Design of Reinforced Concrete Structures
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Lecture - 23
Design of Columns Part – V

Well so far we have done that up to uniaxial bending column and uniaxial bending.

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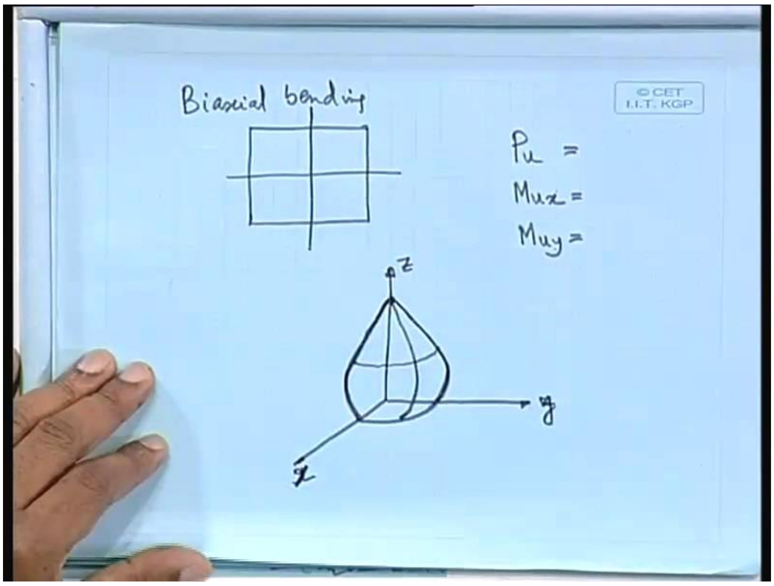

Now, whatever say bi axial bending how shall we do the bi axial bending that if the section is having in both ways that means, axial load Pu, Mux and Muy. So, Pu Mux and Muy that is given then, we have to find out a suitable section along with that percentage of steel. So, you have to find out the percentage of steel and the suitable section what happens here if we have say x y and z, I think we have done something wrong anyway. So, what we can do it here I think let us, make it this is x this is y then we can follow the same coordinate system.

So, x y and z what we can do the section having say something like this is the interaction diagram about 1 axis. Similarly, about the other axis also it can have something like this and we are having because, Mu x and Mu y we can have the resultant also that way also we can find out. So, the curve may be say something like this it is just say once in 3 dimensional I am talking when, I am talking this particular 1 interaction diagram it is difficult to get in 3 dimension, so far we have done for uniaxial that say moment and force interaction curve that we have got it. And that is given in sv 16 also and 1 can make on your own also that means, it can develop on your own, there is nothing say great thing, you can develop your own thing also. Anyway that we shall come later on what I am trying to say, the curve you are having along these axis that means, y and z axis so, you are having this 1 interaction curve.

Similarly, z and x axis here that is also another curve that means, in another axis somewhere I can get another 1. So, like that I can make so many interaction curve that means, as if you can consider this 1 as if that you are taking 1 quarter of and only 1 as simple as that. If you take that only 1 quarter and you are cutting vertically so, that portion you image that shape which will get it as a say interaction curve or interaction diagram in say 3 dimension.

So, when you get that 1 that means, now if you know Mu x Mu y and Pu there are 3 parameters now. And I have find out a section along with the area of steel so that, I can say the section is safe. For that what we do so this is that 1 obviously, bi axial bending. What we do, how shall we design it?

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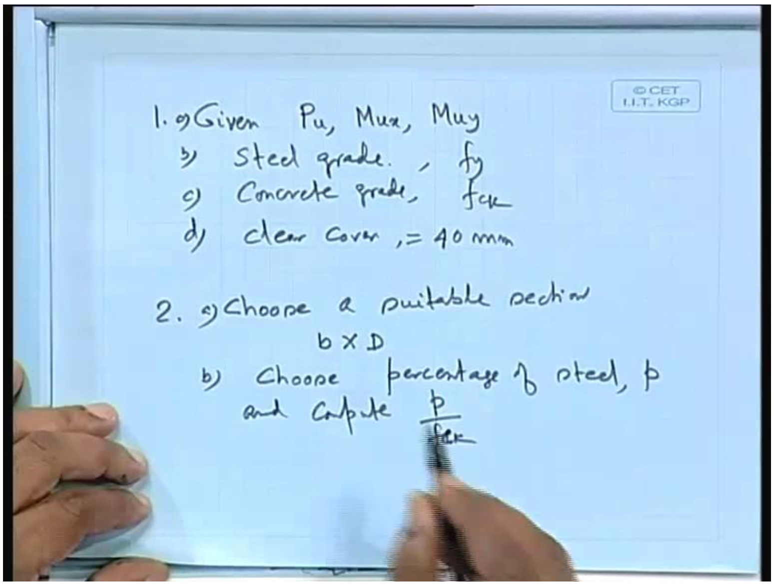

We design it in a fashion let us, make it this way that given. Let us, first find out given Pu, Mu x, Mu y please note we are talking say design load when, we shall generally it happens that p is coming from the torf say bending moment also, coming at the column junction that all those things are coming p also coming the actual load. Now, after multiplication of 1.5 all those things including the self-rate of the column also you have to take.

So, then finally it is coming as a Pu so, that Mu x, Mu y all those things whatever way it is coming. So, as if we have assume final form, but when will you do the actual say your analysis for a particular structure analysis there you have to take care say self rate lot of other things without calculations you have to take care it. Anyway, let us take say Pu, Mu x, Mu y that is given.

The steel grade specified by say fy, concrete grade say specified by say fck, clear cover that is also say specified. Now, what we have to do choose a suitable section let us, say b times d also choose percentage of steel. So, that is say p so, this all those things are given or assumed clear cover we can assume 40 millimeter or 50 millimeter whatever we give let us, say that we shall give for all the cases we shall give 40 millimeter anyway.

But others I specified we have check 40 millimeter. So, now choose a suitable section b times D here in this case, you can say as if you are doing the analysis rather than design compared to your say beam or slab where you are providing the section you are calculation the say effective depth and then, you are providing your section. But in column design you can say, analogous to that I can say that here at least as if I am doing the analysis part.

So that means, I am taking all the things and then I am checking whether that my trial section is correct or not, whether it is safe or not that is what I am trying to do it. So, you are choosing a section b times D choose percentage of steel also and compute p by fck what we can do now since, if I know Pu.

