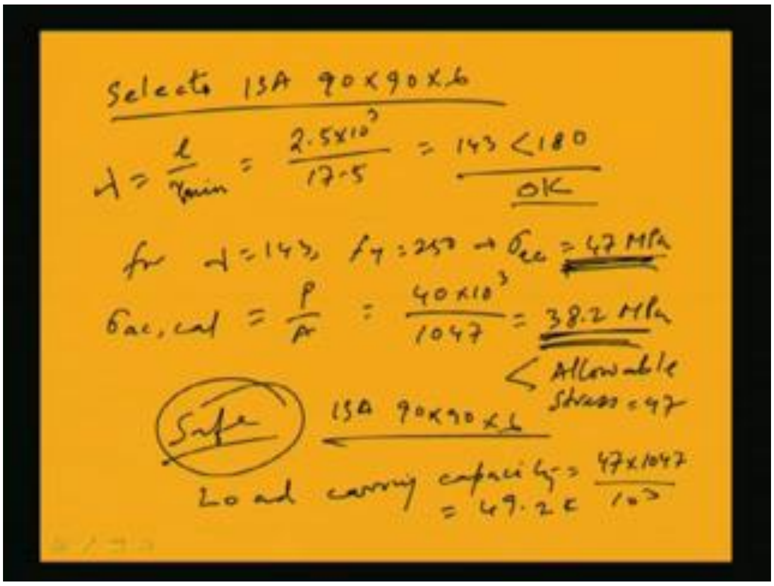

Now, let us go with an increased dimension in the section. So, let us select say ISA 90 by 90 by 6. So, if we select this, we will find out l by r minimum and that will be 2.5 by r minimum. This will become 143 which is less than 180. So, from slenderness point of view, the section is (( )). Now, we will find out the allowable stress in the member for this particular member and the calculated stress. So, for lambda is equal to 143 and fy is equal to 250, we can find out the allowable compressive stress sigma ac as 47 MPa. So, allowable stress we are getting as 47 MPa.

Now, we can find out the developed compressive stress or calculated transfer ratio which will be P by A. P was given as 40 into 10 cube and area is given 1047. So, if I make this will become 38.2 MPa. So, sigma ac calculated will become 38.2 Mpa, right which is less than the allowable stress that is 47 MPa. So, the design is safe because developed stress, compressive stress is coming 38.2 and allowable stress for this particular member is 47 MPa. So, the member is safe. So, we can say that ISA 90 by 90 by 6 can be provided for this type of connections, right.

Now, here load carrying capacity is becoming how much? This will become 47 into area 1047 by kilo Newton. So, this is coming 49.2 kilo Newton. So, here load carrying capacity is coming 49.2 and the given load is 40 kilo Newton. Thus, the section is quite if we choose the section dimension as 90 by 90 by 6 angles.

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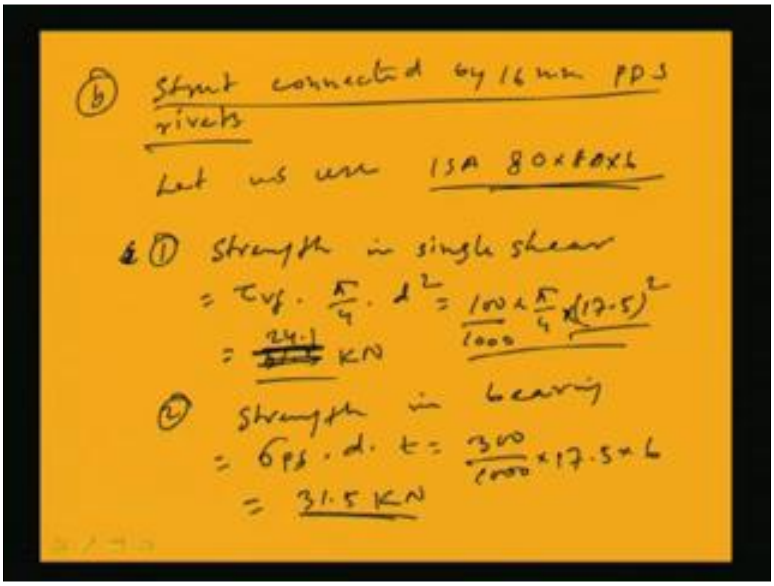

Now, let us see the second case if the strut connected by 16 mm power driven soft rivets. Now, with these strut connections, let us see how the design is going to vary. So, now let us first use say previous section 80 by 80 by 6 which was unsafe. For earlier case, let us use ISA 80 by 80 by 6 sections which was unsafe in the previous connection. Now, we will see whether this is safe or not. If it is not safe, then we can go for the next section.

