Design of Reinforced Concrete Structures

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Lecture - 21
Design of Columns – III

So, let us start with continue with the design of columns. Last class we have done that, axially loaded column and we have axial uniaxial bending as well biaxial bending. But today we shall with that one problem, example problem. We shall start one example problem on axial loaded column.

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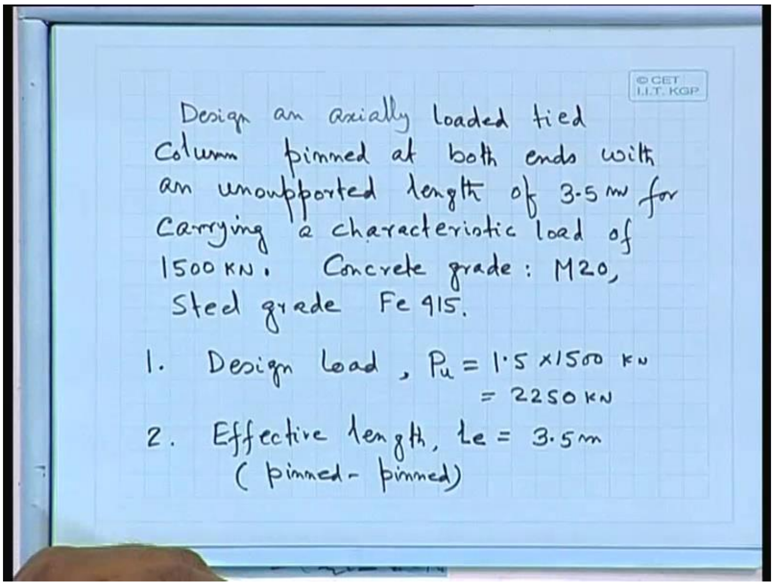

So, let us take one example design and axially loaded tied column, pinned at both ends. So, this will give the effective length with an unsupported length of 3.5 meter for carrying characteristics load of 1500 kilo newton and concrete grade M20, steel grade Fe 415, please note, the characteristics load of 500 Kilo Newton.

So, what about the design load? And this is axially loaded column, design load which is Pu, we shall take it as a 1 5 times. The characteristics load unless otherwise, specified. So, it will be different for different cases sismic load, wind load, like that but in way even if it is not specified anything. So, we shall assume 1.5 which comes as 2250 Kilo newton. What about the Effective length? Effective length, say le will be equal to same as the unsupported length. Because, it is pinned so, it is pinned condition. So, for this case it will have 3.5 metre what we have to do, we have to assume a section we can and how shall what is the guideline? That guideline is that, l by d less than 12. Because, we are considering it as a short column, since it is a short column so, l by d less than 12.

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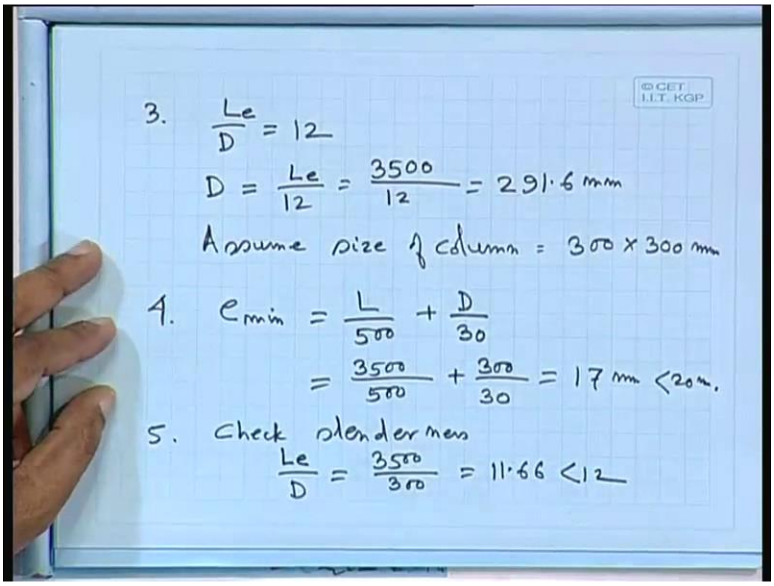

So, if l by d equal to 12 D will be equal to l by 12 equal to 3500 divided by 12 which comes as 291.6 millimetre. So, we can assume side of the column 291.6 why shall I got 325 or 350 for the time being let us, start that assume size of column 300 by 300 whatever the e mean as per the code eccentrically minimum l by 500 plus D by 30 which comes as 3500 divided by 500 plus 300 by 30 which comes as a 17 less than here 20 millimetre.