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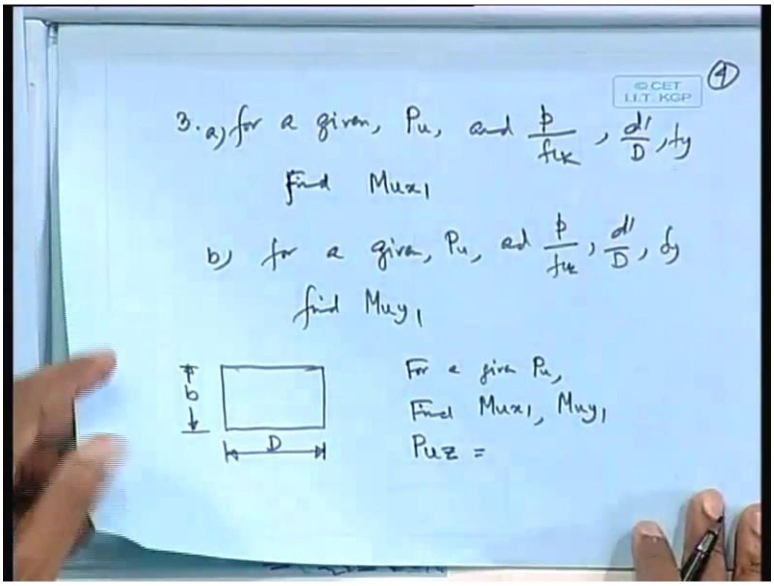

For a given Pu and p by fck, find and also d dash by d find Mu x1 what does it mean? It means, that Pu is given I have already chosen p by fck and also I know d dash by d that means, I can go to a since I know p by fck d dash by d also, I know fy; fy is the that steel grade. So, since I know Pu, p by fck, d dash by d fy. So, I can go to proper chart of sv 16 and then, what I can do since I know Pu.

So, for that p by fck I can find out what is the maximum that uniaxial bending that 1 how much it can take, that also I can find out. So, I can calculate Mu x 1 also that means, if the Pu is given. So, I can find out the maximum uniaxial bending about the particular axis. So, that is your Mu x1. Similarly I can find out for given the same Pu and p by fck, d dash by d and fy find Mu y1 so that means, I can find out about the other axis.

So, what I can do if this is your section b and D so I can find out for find that what I have told Mu x1 and Mu y1 not only that, I can also find out Pu z. What is Pu z? Pu z is the maximum axial load capacity of the column. The section you have chosen, what is the axial load capacity that also I can find out that is you say Pu z.

So that means, when I am choosing a section and the area of steel or p by fck on the basis of that, I can find out Mu x1 for a given Pu, Mu y1 also that Pu z the maximum axial load capacity that means, all of them I can find out. So, if I get that 1 now shall go a check what is the check?

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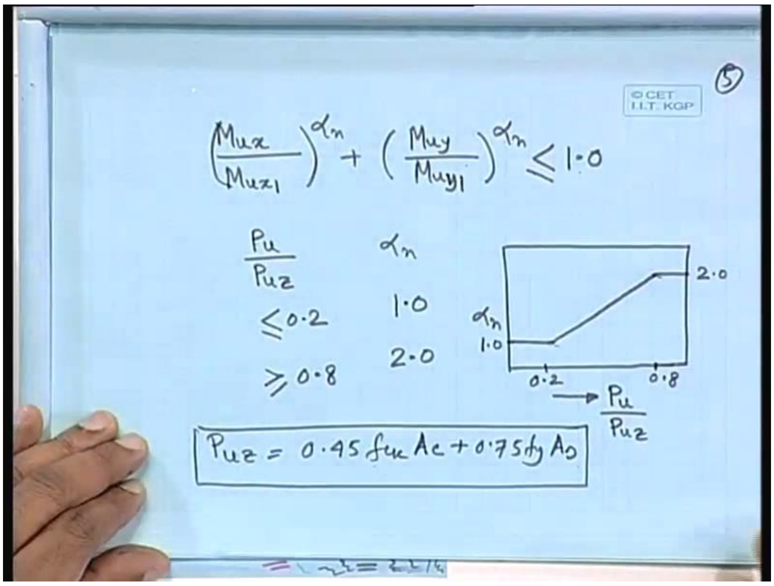

The check is Mu x by Mu x1 to the power alpha n Mu y by Mu y1 y1 times alpha n should be less than equal to 1.0 what about this I know Mu x that is given for that I have to design, I know Mu y for that I have to design. And Mu x1 I have got it from the proper chart with d dash by d fy all of them I have got Mu x1, I have got Mu y1, but I do not know alpha n, what is that alpha n? Alpha n is dependent on Pu by Pu z I have already computed Pu z.

So, Pu by Pu z and alpha n if Pu by Pu z less than equal to 0.2 then, alpha n will be 1. And if it is greater than equal to 0.8 then, this 1 will be 2.0. So, I can say the curve looks like this this 1 will be your Pu by Pu z and this is your alpha n I can find out somewhere here. Let us, say this is your 1 and this 1 say 2 so, curve comes like this, this is your 2, this is your 1, and this is your 0.2 and this is your 0.8.

The curve that say your that means, this is the interpolation you can do it. That means, if it is less than equal to 0.2 it is 1, if it is greater than equal to 0.8 then it is 2 in between that, you just simply linearly interpolate. That values of alpha n the value which we have to put it here, but what about your Pu z? Pu z equal to 0.45 fck Ac plus 0.75 fy times As this is your Pu z.

So, Pu z also I know Pu z equal to 0.45 fck Ac plus 0.75 fy As this is the 1. So, I know everything so that means, the biaxial bending for that the design is very simple what you have to do, that you find out Mu x1, Mu y1 for a selected value of say your percentage of steel then, you find out Pu z, find out alpha n on the basis of Pu by Pu z and you find out using this equation less than equal to 1.0. If it less than equal to 1.0 then, you just stop otherwise, again you have to change the section or percentage of steel and then, again you have to do your calculation. That is all what we do it in say biaxial bending. So, I think we can try 1 problem very simple problem that we can try and we can find out.