First strength in single shear let us calculate the strength in single shear. That will be tau vf into 5 by 4 into d square that is 100 into 5 by 4 into d square. D will become 17.5 because 16 millimeter power driven soft rivets are used. So, 17.5 millimeter will be the gross diameter of the rivet. So, we can find out the value as if I divide by 1000, we will be getting kilo Newton that is coming 31.5 kilo Newton. Similarly, the second case if we go, second case is that strength in bearing. That will be sigma pf into d into t, so 300 into d into t 6 mm. So, this is becoming 31.5 Newton, sorry this will become 24.1 kilo Newton.

If we calculate this value, we will get this value as 24.1 kilo Newton and here we will get strength in bearing as 31.5 kilo Newton. So, out of these two values, we will take the lesser one as a rivet value.

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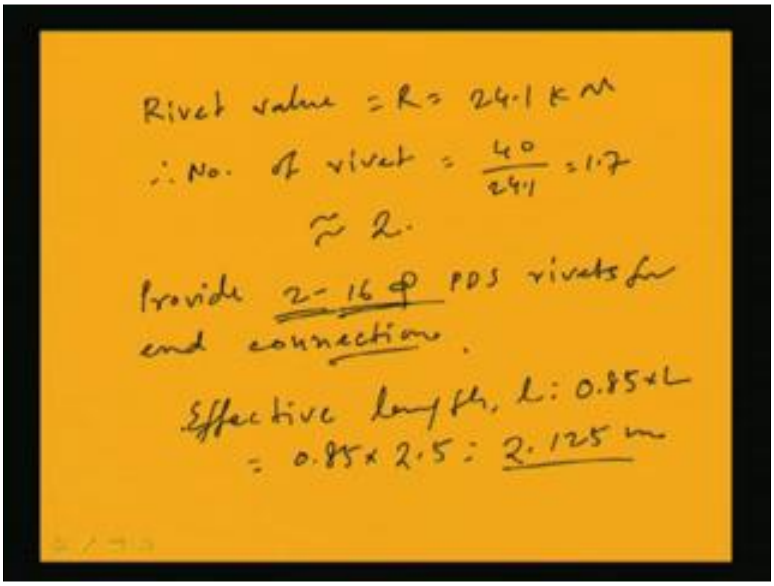

So, rivet value will become lesser of this two. That means that will become 24.2 kilo Newton. So, number of rivet at each end will be that will be 40 by 24.1. This will be coming 1.7. That means we can use 2. That means we can provide two numbers of 16 mm diameter of power driven soft rivet for end connection. So, the connections when we are going to make by the use of 16 phi rivets, then we will be requiring two numbers of rivets at each end. So, for these types of connections, the effective length will become as per the codal provision. Effective length l will become 0.85l. So, 0.85 into length will be 2.5, so 2.125 meter. So, here effective length is going to change because of the type of connections. So, what we will do now?

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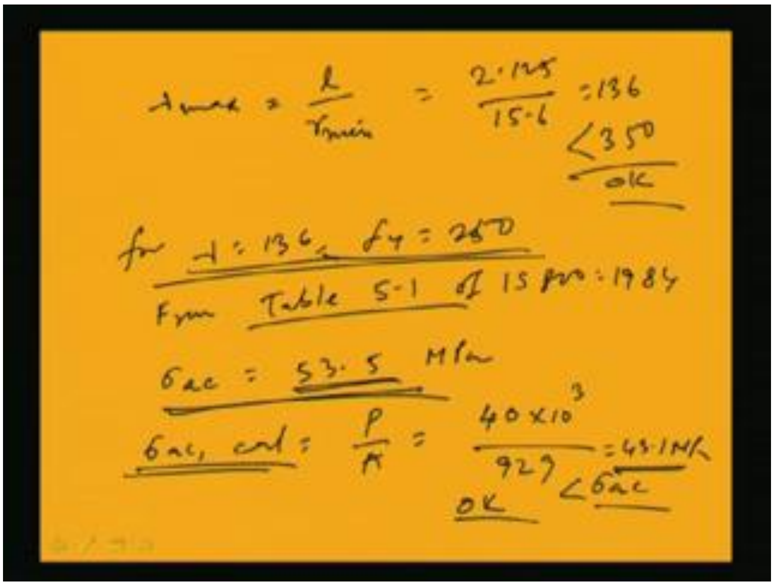

