Course on Design of Steel Structures
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Lecture 34
Module 7
Design of Compression Members

So far we have discussed about the design strength of Compression Member that means how to calculate the strength of a compression member that we have understood if a dimension of a compression member means cross sectional dimension of a member is given and the type of member is given then we can find out the strength of that member. Today I will discuss how to design a compression member that means when the load is given then how to find out a appropriate section.

Now to find out appropriate section first we have to decide what type of sections we are going to choose it may be I section, it may be channel section, it may be angle section, it may be built-up section. So according to the requirement we have to choose a particular type of section it may be built-up or certain individual section. Then what type of means what will be the dimension of the section, what will be the size of the section, how do we decide.

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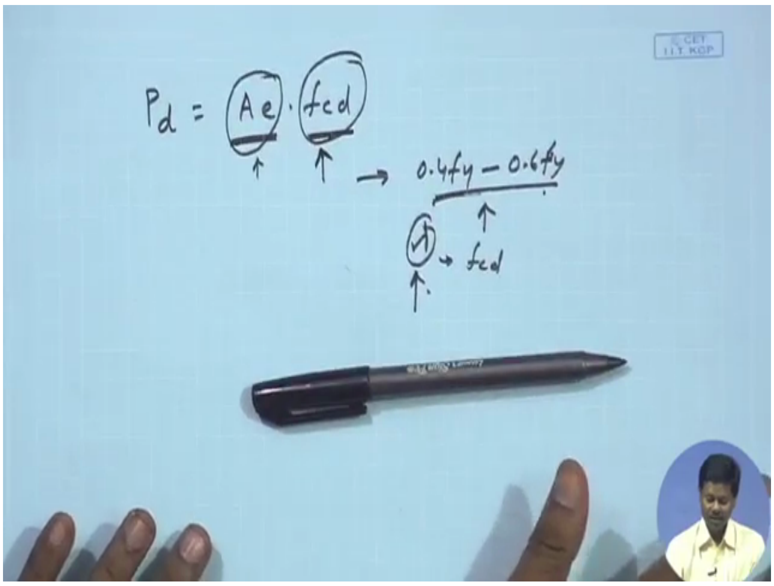

Here there is a iterative process we have to follow because if we see the design strength calculation Pd the force compressive force design compressive force Pd is equal to you know Ae into fcd. Now we do not know Ae because we do not know the dimension of the section, so effective area we do not know. Also we do not know the compressive stress allowable compressive stress of the member because it depends on the slenderness ratio again slenderness ratio depends on the radius of gyration, radius of gyration will be depending on the dimension of the section. So both the parameters are unknown, so and both the parameters are dependent on each other. Therefore there is no linear process to find out simply the dimension of the section.

So what we need to do either we have to consider certain means we have to assume certain compressive stress fcd, then we can find out the area required and then again we can go for the design or fcd directly we can find out generally we consider fcd as 0.4 to 0.4fy to 0.6fy, generally we consider. However means this is a trial process means at the beginning we can start with that and then we will we will we will be able to understand at the end whether the member whatever we are going to choose is fine or not, if it is not fine then either we have to increase or decrease according to the results.

Otherwise also we can consider that lambda value the radius of gyration, now radius of gyration if we know then from table 9 we can find out the value of fcd. So either we can choose radius of gyration or we can choose fcd directly then we have to go.

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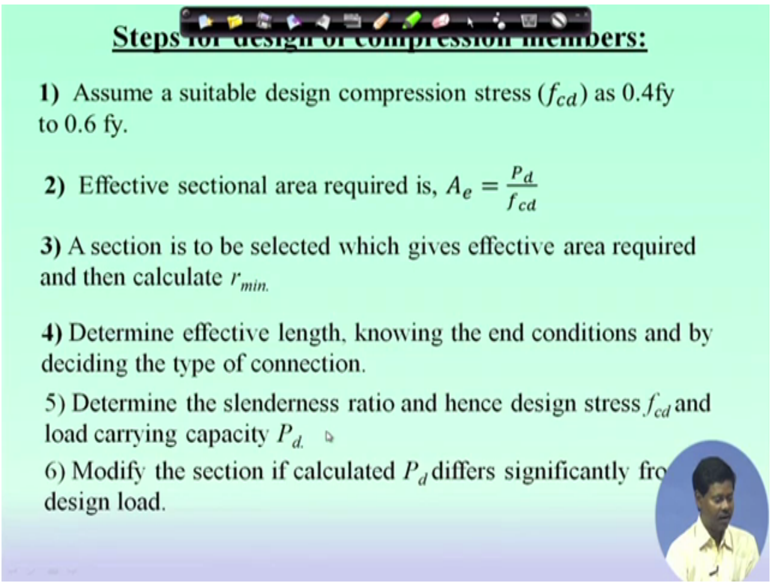

Now let us see what are the steps we should follow. So I have written here the steps which can be followed to design a compressive member, first what we can do that assume a suitable design compression stress fcd, it may be 0.4fy to 0.6fy. Now if the slenderness ratio is less then we can consider little higher side, if the slenderness ratio is high we can consider lower side but we do not know slenderness ratio but we know the effective length, length of the member is known.

So if length of member is high then we have to choose a lower value and if effective length is less then we can choose a higher value also. So this way we can start, then what we can find out that effective sectional area. So if we assume certain fcd value then in next step we can find out the effective sectional area Ae. Now once we find Ae then we can find a suitable section from SP: 6, right. A section is to be selected which gives effective area required and then calculate r minimum.