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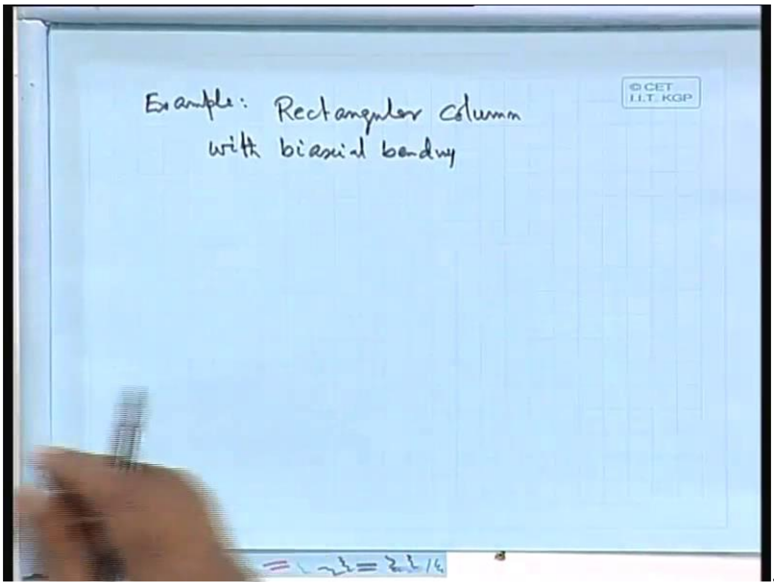

So, let us take 1 example so, rectangular column 1 thing I think I should tell these 1. Because, I have telling so far that sp 17 this 1, but where is that in IS 456 that clause I think I should refer that 1.

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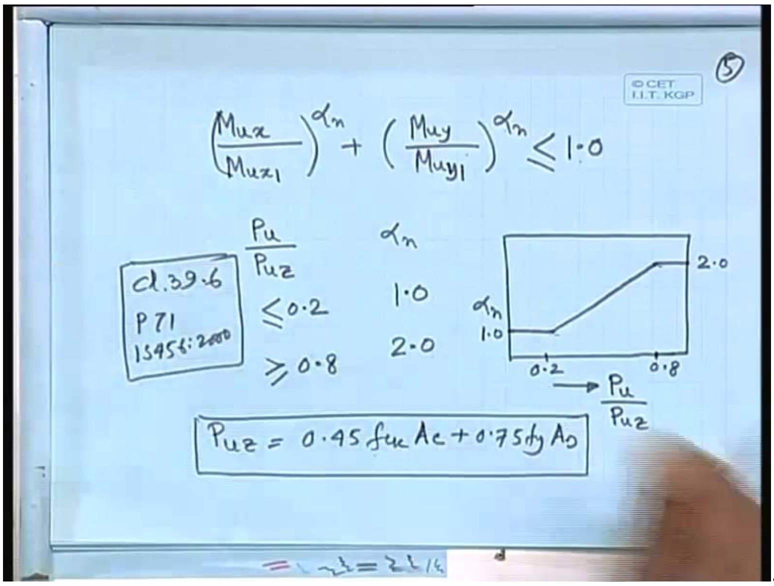

So, that 1 you will get in clause last 1 so, clause 39.6 page 71 IS: 456: 2000. So, please note this clause 39.6 page 71 IS 456: 2000, where will get that whatever I have told this particular 1.

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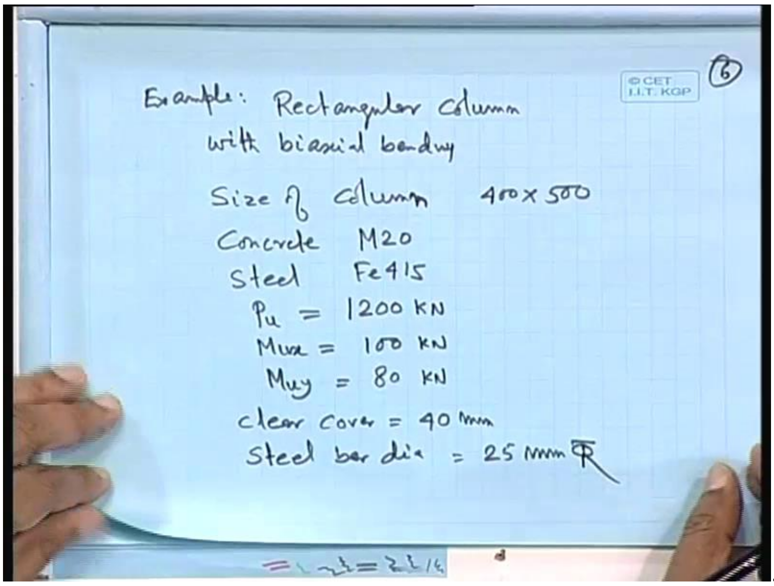

So, let us take the column section size of column 400 by 500 concrete M20 steel fe 415 Pu let us, take n 1200 Mu x let us take 100 kilo newton Mu y let us, take 8 kilo newton clear cover 40 millimeter. So, and we shall let us try 20 millimeter bar steel bar dia so, what we can do it here d dash by d let us compute.

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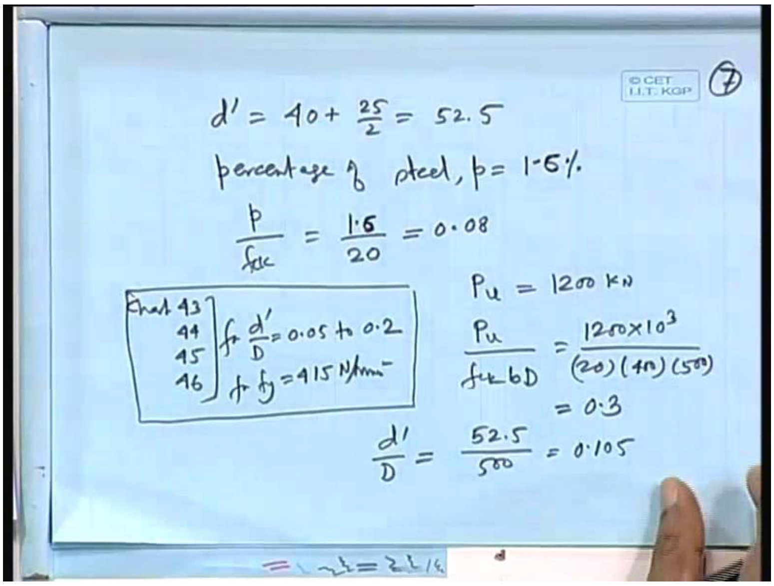

d dash 40 plus 25 by 2 52 5 and we have and percentage of steel let us, take percentage of steel shall I take 1.5 percent. So, p by fck equal to 1.5 by 20 or we can do some tricky thing I think that, what we shall do. Let us, take a section we shall go little far and what we have our that your say sp 16 says. So, our that chart will start from we shall assume that we shall provide the reinforcement in all 4 sides.