So, lambda max will be l by r minimum. So, l is 2.125 by r minimum means 15.6. So, this is coming 136 which is less than 350 as per codal provision. So, this is right. Now, for lambda is equal to 136 and fy is equal to 250 from table 5.1 of IS 800-1964, sorry 1984. We can find out that sigma ac will become 53.5 MPa. Allowable compressive stress in the member will become 53.5 MPa which can be found by the linear interpolation from the table 5.1 of IS 800. For values of lambda as is equal to 136 and for the steel of fy 250. So, we can find out sigma ac calculated.

Now, this will be P by A. So, P is given 940 kilo Newton P and area is 929 millimeter square. So, this is becoming 43.1 MPa which is less than the allowable sigma ac that is 53.5 MPa. So, the design is safe. So, design can be safe because the calculated or developed compressive stress is becoming 43.1 MPa and allowable compressive stress is 53.5 MPa. So, that design is safe. Now, I can find out the load carrying capacity.

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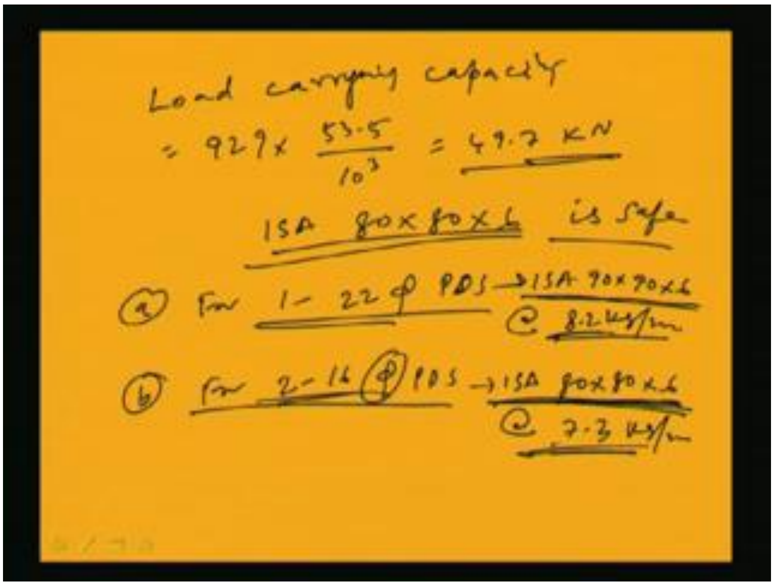

Load carrying capacity will be 929 into 53.5 by 10 cube. So, this will become 49.7 kilo Newton, right. So, what we have seen here that ISA: 80 by 80 by 6 section is safe whereas, for the earlier case using 22 mm diameter of rivet, this section was unsafe. So, for first case what we have seen that for 122 phi PDS ISA: 90 by 90 by 6 and its weight is 8.2 kg per meter and in second case, 216 phi PDS power driven soft rivets here we need ISA: 80 by 80 by 6 at 7.3 kg per meter. So, what we have seen? If we use 22 mm power driven soft rivets, we need ISA: 90 by 90 by 6 where weight is 8.2 kg per meter.

At the same time if we use 16 mm diameter of power driven soft rivets and if we use two rivets, then the ISA: 80 by 80 by 6 at rate of 7.3 kg per meter, this section is safe. We have seen earlier that in case of single rivet using 22 mm diameter, the section ISA: 80 by 80 by 6 was unsafe. We have to go for ISA: 90 by 90 by 6 whereas, if we use two numbers of rivets with a lesser diameter, then we will see that 80 by 80 by 6 section is quite. That means we can make the section economy. Here, it is 8.2 kg per meter. Here it is 7.3 kg per meter. So, the section weight can be reduced by the use of 16 means reduce diameter of rivets by the use of more number of rivets. In place of single rivet if we increase into two rivets, then we can get little economy in terms of weight of the section.