That means from effective area we can find out a suitable section that means whether it is angle section or channel section that we have to first choose, then which section is more means the area of which section is more than the this that we have to find out, then we can select that particular section. Then if we select a particular section then we can find out the r minimum of that value and that also we can find out directly from the table in SP: 6, or if we use built-up section then we have to find out means we have to calculate we have to find out.

Next step is we can we know the effective length then we can find out the slenderness ratio because if we know the end condition and then we can find out the effective length and then l by r minimum ratio the slenderness ratio. Now if I know the slenderness ratio, I can find out the fcd value directly from table 9 or by calculation fcd value I can calculate and once fcd value is calculated we can find out the load carrying capacity.

Now if load carrying capacity is more than the external load Pd then we can say the member is fine that means the design is fine whatever section we have chosen is okay, otherwise we have to choose a higher section and we have to go to step 3 again and then we have to choose a higher section. And if we see that load carrying capacity if load carrying capacity is quite high then the external force then we have to reduce the member size, the section size because otherwise it will be much more conservative it will be uneconomic.

So to make it economic we have to means choose a section in such a way that the external force and design compressive force are coming more or less similar and design compressive force will be slightly more than the external force then it will be economic. So this is how by iterative process we can design a compressive member.

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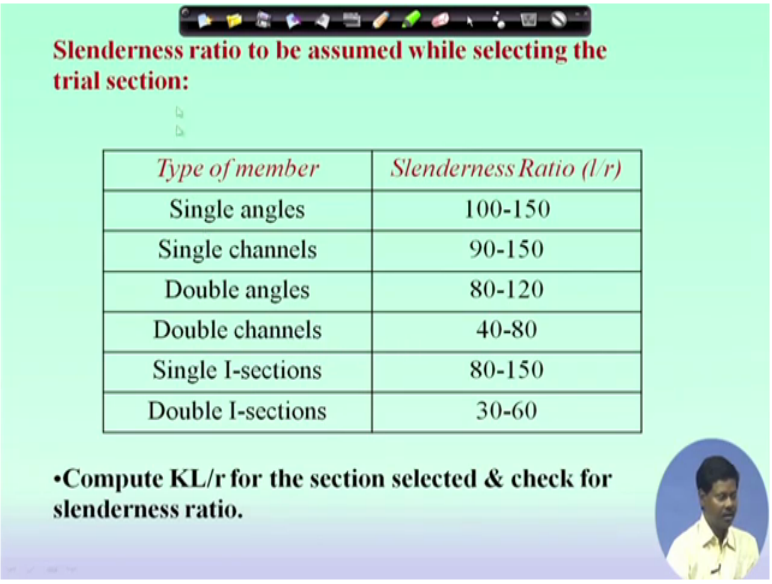

Now another way to find out the lambda value means in place of fcd one can choose a lambda which are given in this table approximately we can choose this set of slenderness ratio, like in case of single angle section we can use means we can choose slenderness ratio as 100 to 150, in case of channel section single channel section 90 to 150 can be chosen. Double angle if it is then 80 to 120, for double channel the slenderness ratio value can be considered much less 40 to 80, similarly single I-sections 80 to 150, double I-sections 30 to 60. So from this l by r value we can find out the fcd value from table 9 and then we can find out the particular section then we can iterate in.

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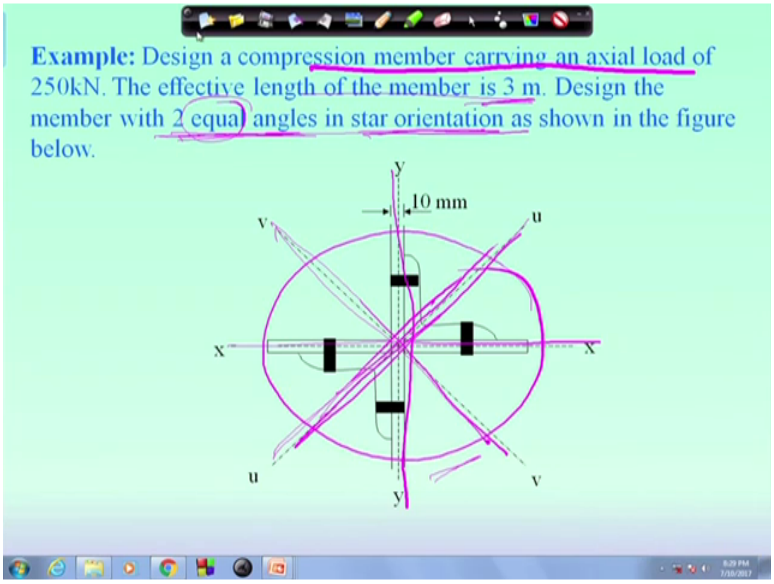

So this will be clear if I go through this example, now I have provided one example to design a compressive member. Now design if I see here it is written that design a compressive member carrying an axial load of 250 kilonewton the effective length of the member is 3 meter, right. And design the member with 2 equal angles in star orientation as shown in the figure.