Let us, check the slenderness obviously; it will be less than 12. So, you can check it le by d equal to 3500 by 300 which comes as 11.66 less than 12. So, this is your short column was also less than 20 and we have so far we have assumed that 300 by 300. But we do not know, that whether 300 by 300 sufficient from the strength point of view. We are talking this is the preliminary design, that we are getting these dimensions 300 by 300 on the basis of that we would like to make it a short column.

So, for that we have taken 300 by 300, but so far we do not know whether that your 2250 kilo newton the design load which is applied here; whether, this section is sufficient that we do know. So, let us continue we can find out the design load compute area of steel.

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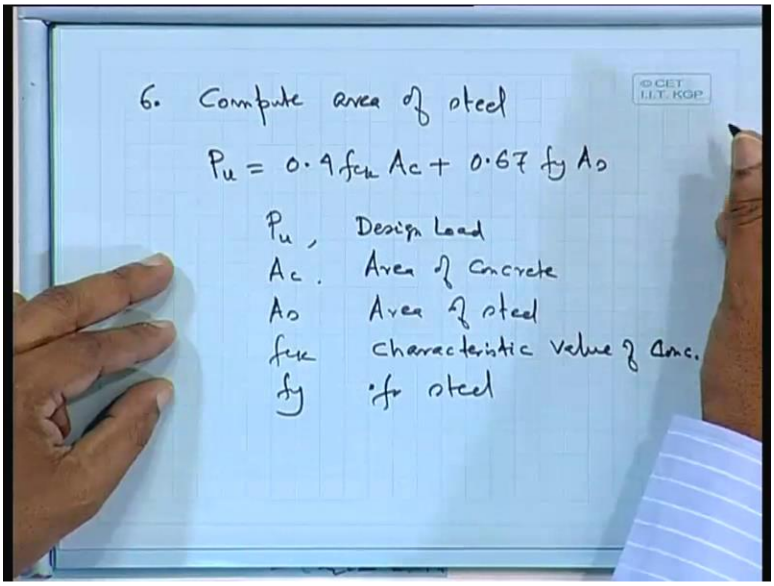

List of that, how shall we do compute area of steel. So, Pu as per the code Pu equal to 0.4 fck Ac plus 0.67 fy area of steel. Let us, write down Pu design load, Ac area of concrete, As area of steel, fck that I can say characteristics value of concrete, fy for steel. So, we can now find out what about the Ac? Ac equal to Ac we can find out.

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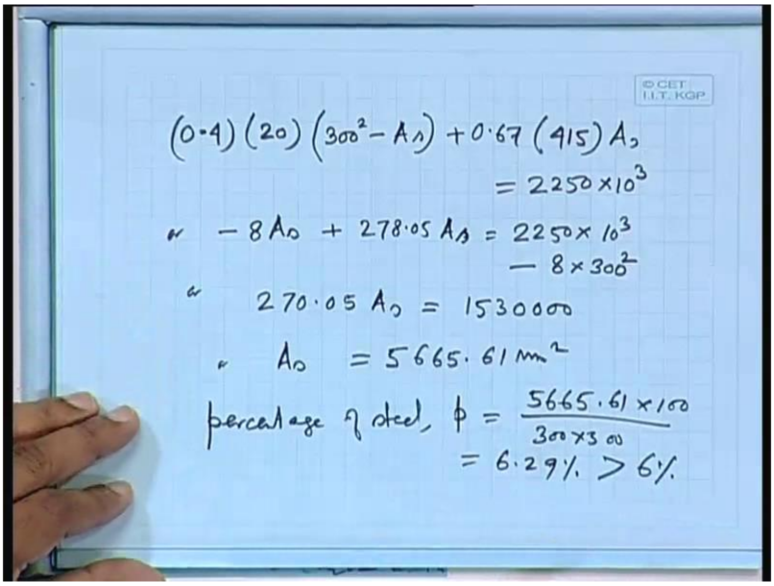

So, we can write down here the 0.4 fck is 20 then Ac will be equal to 300 square minus As. Because, we are taking only concrete part, 300 square minus is plus 0.67 times 415 times As should be equal to 2250 into 10 to the power 3 let us make it everything in newton. So, we can get this part minus 8 As 0.4 into 20 plus this part is coming as 278.05 as will be equal to 2250 into 10 to the power of 3 minus 8 into 300 square I am taking this side.