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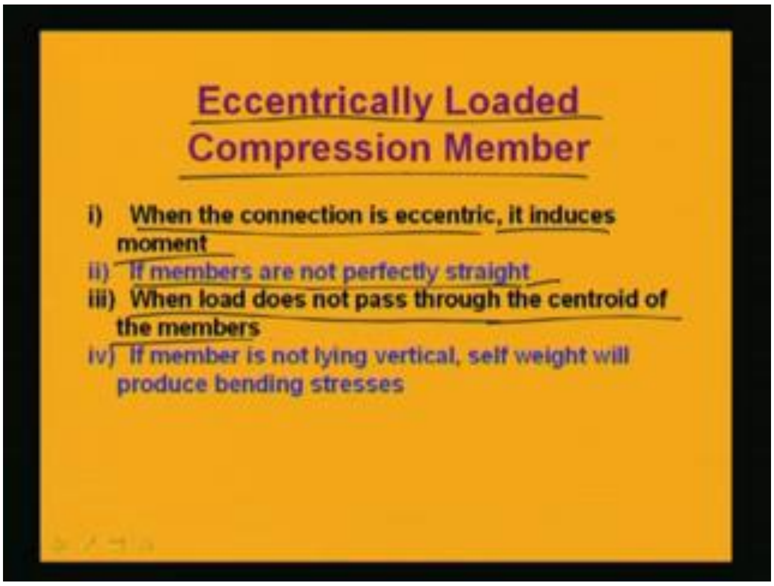

So far we have discussed about only compressive load, axially compressive load. Here now we will go with eccentrically loaded compression member. Generally when the connection is eccentric, it induces moment as we know and if members are not perfectly straight, then also these types of situations will arise. Again when load does not pass through the centroid of the member, then also chances of eccentricity will be there. If the member is not lying vertical, then self-weight will produce bending stresses.

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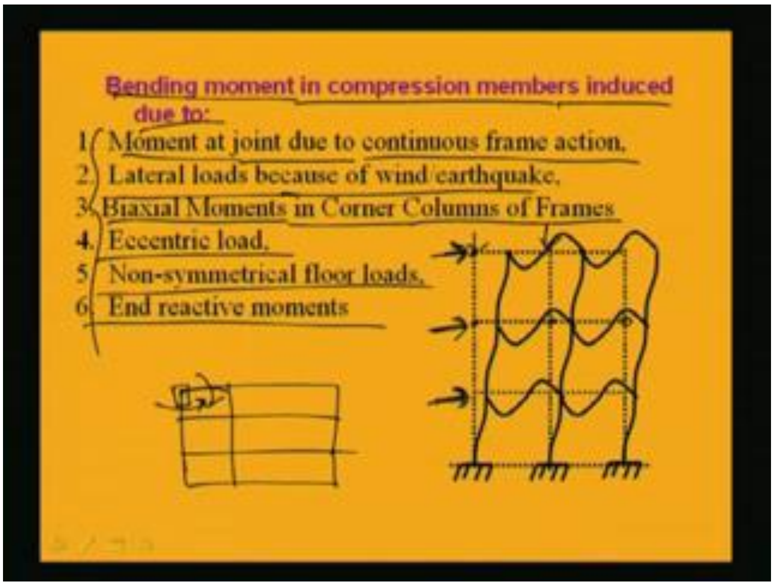

Bending moment in compression members induced due to one is moment at joint due to continuous frame action. Here moment at the joint due to continuous frame actions, it may be induced. Another is lateral loads because of wind and earthquake. If lateral loads are there because of wind or earthquake, we can find out the equivalent lateral load at the beam column joint. So, we can find out the load because of those things. Another thing is biaxial moments in corner columns of frames if we see the plan of the building frame. So, the column in the corner will be developing biaxial moment. Another is eccentric load, non-symmetrical floor loads and end reactive moments. So, because of these types of situations, the bending moment in compressive member will be developed.