Now in the figure the orientation has been shown now before going to design certain things have been told already, like we have to choose a equal angle section 2 equal angle section not single equal angle section, 2 equal angle section and it will be star orientation. We can use 2 angle section back to back in same side of the gusset plate, opposite side of the gusset plate, but in this case it mentioned that we have to make it star orientation and we have to use equal angle section, right. So accordingly we will try to find out.

Now if star angle section is used in star orientation if the angle sections are used then you see we can find out Ixx value, Iyy value similarly Iuu and Ivv. Now from this we can see that the minor axis will be vv, right sorry minor axis will be uu here in this case, right. So I have to find out ruu which will be minimum, I have to find out ruu value and about uu it will buckle fast, so I have to find out the moment of inertia of the combined section about uu axis and then radius of gyration about uu axis then I have to find out the slenderness ratio.

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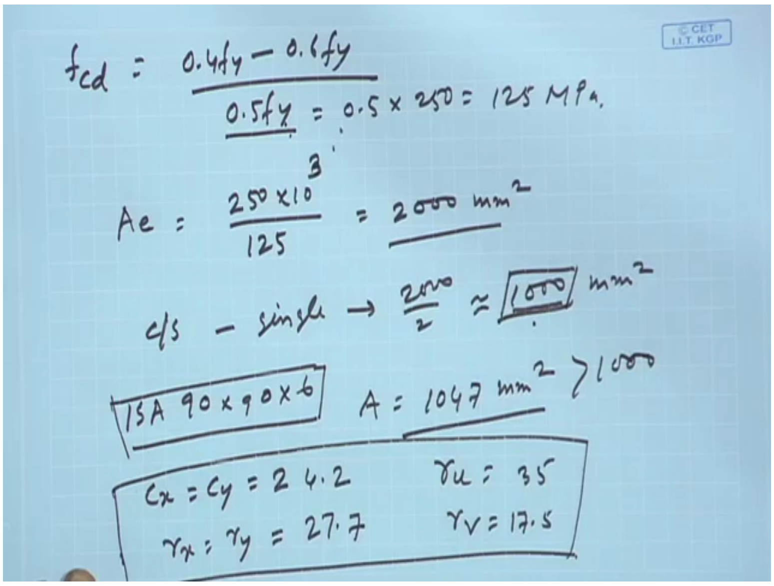

Now let us go through the design process, so first I can find out the fcd value means I can assume a suitable fcd value which was told 0.4fy to 0.6fy, now let us consider point say 0.5fy, right. So if I use fcd as 0.5fy that means 0.5 into 250 that means 125 MPa. So Ae the required area I can find out that will be Pd Pd is 250 kilonewton by fcd fcd value is 125, so from this I can find out 2000 millimetre square, right that means Ae will be 2000 millimetre square.

That means the cross sectional area of single angle should be around 2000 by 2 means 1000 millimetre square. So I have to look a section means angle section where the area is little higher than 1000 millimetre square and that has to be equal angle section. So coming to table 3 of SP: 6, I can find out a section ISA 90 by 90 which is single equal section by 6 if I use, its area is becoming 1047 which is slightly more than 1000, right so this is how I have chosen a angle section.

And I can find out now the value of Cx, Cy, etc from the SP: 6, so Cx, Cy, I can find out as 24.2, rx and ry as it is a angle equal angle section so I can means rx and ry will be same which is 27.7 and ru value is 35 and rv value is 17.5, these are the property of individual angle section. Now I have to find out the property of the combined section.

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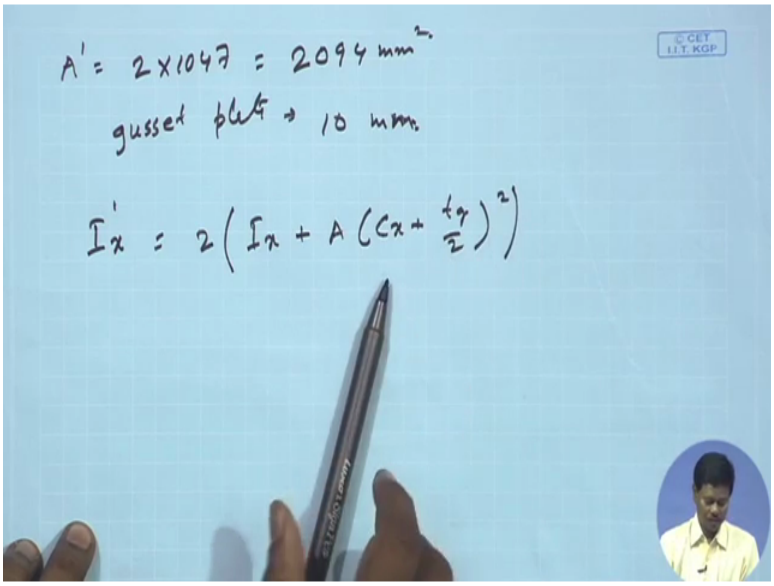

So property of the combined section can be found as A dash the area of the combined section will be 2 into 1047 that will be 2094 and let us use a gusset plate gusset plate and its thickness is say 10 mm, okay. So if we use a gusset plate of 10 mm then I can find out Ix value, so I dash x we can find out I dash x as 2 into Ix plus A into Cx plus tg by 2 whole square, right.