Because, we are talking say your biaxial bending. So, we shall provide the reinforcement in all 4 sides and what we can do, that our 1 chart starts from chart 43 44 45 and 46 these are the 4 charts. So, let us write down here chart 43 44 45 46 for d dash by d equal to 0.5 to 0.2 for fy equal to 415 newton per square millimeter we shall provide this 1 now what about the tricky thing, what I am telling here 1.5 by 2 it means, it will be 0 75.

But what have in here, that in these sp 16 it gives in point 0.2 0.4 0.6 0.8 in this fashion. So, that is why I am telling so, let take instead of taking 1.5 percent let us take 1 6 percent. Because, we are assuming it will be little bit easier so, I can take 0.08 that mean I need not again estimation all those things. I need not do it because; directly I shall get 1 curve that is p by fck 0.8 that curve I can choose it. I can take it 1.4 also.

So, that way this tricky thing I am doing here. So, this your p by fck equal to 1 5 by so, 0.8. Now, what about your Pu equal 1200 Kilonewton and Pu by fck bD equal to 1200 into 10 to the power 3 divided 20 times 400 by 500 which comes as let us, see how much it is coming. So, 0 3 Pu by fck bD is coming 0 3 and p by fck 0.8 d dash by D 52.5

divided by 500 1 case d dash by b also will be there. So, there by 2 cases so, 52.5 by 500 0.105. So, let us just summarize the whole thing.

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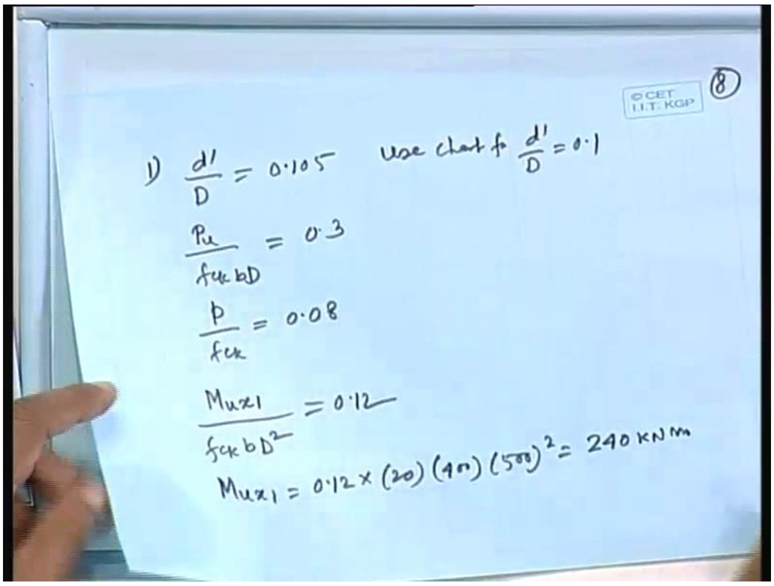

The d dash by case 1 d dash by D we can talk about say 1 about major axis, another about minor axis. In that case, I can say 0.105 Pu by fck bD equal to 0 3 p by fck equal to 0.8 and. So, Mu x1 divided by fck bD square how much will be Mu we are talking say about major axis. So, about D we are talking so, Mu x1 by fck bD square we are talking say and x we can always talk say your major axis.

So, if that be the case our d dash by d equal to 0 105 use chart for d dash by d equal to 0.1. So, that 1 comes in chart 44 this is your chart 44 and your Pu by fck bD 0.3 and 0.08. So, which is coming as 0.1 0.11 0 12 so, that 1 it comes as 0.12 from the chart what I am doing here please note I am doing here that, there are so many starting from 0 0.2 0.4 0.6 p by fck what I am doing Pu by fck bD is 0.3.

So, I am going along this and then where ever it is cutting that curve of p by fck 0.8 then, I am coming down then I can get where it is cutting here it is cutting here 0.12. So, this is the value that means, in other way if it is uniaxial bending then whatever I have chosen. So, I shall get that curve say p by fck 0.8 so, I Pu by fck 0.3.

So, I am coming moving like this for your sake at least let me spoil my book at least. So, I am coming here and then, I am coming down like this is it correct? So, this is the thing what I am doing. So, I am going so I have started here Pu by fck bD 0.3 then, p by fck 0.8 this curve and you come down wherever, it is cutting it is cutting at Mu x mu by fck bD square that is your 0.12.

So, that value we have taken and that is we have taken from d dash by d equal to 0.1. So that Mu x1 by fck bD which is coming as 0.12. So, what is the value of Mu x1 then? Equal to 0.12 times 20 times your what about the 400 times 500 square. So, 500 into 500 into 400 into 20 to 2.12 so, 240 kilo newton meter. Similarly, I can try for the other 1.

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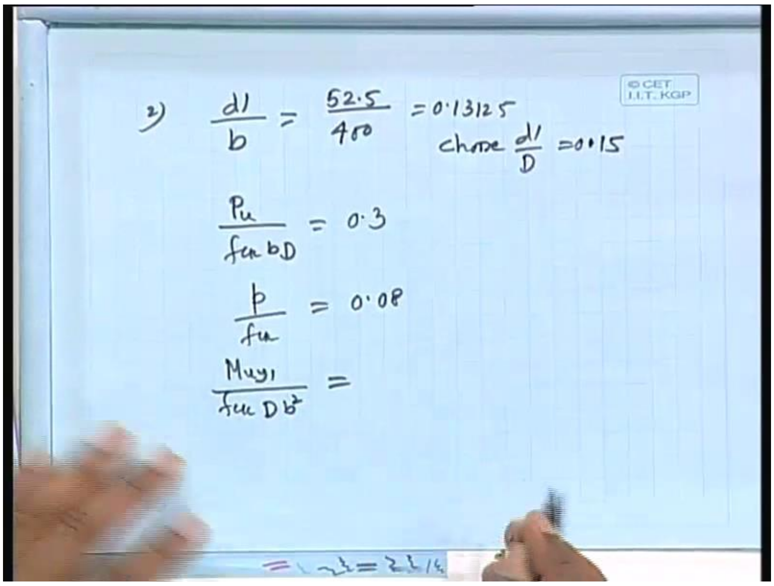

So, number 2 d dash by b will be equal to 52 5 divided by 400 because, so, I am taking about the other axis. Let us, say that is the minor axis so 52 5 divided by 400 0 13125. So, choose d dash by d equal to 0 15 I shall take that chart, where d dash by d equal to 0.15 Pu by fck bD there you no problem, it will be same 0 3 only there no change p by fck also there is no change 0 8 Mu y1 by fck bD squared that 1 we shall get it. And where from we shall get it, we can get it from the chart 45.