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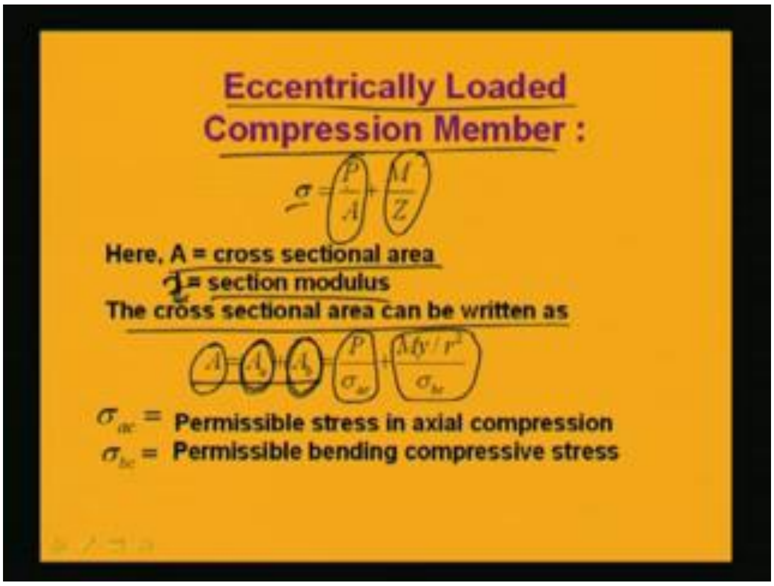

So, eccentrically loaded compression member. So, what are the stresses will come? Stresses will come sigma is equal to as P by A. Earlier we have seen only P by A along with M by Z. So, additional stress because of moment will come into picture, where M is the bending moment and P is the axial force. A is the cross-sectional area and Z is this. Z will be the section modulus. So, the cross-sectional area can be written as like this. A A plus AB. A is area due to the compressive load, direct compressive load and AB is due to the bending. So, total area required will be area due to the compressive load and area due to the bending.

So, I can write area due to the compressive load, this is P by sigma ac where sigma ac is the allowable stress and this is M by sigma bc into y by r square My by r square by sigma bc. This will be the area due to bending, where sigma ac can be written as permissible stress in axial compression and sigma bc is the permissible bending. Compressive stress sigma bc is the permissible bending in compressive stress.

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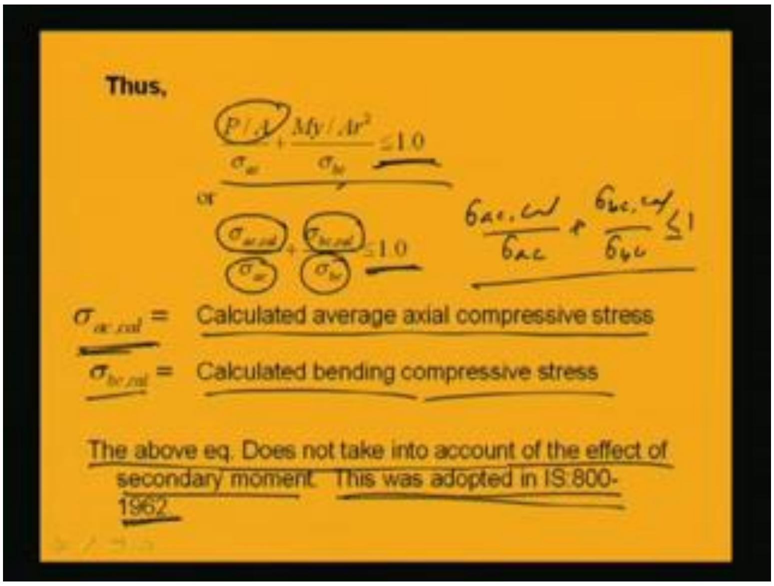

So, we can write the earlier equation as P by A by sigma ac plus My by Ar square by sigma bc which should be less than or equal to 1. That means if we divide this A with this equation, then we will get this one. If we divide the A with both the sides, then we will get P by A by sigma ac and My by Ar square by sigma bc which will be less than or equal to 1, or we can write P by A is nothing, but the sigma ac calculated. So, sigma ac calculated by sigma ac plus.

Similarly, this is sigma bc calculated My by Ar square by sigma bc should be less than or equal to 1. That means this will be the equation which has to be satisfied if the member is inducing moment along with the compressive forces. Here sigma ac as we told is calculated average axial compressive stress and sigma bc cal is the calculated bending compressive stress. Compressive stress due to bending and compressive stress due to axial force sigma ac cal. Now, the above equation does not take into account of the effect of secondary moment. This was adopted in IS: 800-1962. So, in 1962 this equation sigma ac cal by sigma ac plus sigma bc cal by sigma bc. This equation has been adopted in 1962 where the effect of secondary moment has not been taken into consideration.