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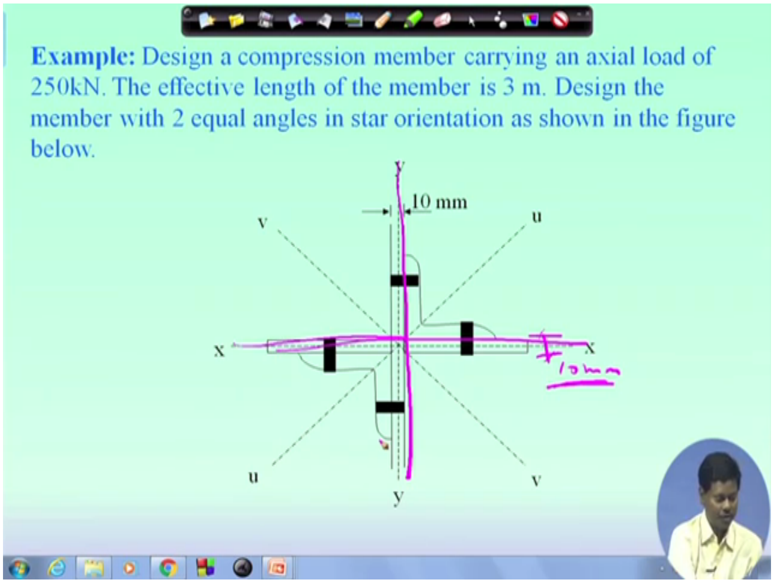

So if we see the orientation of the angle it is something like this, so this thickness of the gusset plate is 10 mm, right. So Ix I can find out like this Ix means in this direction Ix and Iy will be in this direction and Ix and Iy will be same.

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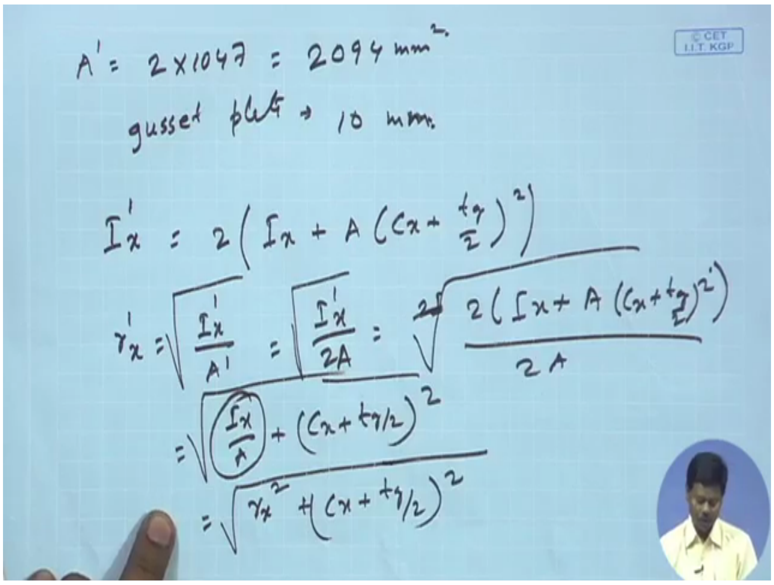

So Ix let us find out Ix means combined section. So here I can find out r dash x as I dash x by A dash, so I dash x by A dash means 2A, so this can be found as I dash x means 2Ix so I can find out 2 into Ix plus A into Cx plus tg by 2 whole square by 2A. So from this I can find out Ix by A plus Cx plus tg by 2 whole square, so Ix by A means rx square so rx square plus so this will be square root, so rx square plus Cx plus tg by 2 whole square. So rx dash simply I can find out from this formula.

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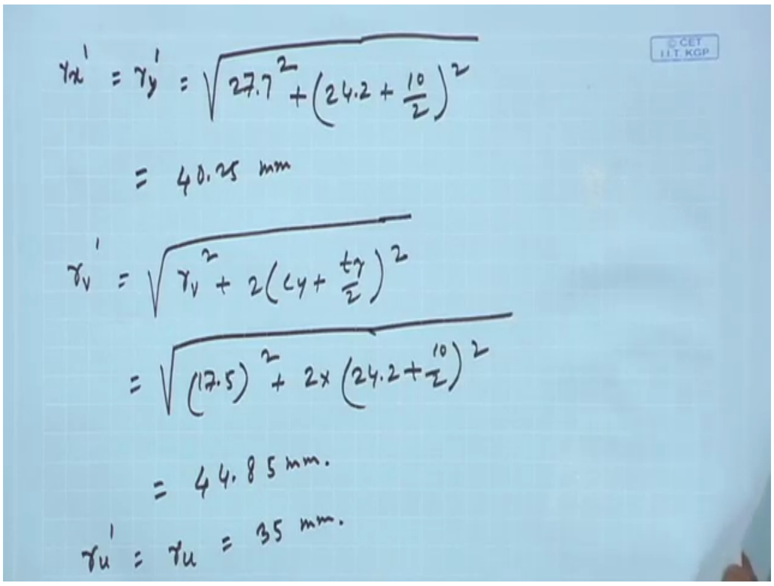

So rx dash will become simply same as ry dash is equal to rx value is 27.7, Cx is 24.2, tg is 10. So from this I can find out rx dash and ry dash as 40.25 millimetre, right. Now similarly rv dash can be found rv dash will be in a similar fashion I can find out the value of rv dash is equal to rv square plus 2 into Cy plus tg by 2 whole square. So from this I can find out rv as 17.5 square plus 2 into 24.2 plus 10 by 2 whole square. So from this the value of rv dash will be 44.85 millimetre. And ru dash will be simply ru, right ru dash will be ru, so that will be 35 millimetre. So we could find out rx dash, ry dash, ru dash, rv dash.