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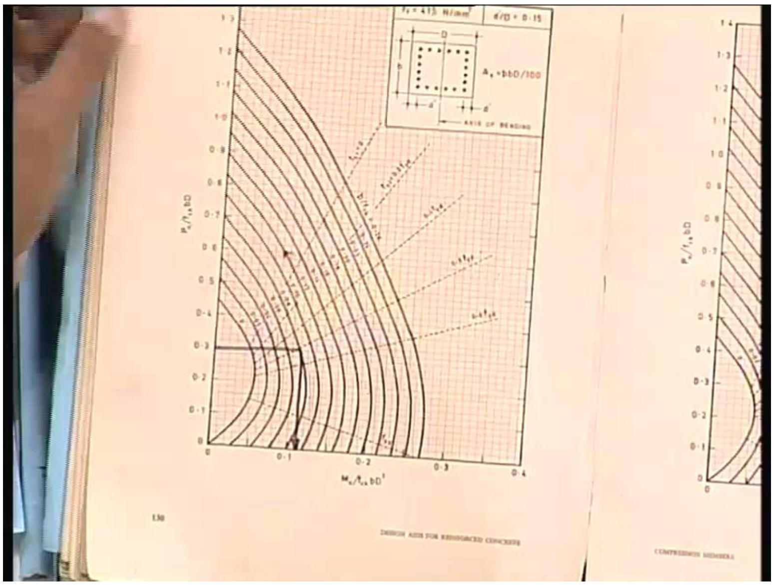

So, we are getting from the chart 45 so, 0 3 and come down 0 11. So, the value is 0 11 0 3 I have started and then, I am coming down here. So, it is 0 1 and you will get it in chart 45.

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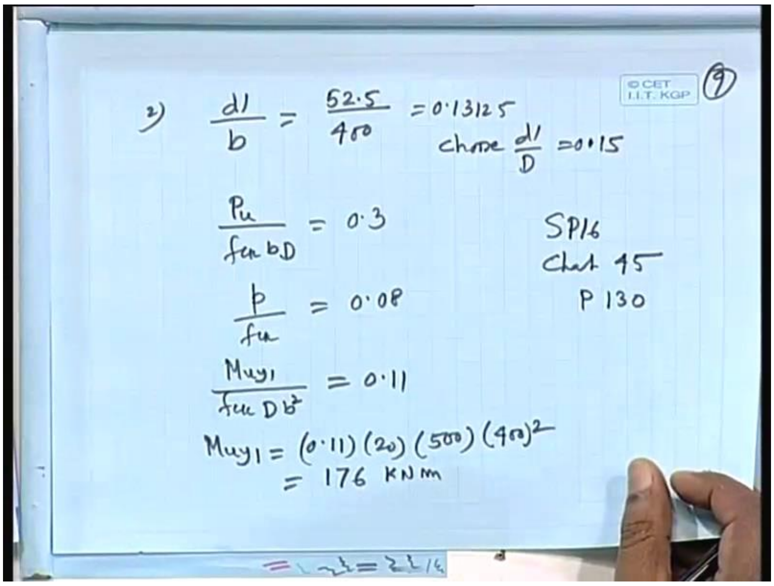

So, SP16 chart 45 page 130 and this is 0 11. So, Mu y1 equal to 0.1 times 30 times 500 times 400 whole square. So, let us check 176 shall I accept it 176 kilo newton meter right. So, Mu y1 that is say 100 and 176 kilo newton meter. So, we know Mu x1, we know Mu y1 what about Pu z?

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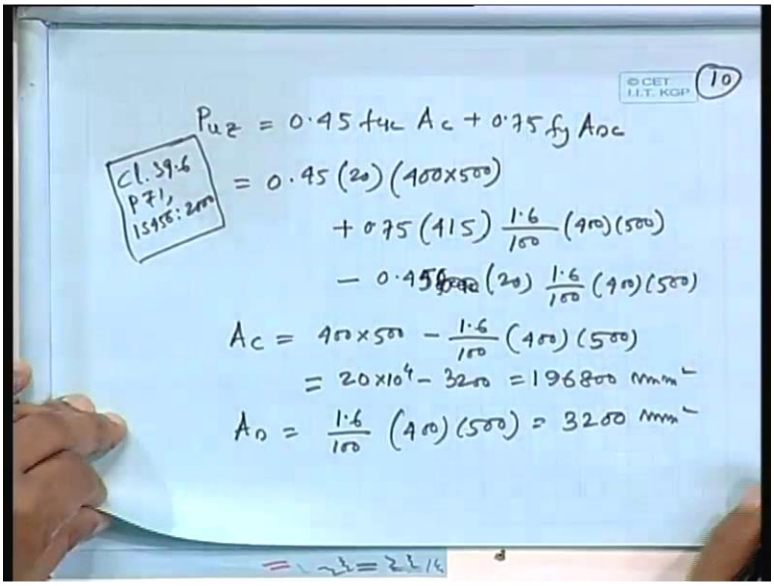

So, Pu z equal to 45 fck Ac plus 0 75 fy Ac equals this 1 you will get it again clause 36 9 page 71, IS456: 2000. So, 0 45 times 20 times 400 times 500 plus 0.75 times 415 times p how much you have chosen p equal to 1.6. So, 1 6 by 100 times 400 times 500 so, this much is your area of steel we are getting it here and we should not stop it here.

Because, we shall get it here again how much will be that 1 minus 0.45 let us, check this or 0.45 fck times 20 I can make it times 1.6 by 100 times 400 times 500 I am just subtracting the portion. Because, already I have taken the full 1 either Ac will be equal to if you would like to make it very clear. The other way also, you can make it these portion you can omit it. So, let us find out Ac will be equal to 400 times 500 minus 1.6 by 100 times 400 times 500 this I can do it because, this is the 1 that exactly the area of concrete.

So, 1.6 by 100 into 400 into 500 so, area of steel As equal to 1.6 by 100 times 400 times 500 equals 3200 square millimeter this 1 comes as so 400 into 500 minus so, 196800 square millimeter. So, either you can do it here this portion you can just simply write down or you can deduct the portion whatever way you feel. The same way, I am doing the same thing so, what I can do it here then let us make it.