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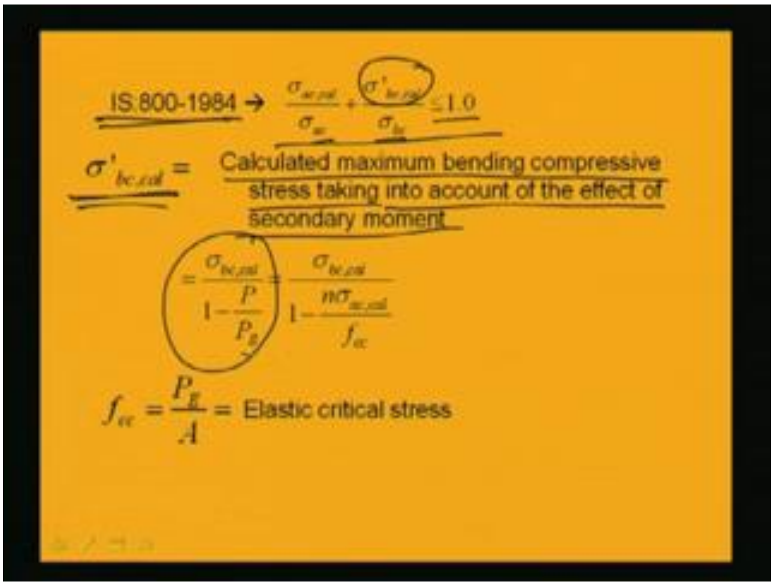

Now, with the considerations of these two in IS: 800-1984, the expression has been slightly modified. What is that? That is sigma ac calculated by sigma ac plus sigma bc calculate dash sigma dash bc calculated by sigma bc is less than or equal to 1, where sigma d dash bc calculated is the calculated maximum bending compressive stress taking into account of the effect of secondary moment. That means in IS: 800-1984, the secondary moment, the stresses developed due to secondary moment has been taken into consideration whereas, in 1962 that code it was not been considered.

So, this sigma dash bc calculated has been modified. So, how it has been modified? This sigma bc dash calculated has been written in terms of this expression. Sigma bc calculated by 1 minus P by PE where PE is the Euler's route. So, this can be written as like this 1 minus n sigma ac calculated by fcc, where fcc is PE by A which is called elastic critical stress.

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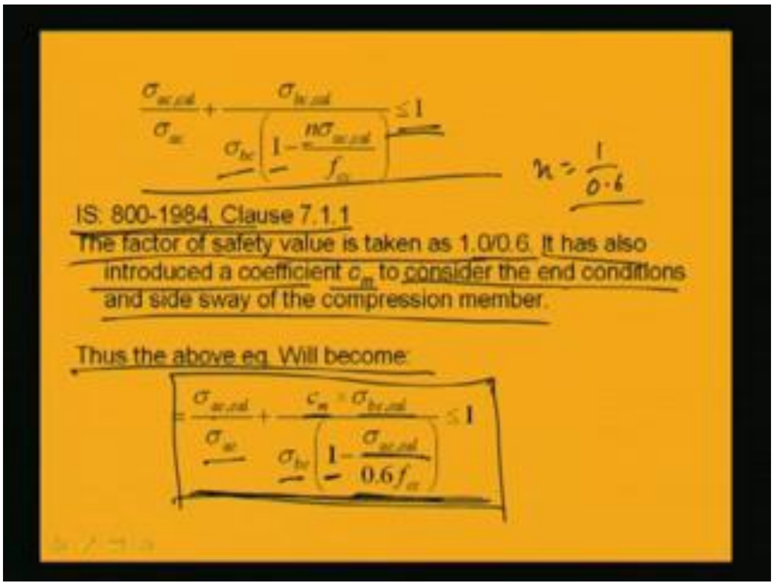

So, with the modification we can write now the earlier equation as like this. Sigma ac calculated by sigma ac plus sigma bc calculated by sigma bc into 1 minus n into sigma ac cal by fcc which should be less than or equal to 1. Now, as per the IS: 800-1984 clause 7.1.1, the factor of safety value is taken as 1 by 0.6. So, the factor of safety is taken as n is equal to 1 by 0.6. So, it has also introduced a coefficient Cm to consider the end conditions and sides way of the compression member. Thus, the above equation will become like this that is sigma ac calculated by sigma ac plus Cm into sigma bc calculated by sigma bc into 1 minus sigma ac calculated by 0.6 fcc. So, the modified equation will become this as per the new codal provision given in IS: 800-1984.