Or 270.05 As equals 15300 so, this is the thing or As area of steel equal to 5665.61 millimetre. Let us, say 5665 what about the percentage of steel p? That we have to check it equal to let us, ay 5665 only divided by 300 into 300 into 100 which comes as 6.29 percent greater than 6 percent. So, this section is not we cannot provide this section.

Because, the area of steel is coming greater than 6 percent so, we cannot provide this section. So that means, here that we have started with the start column with the criteria that it should be less than 12 even then, you have to come to that here that from the strength the load that, the load you have to bear the column has to bear. So, with that 300 by 300 that steel is coming more let us, say 6.29 percent 5665 what is the what difficult we can face? Even we provide that 1 say.

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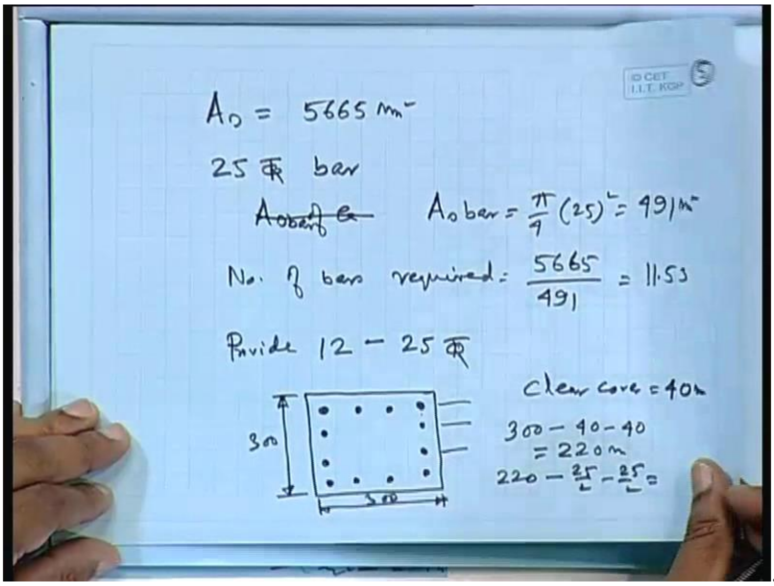

Let us, find out the area of steel As 5665 millimetre square let us consider 25 tau bar. So, area of steel of each bar or As bar I can say that is coming as which comes as 491 square millimetre. So, number of bars required 5665 by 491 which comes as 11.53. So, we have to provide 12 numbers 25 tau it means, this is a section this is 300 1 2 3 4 corner 5 6 7 8 9 10 11 12.

So, each side 2 more so what is spacing here we are getting. The space we will get it here, the cover the clear cover for columns it is 40 millimeter. The clear cover is 40 millimeter for columns so, from both sides 300 minus 40 minus 40 which comes as 220 millimeter. So, 220 minus 25 by 2 minus 25 by 2 it means, from both sides from the center I am talking.

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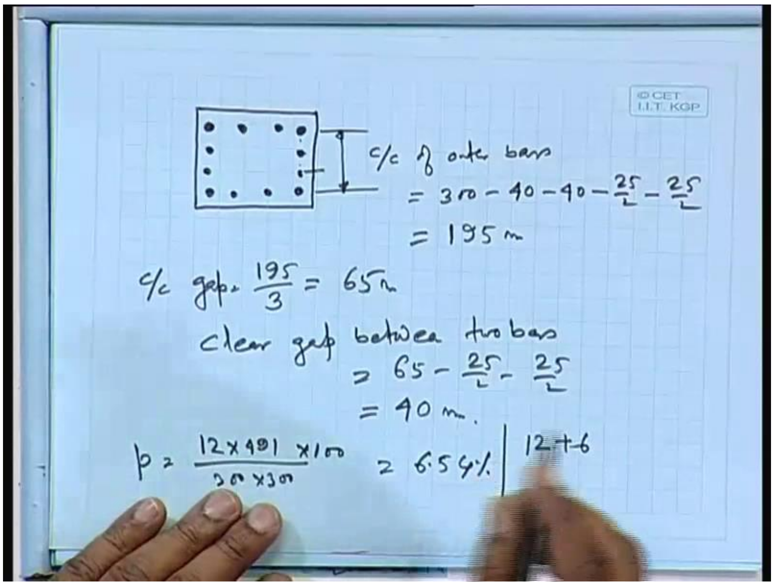

So, what we are getting it here? This is the Let us, see that how much gap we have. So, we will say 12 bars uniformly distributed after all it is an axially loaded column so, we can distribute uniformly. So, this distance centre to centre of outer bars equal to 300 minus 40 is the clear cover minus 40 the clear cover other side minus 25 by 2 minus 25 by 2 which comes as.