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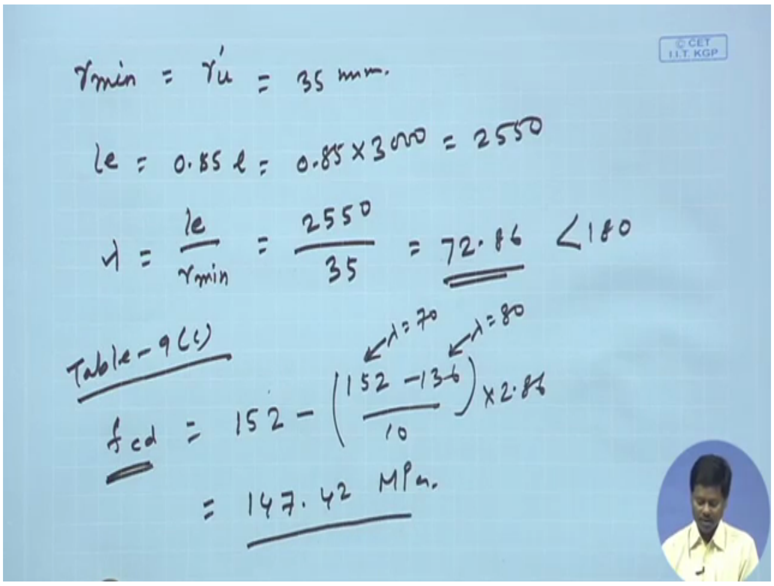

So out of these four the r minimum can be obtained. So r minimum will be basically ru or ru dash that will be 35, right. And effective length le we can find as 0.85l that will be 0.85 into

3000 is equal to 2550. So once we find the value of effective length I can find out the radius lambda slenderness ratio. So slenderness ratio will be le by r minimum, so le is 2550, r minimum is 35, so from this I can find out the value as 72.86 which is less than the allowable slenderness ratio, so this is okay.

And we know that this is an angle section, so buckling class C will be used, so table 9c will be the appropriate one to find out the value of fcd. So fcd value I can find out from the table 9c correspondent to fy 250 that will be 152 minus 136 by 10 into 2.86, this is 72.86 so this is lambda for 70 and this is lambda for 80. So by interpolation we can find out the value as 147.42 MPa, right. So fcd value we could find as 147.42.

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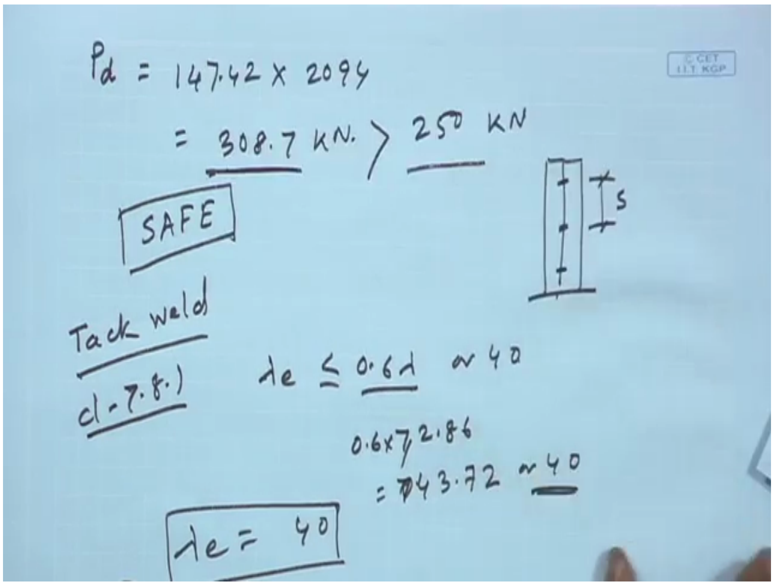

So the strength of the member strength of the member can be found Ae into fcd, say 147.42 is the fcd value and Ae is 2094. So this is coming 308.7 kilonewton, so member is safe, right because it is more than 250 kilonewton. So what we could see here that we have assume certain fcd value and on the basis of fcd value we found a particular section and after finding that particular section we try to find out the strength of that section and we could see the strength of that section is 308.7 kilonewton which is much higher than the applied load.

So though member is safe theoretically what we should do we should decrease the member size and we should see in which member it is going to be safe marginally, right. So once it is done now suppose we are making safe this one and we are using this section. So if it is used this section whatever we have found is used then we have to go for tack welding because the two sections are two sections are to be tacked at different places to make it proper placement, okay.

So to avoid local buckling along the length we need to provide tack welding and as per the clause 7.8.1 clause 7.8.1 the lambda e value has to be less than 0.6 lambda. So lambda e we will find out lambda e means for local buckling means between two tack welding the lambda e has to be found and that has to be less than 0.6 into lambda or 40, whichever is less.

So in this case this value is coming 0.6 into (72 point) 72.86 that 43.72 or 40 whichever is less, so we can consider lambda e value as 40, okay. So lambda e value is 40, if this is S, the spacing.