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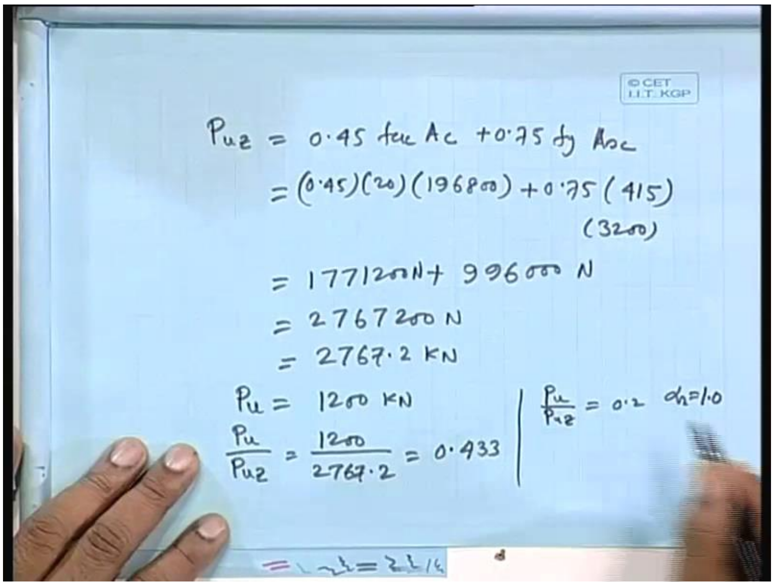

Pu z I have calculate so, 0.4 fck times Ac plus 0.75 fy Ac equal to 0.45 times 20 times 196800 plus 0.75 times 415 times 3200. So, 0 5 times 20 times 196800 175 times. So, 1771200 plus 175 times 415 times 3200 9960 these are all in newton. So, last 1771200 2767200 newton which comes as 2767 2 kilo newton. So, P uz equal to 2767.2 kilo newton what about your Pu equal to 1200 Pu by P uz equal to 1200 divided by 2767.2 equals 0.433 alpha n alpha n equal to 1. Let me, do it in the next page.

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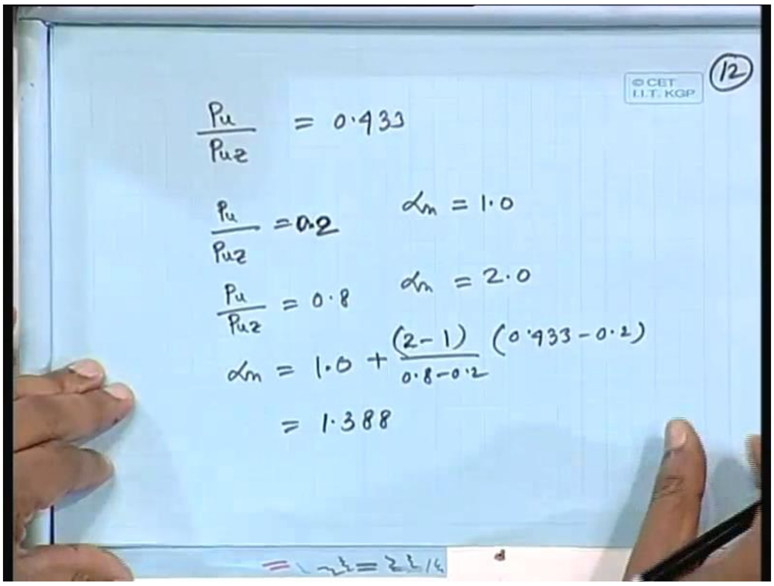

So, Pu by P uz we have computed 0.433 for Pu by P uz equal to 1.0 alpha n 0.2 this is 0.2 alpha n equal to 1.0 Pu by P uz equal to 0.8 alpha n equal to 2.0. So, alpha n equal to 1.0 plus minus 1 times 0.433 minus 0.2. So, how much is coming so, 0.233 divided by 0.6 plus 1 so 1.388 .So, we have got that alpha n equal to 1.388. So, let us now summarize the thing.

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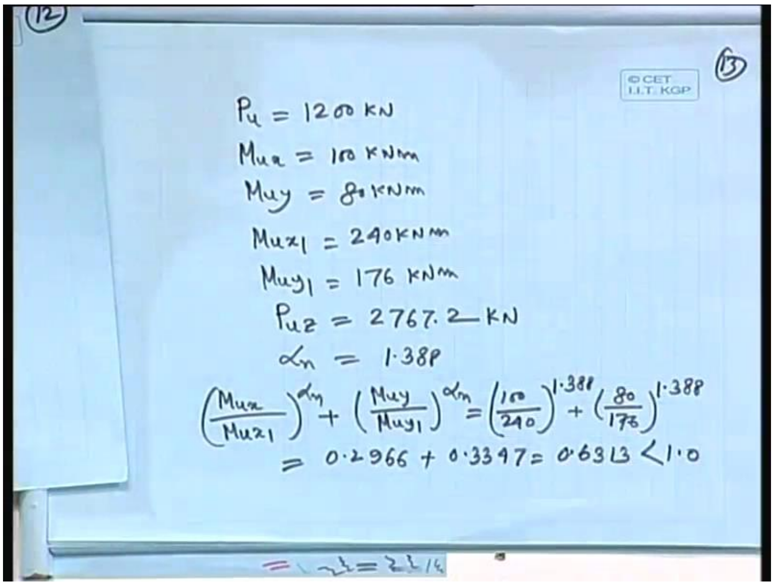

So, what we shall do it here Pu 1200 let me come to that portion, where I have missed those values yes. Pu equal to 1200 Kilonewton Mu x equal to 100 Kilonewton Mu y equal to 80 Kilonewton Mu x1 how much you have got Mu x1, 240 Kilonewton meter this 1 all meter Kilonewton meter and Mu y1 176 Kilonewton meter again I am out of paper Mu x1 Mu y1 and P uz 2767.2 kilo newton. So, we can add alpha n computed equal to 1.388.

So, Mu x by Mu x1 to the power alpha n plus Mu y by Mu y1 to the power alpha n equals Mu x equal to 100 divided by 240 to the power 1.388 plus 80 by 176 to the power 1 388. Let us, find out how much we are getting 100 divided by 240 so, first part I am getting here 2.2966 plus 80 divided by 176 0.3347. So, you are lucky when 0.296 plus 0.3347 which is coming as 0.6313 less than 1.0.

So that means, the section you have chosen that we can at least it is safe we cannot say economic, but at least we can say it is safe. So, we can reduce the section and then also we can try and we can find out that, whether we are we can find out that section that means, whether we can make say little bit less say instead of making 450, we can try say 350 like that we can try and we can find out. So, this is the thing that we do it say your biaxial bending.

So, we know now axial loaded column, uniaxial bending and biaxial bending using this sp 16 the chart extensively so far we have done the slab as well as beam, that we have done as far as possible we have used formula. But here we are extensively using that say chart, other alternative obviously, that you have to do it that lot of calculation that you have to do. 1 more thing I now I would like to tell, that how shall we make this introduction curve.