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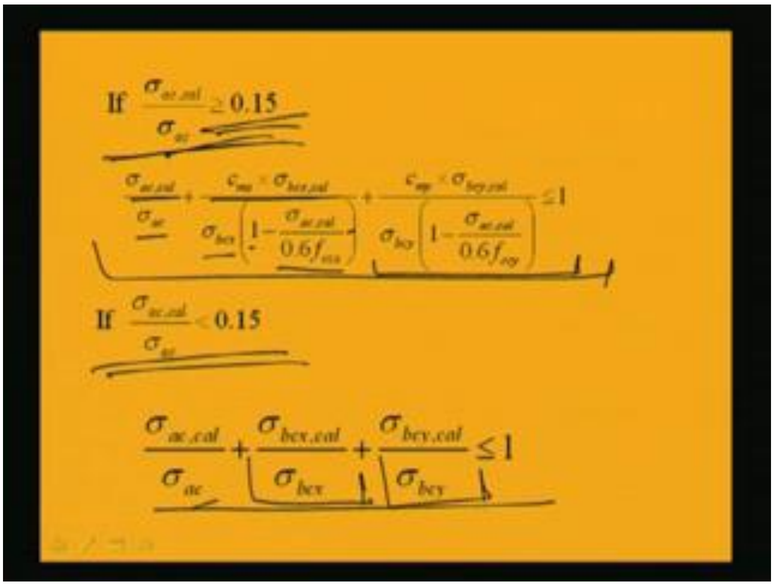

If sigma ac calculated by sigma ac is greater than 0.15, then for the biaxial moment we can write in this way that is sigma ac calculated by sigma ac plus Cmx into sigma bc x calculated by sigma sigma bc x into 1 minus sigma ac calculated by 0.6 fccx. Similarly in y direction, this is given in the code. If the sigma ac calculated by sigma ac is greater than or equal to 0.15. Otherwise, if it is less than 0.15, then simply we can use this one, that is sigma ac calculated by sigma ac plus sigma bc calculated by sigma bcx plus sigma bcy calculated by sigma bcy which should be less than or equal to 1. So, these are given in the codal provision.

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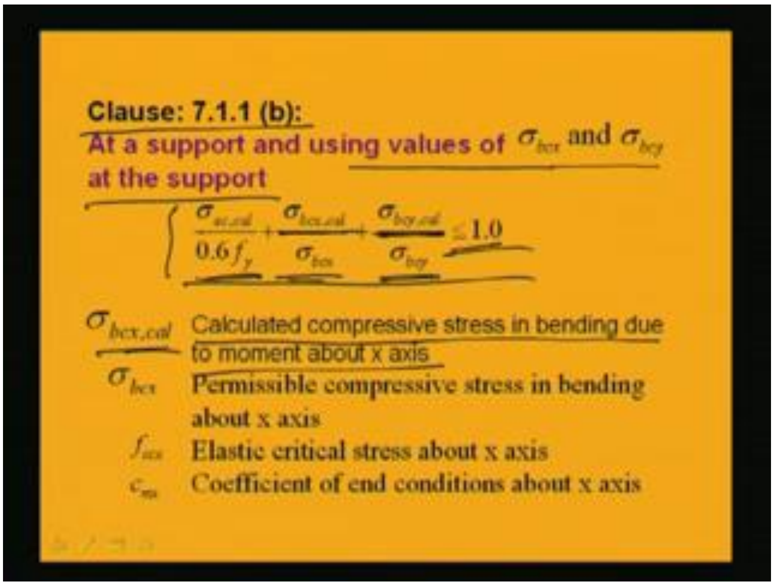

In clause 7.1.1 b, it has given like this that is at a support and using values of sigma bcx and bcy, this will be this. That is sigma ac calculated by 0.6 fy plus sigma bcx calculated by bcx plus sigma bcy calculated by sigma bcy should be less than or equal to 1, where sigma bcx calculated is the calculated compressive stress in bending due to moment about x axis and sigma bcx is permissible compressive stress in bending about x axis. Similarly, sigma bcy will be about y axis and fccx is the elastic critical stress about x axis and Cmx is the coefficient of end condition about x axis. Similarly, for y axis it will be. So, with this I will have to conclude today's lecture. In next lecture, we will see how to design the compression member along with moment.