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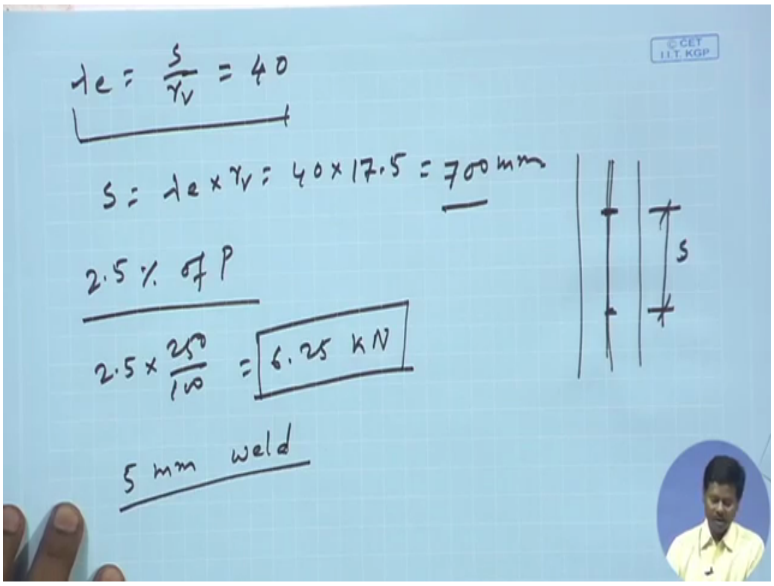

Then I can find out lambda e as S by rv rv is the radius of gyration means minimum radius of gyration so and it has to be 40, so if I consider this I can find out the value of S as lambda e into rv that is 40 into rv rv is the minimum radius of gyration of the individual member that is 17.5. So this will be 700 mm. That means when the members are tacked, say for example it is tacked here so this spacing will be 700.

And now we have to make tack welding means if we make welding then I have to find out the weld size, so we know the weld has to be designed to resist transverse force and transverse force is considered 2.5 percent of the load, so 2.5 percent of load means 2.5 into 250 by 100 that means 6.25 kilonewton, that means I have to design a weld to carry this transverse load. So if we use a 5 mm weld size of the weld as 5 mm then length of the weld I can find out.

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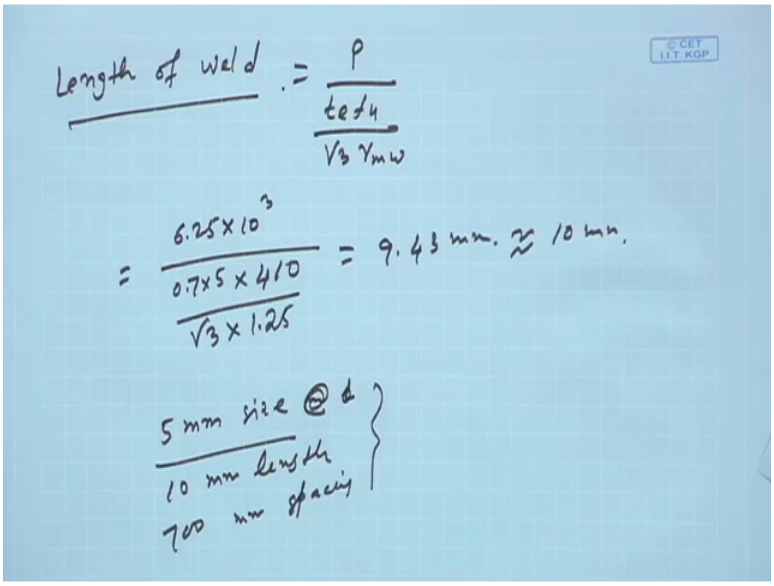

So length of the weld will be length of weld will be P by te into fu by root 3 gamma mw. So if I put the value P is 6.25 the transverse load that is 2.5 percent of the axial load P by te is 0.7 into S that is 5, the weld size, fu is 410 by root 3 gamma mw we can consider 1.25 using soft weld so that is becoming 9.43 mm. So length of weld is 9.43 mm or 10 mm, that means we can provide the tack welding of 5 mm size at a with a length 5 mm size and 10 mm length and 700 mm spacing, this is what we have to do, right.

So we we have seen here how to how to make tack welding and how to find out the weld distribution, weld size and weld length for tack welding. Now what I was going to tell earlier once again I would like to repeat that for this case we have seen that the load is coming 250 kilonewton whereas whenever we have done the assume section here we got the load carrying capacity as 308.7 kilonewton. That means we have to repeat the design to get an economical section because if we use this section it will not be economic so but this is a tds job.

So it is always better to make a program at our own and use that, if we make a program and do it then we can find out the economic section, because in programming required amount of iteration will be done automatically if we make the algorithm properly, so we do not have to do anything means once we develop a program then we can find out an economic section because in computer algorithm the iteration will be done, so through iteration it will search which one will be the best section to carry out that much external load.