The 1 can do that 1 say adventure making the whole sp 16 your say as say 1 can make it say computer edit whole that chart and tables all those things take and make it. Or other way, 1 can make it say whole thing that concrete design you can make it say computer edit. Now, here what we do it interaction curve particularly.

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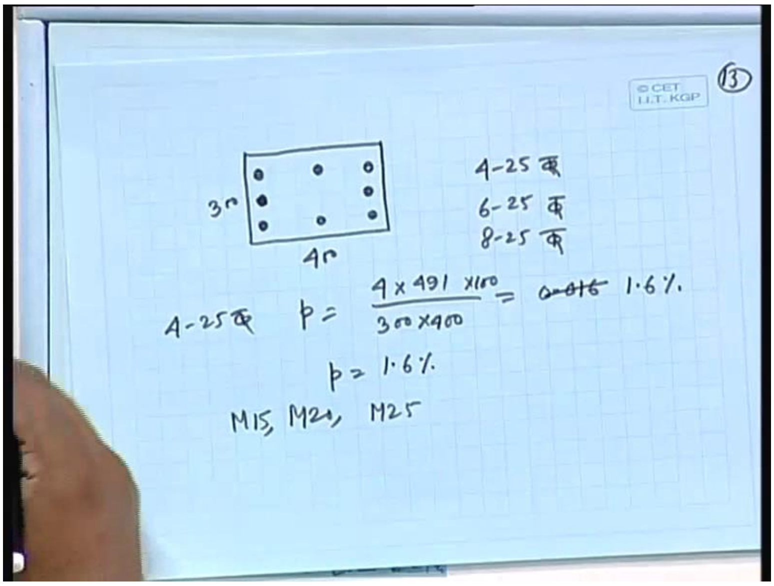

I do not go this curve say on the basis of these interaction curve what I do actually, I do it directly I make my say this is the section. Let us, say 300 by 400 I do not go the percent of steel why shall I use the percentage of steel instead of that, I prefer that let me try with say 4 number of bars say 425 torque. May be little more also, say like this we can provide.

Then, what I can do or 6 we can provide say 625 torque or if I provide say here all sides 825 torque that means I am directly when I am doing the computed design, but then why shall I go with this non dimensional 1. So, here they are using non dimensional that means, so that with the minimum number of charts of tables they can use as many designs as possible that is the whole objective.

But when, you are doing that computed design that means, you are using computed. So in that case, why shall I go again non dimensional instead of that I prefer that I would like to provide these section whatever, area of steel coming is fine. So that means, here in this case Pu will be equal to if I take say 4 numbers 425 torque then, 4 times 491 divided by 300 by 400 I am getting the minimum reinforcement. Let us, check it first that 1 also required.

So, p equal to into 100 let us make it then, it will be clear. So, 1.6 percent when we are getting this 1.6 percent the area of steel I prefer that let us, use this 1 and find out that interaction curve. And then, check whether we are whether it is safe or not because, I do not know prefer that p by fck all those things, directly I can get it and I can find out. Another 1 here and also if I use say M20 grade or say M25 or M15 I can use that grade also that steel.

Because, in this particular chart they have used that M20 grade all along for preparing the chart wherever they need that 1 say your fck value, there you have used assume that they are using concrete grade that say M20. But that is not the case so, what I can do when I am doing the computer design. So, I shall obviously, I shall use that 1 also that whatever grade of concrete you are using so, let us use that grade itself.

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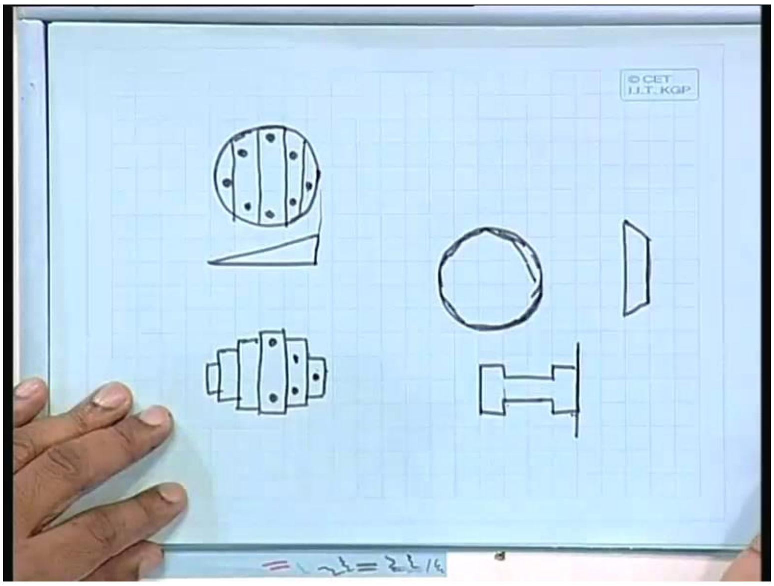

So, that way we do it, not only that what we do it we can do it for circular column also how do you do the circular column? What we will do the same passion you have to do it that means the maximum compression side and this is your maximum compression side say what we have to do it how shall we get this 1, I prefer that let us take a small small strip may be 5 millimeter, may be 10 millimeter strip.

So that means, each of them could be 1 can make it like this also as if this is 1 rectangular 1 which may have this 1, other 1 may be something like this. So, like that it can happen may be you are having this 1 bar here, may be you can have 1 bar here 2 bars like that it can go.

The same circular section I am doing it as a rectangular 1 so, like that I can do it. So, this is the 1 that circular 1 you can make it the way. So, as if this is like this 1 can do it also this way also hexagonal thing also, like that also 1 can do it say something in this way I can do it. If you would like to make it trapezoid as, the whole circular section that 1 we are making it as a trapezoidal section that mean, in a hexagon or in a polygonal form like this.

Because, it is not possible to make it your say whole that circular 1 so, what I can do I can take a section as if the section is like this. If you can find out for this then, I can provide it for any 1 of them this is the 1 that you can do it. That means, it is more closer to the 1 circular 1 instead of being this 1 that means, if in this case if you can develop say for rectangular 1, you can do it for the circular 1 also that you are doing that equivalent section in this fashion. That mean, modelling the circular section in this fashion.