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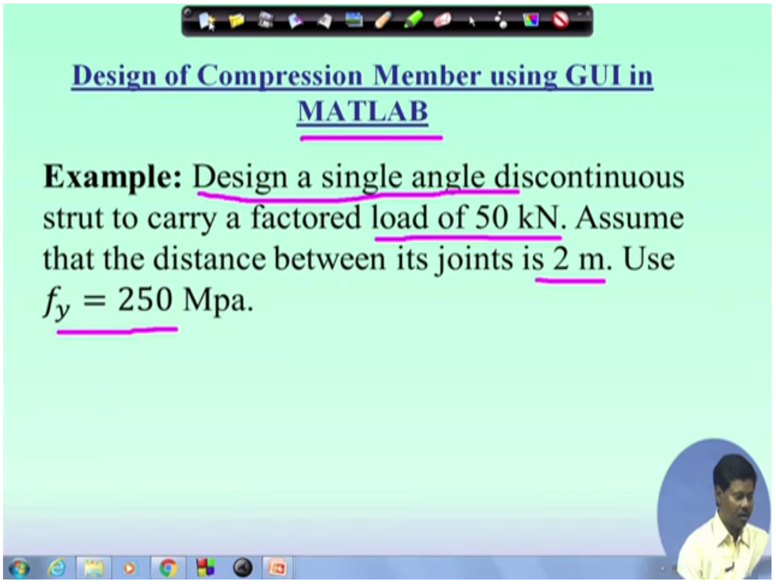

So here I will just show a demonstration, here you see I have developed a program means my students have developed a program for design of compression member using MATLAB environment and it is graphical user interface based program has been developed. So there this problem has been demonstrated that design a single angle discontinuous strut to carry a factor load of 50 kilonewton. So load is 50 kilonewton and assume that the distance between its joints is 2 meter. Use fy as 250 MPa. So with this data we will see how to find out the required sectional area.

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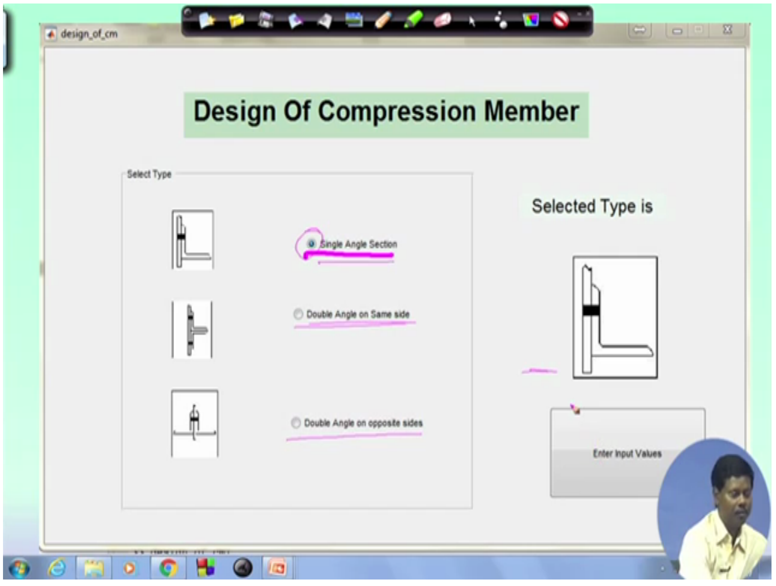

So this is the GUI of the program in first page it will show you the different option here we have made three options only one is single angle section, another is double angle section on same side and double angle section on opposite side, for these three cases we have developed the program for other cases we have to develop. So those who want to develop they can make the algorithm in such a way that the different type of orientation of the angle sections can be used.

So for this case as it is told that single angle section, so we have to click on single angle section then it will show this type of section and then if we click on enter the input values then it will go to next page.

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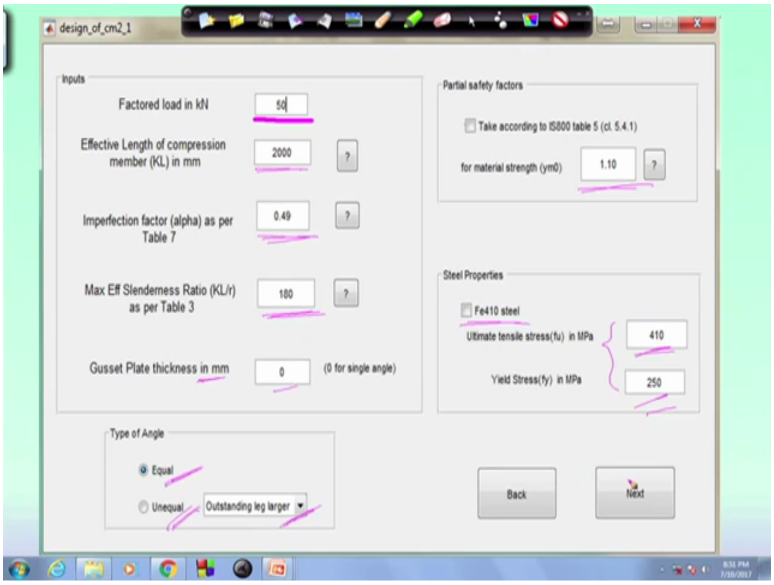

In next page u see that it is shown that factor load it was actually 50 kilonewton and effective length of compression member was given 2 meter which is 2000 millimetre, imperfection factor as it is angle section so imperfection factor also can be given using table 7, then maximum effective slenderness ratio can be defined as per table 3, then the gusset plate thickness if we are going to use, double angle section then we have to provide gusset plate thickness otherwise we can provide 0 because we are not using any gusset plate.