Whereas, if you like to little bit more adventures then, you can take it say your trapezoidal 1, which should be more closer to the your circular section. So, this way that you can make your own design, not only that you can take a section say like this, a column is like this. So, which is nothing, but this is 3 rectangular. So, I can take this 1 this another 1, this another 1, 3 rectangular and each of them stressed at different level not only the this 1 has the say highly stressed level, this 1 in the middle this 1 at the end.

So, for each of them you have to find out that what is the moment capacity and what is the axial load capacity. The moment capacity always, take it to the respective this point with respect to this line. If u take that means, say from that maximum stressed 1 or we can take it with the respect to say neutral the say mid section that also can do it and then, we have to find out that your say moment capacity all those things.

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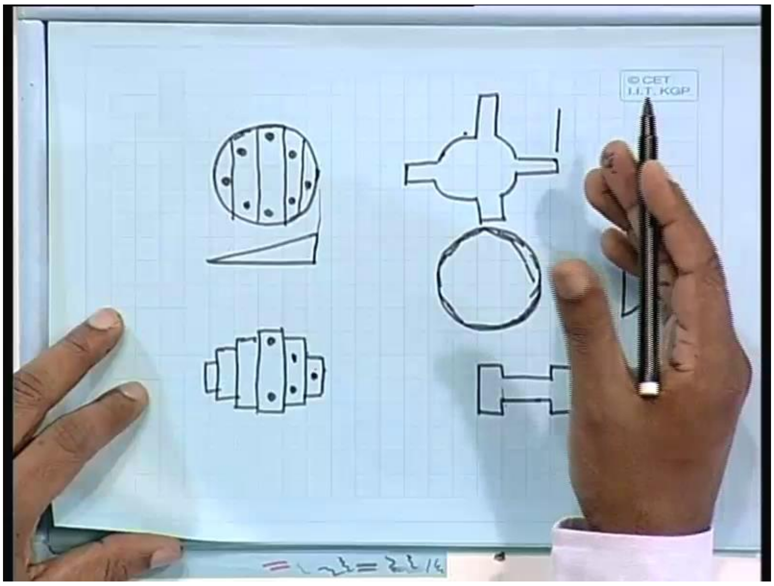

So, this way you can do it not only that 1 can do a section say it goes something like this the section goes little bit complicated, but the section may come like this. Whenever, if the section is coming in this fashion then, what we can do then what we can do, we have to design. Then, what we can do that again we have to find same strain diagram as if you are having this width the maximum stressed.

So, I can find out the what is the maximum stressed and this is minimum stressed and I can find out the again interaction diagram for this curve.

In fact actually, when I started this interaction curve when, I got this type of problem in the step problem then, I thought let me do my own because, nowhere I cannot do anything using say sp 16. So, I have to make my own so, then I started finding that how can we do it and not only that there is further possibility that as if it is like this.

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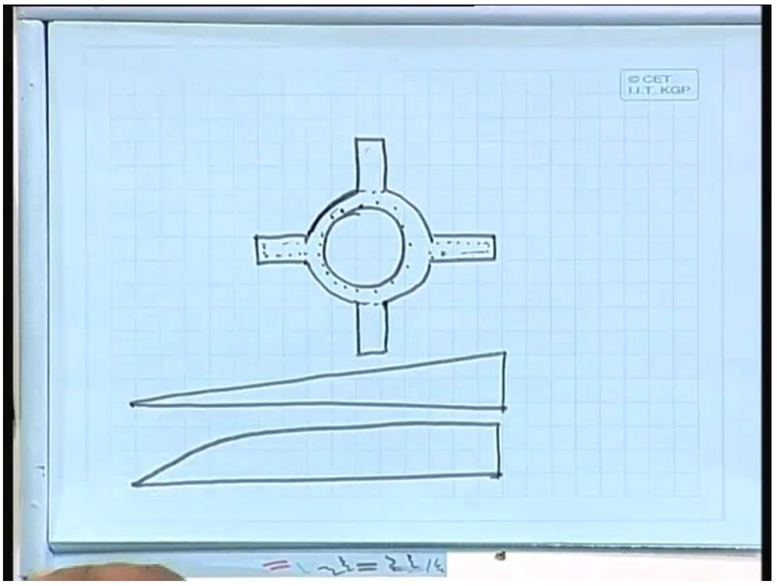

Then, we are having the section it goes in this fashion. So, if the section say hollow and also you are having little bit say stiffener you can say this 1 if the column is going like up like. So, now we have to do this that means, here not only that that there is 1 rectangular portion. So, if I see the stressed model whatever here the neutral axis say some where here. The strain is here, neutral axis say some where here what about the stress diagram?

The stress diagram I can if I plot it may come something like this now you can imagine the certain portion here, certain portion here, certain portion you have to remove it certain portion here the rectangular 1; that means, this is your rectangular 1, this is another rectangular, this another rectangular, this another rectangular and all the your reinforcement along the (( )) say you giving all the reinforcement around the and also including here also that means, the reinforcement here also.

Then, reinforcement along this so that means, so many reinforcement you are providing. So, for each and every component you have to make it, but that itself you can do it using only rectangular and circular. A rectangle that is placed here what is the strain diagram, what is the stress diagram, you find out that portion you individually compute what is the moment capacity and what is axial load capacity. For this section you find out, for this section find out and remove it, subtract it similarly, for this 1 also.

So, wherever you have the stress diagram that means, if you can understand the stress diagram and strain diagram of that say your limit state of method of say concrete design immediately you can find out. And we had always find out the moment capacity, axial load capacity so, all those things you can find out and that is what we are doing here. And it is very simple that 0.0035 and 0.002 these are different strain and on the basis of that you can find out.

So, what I mean to say in all along that apparently it may look like say very complicated, but it is not sure. So, 1 can design your say own thing also your say with the computer related it is very easy. So, also at the same time 1 thing I do not like the software whatever available in the market that is very say software available in market that 1 as if it is a magic box. But that is not the case because, sometimes we find very difficulty they give they come to us and tell us.

So, this is the result I have got it and you have got it from software. Now, another problem it comes that how do we check it? Because, we have to check it those values whether it is coming alright or not because you do not know what method they have used, what they have done that we people do not know. So, that we also actually for that purpose I started developing this software that your say own thing.

But here 1 thing what I am trying to do, that is not a magic that I have to prove; that means, here it will also give the step by step that your results. This is not the 1 and only that let us, provide 10 number of 25 that is fine, but how you have come to that level. If somebody is interested will be able to see that all the information this is the clause this is the result all those thing and that is very important.

I personally feel that it should be supplied in that fashion, not as a magic box what is today now. Anyway, we shall continue and after the say in the later part I shall give all those things in computed design part I think we shall conclude here.

Thank you