Then we can (())(31:34) whether it is equal angle section or unequal angle section, if unequal angle section then again we have option that outstanding leg is larger or the connected leg is larger which one means as we will be choosing according to that orientation will be done and calculation will be made accordingly. Then according to table 5 the material strength means factor for material strength gamma m0 that will be calculated if we click here, if we give the check box automatically it will take the value, otherwise we can put our chosen value also.

Similarly as Fe410 grade of steel if u use then automatically its ultimate tensile strength and yield strength will be shown otherwise u can provide at our own also. Then we have to go to next.

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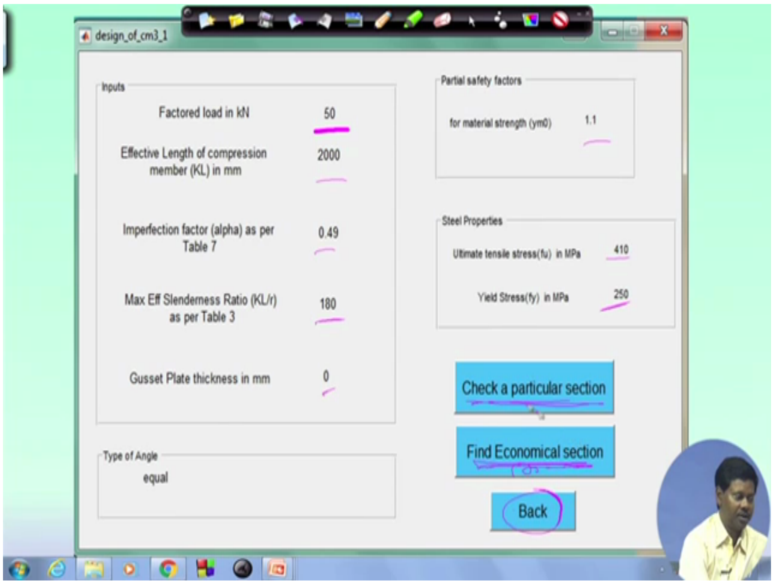

So if we go to next then this type of page will come where the data whatever we have provided has been shown means now if we see that if some data are mistakenly done means by mistake if we have given some data then we can go to back, we can go back and we can provide the proper data, otherwise we can ask means we can click on check a particular section check a particular section means we can give a means if we can click here it will show different section available in SP: 6, so we can check a particular section for example ISA 90 by 90 by 10.

Now if it is okay then it will show okay, otherwise it will show it is unsafe and if we click on this that find economical section then it will start from the least one and it will go on increasing stage by stage for each case it will check whether it is okay or not, if it is not okay then it will go for next higher version higher section and then again it will check. So in this way lot of iteration will happen and finally it will find out the economic section, this is how the program runs.

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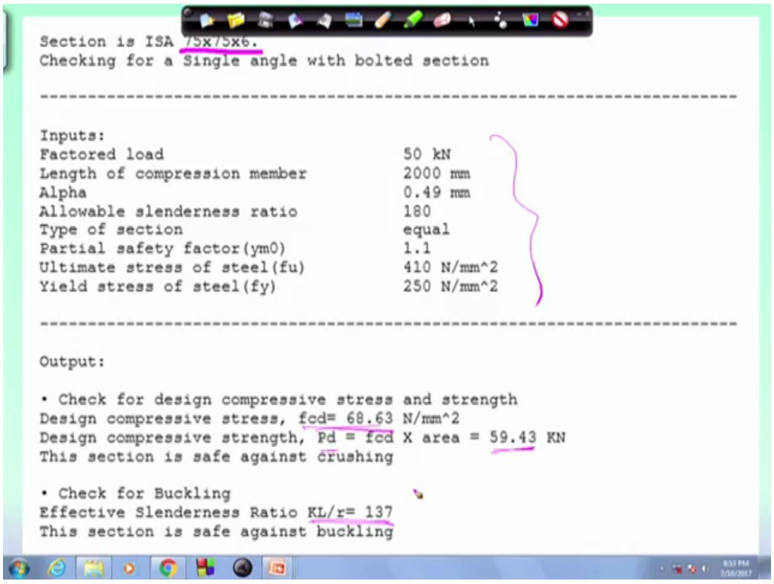

So if we choose a particular section we can make then this is the output if we here u see the 75 by 75 by 6 section has been chosen and these are the inputs which has been given and in output it is shown that fcd value is coming this and the design compressive strength is coming 59.43 whereas the external force was 50 kilonewton. So marginally higher value it is coming and thus effective slenderness ratio also coming 137 and allowable slenderness ratio was 180, so this is how one can find out the values.

So from demonstration of this program what I wanted to say is writing a MATLAB code is very easy if you know the design methodology, if you know how to calculate that design strength of a compression member, then the same can be written in a program and then by providing some loop we can try with different section and finally we can find out a suitable section by trial and error method.

So once if we develop such type of program then next we can just simply use we can we do not have to do anything else, otherwise every time if you do not have program at our hand then we have to calculate every type means those who are design engineer, those who are working in design firm for then every time they have to calculate for designing a particular member but once we develop a customized program then we do not need to give that much effort for every time, we can find out the solution just by running the program, right.

So this is all about the design of compression member with respect to single member single compression member or just means single angle section or double angle section this is what we will do. Next day we will try to find out the built-up sections means how to design a built-up section and for design of built-up section we need to tie the member along its height or length business using lacing or or battening system those will discussed in next class, thank you.