So, 80 plus 25 105 so 195 there are how many gaps 1 2 3 so, 3 gaps are there let us find out. So, 195 by 3 the center to center gap 195 by 3 which comes as 65 the center to center gap was between these 2 bars. So, clear gap between 2 bars will be equal to 65 minus 25 by 2 minus 25 by 2 which comes as 40 millimeter. Now, the question is here this is say 40 millimetre let us say, that you would aggregate maximum aggregate dimension that is also 20 millimeter core segregate. So, that means it should come.

Now, the question is coming whatever would the lapping? Because, we shall get the bar from the bottom to the top we shall not get that bar, that 1 single bar having that sufficient laid may be say 2 storied, 3 storied, or 5 storied we shall not get, that long bar.

So, we will get may be 5 meter or maybe say 10 meter or whatever it is. So, if I get that we have to give lapping of bars required.

So, it means even I say that 50 percent of the bar will be staggered. That all we shall such a way, that all the bars will not curtail in the same position that means, all are going up and then at this level and then, again you are putting on that I do not want that and that is not a good solution. So, it is not desirable then the section will be weak, it will be that your it you can say that crowded with so many bars.

So, even you say that 6 bars will be there even then, increasing that percentage still will be l you are getting 6 point certain percentage I m not talking with the code provisions. So, 6.29 percent so, it will be 9 percent then, because 50 percent of that also will be there that means, if there are 12 bars.

So, I mean to say 12 into 491 divided by 300 into 300 times 10s 100 this is the percentage of the steel provided in this case. So, it comes 12 into 491 divided by 300 divided 300 into 1. So, even then we are getting 6.54 percent so, why we are providing the lap that means, it should be 12 bars plus 6 bars in a particular section. Then, in the side by side if I take it.

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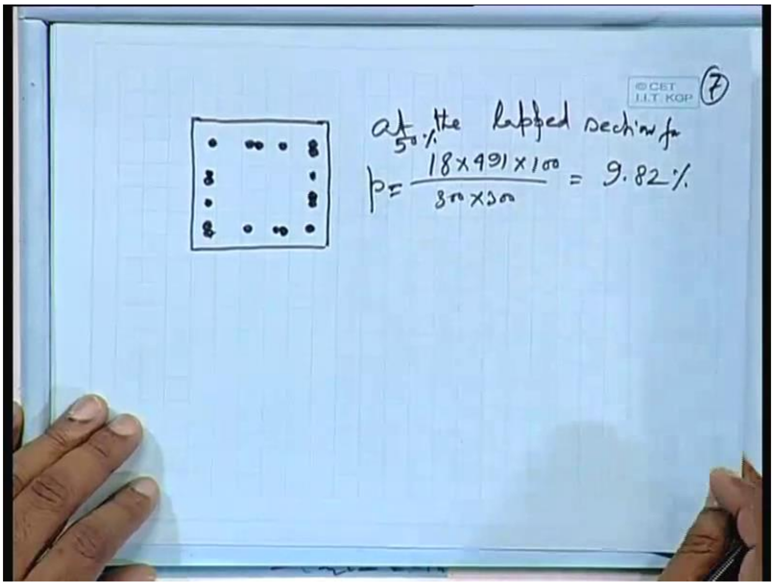

Because, it is very important otherwise, the cracks lot of other problem will arise, that is why that detailing reinforcement all those things are very important. So, what shall we do we can start if I take 50 percent at a particular section. Let us, say we are having this bar and this bar say.

So, I can provide 1 bar here and I can provide 1 bar similarly, I can have 1 bar here, I can have 1 bar here, like that it will go similarly, I can have say 1 bar here and 1 bar here. That means, in a particular section because, these bars are left you are giving the lapping these bars. So, that in particular section you are having 18 bars if you have 18 bars 18 into 491. So, the percentage of steel becomes at the lapped section where you are providing the lapping for 50 percent. Let us, be specific 50 of the bars we are getting here 9.82 percent.

So, it will very difficult to do the concreting and then, the if you if there is a in between the core segregate, if there is a achieve the concrete strength. So, that is why it is very important to use that is why the code says that, you should not use more than 6 percent. But if you uses 6 percent because, you have to provide the lapping so, that ways in that case I can say, it is better the designer we should always prefer you should not be more that 3 percent.

So, if it is 3 percent then, what happens even somebody uses the lapping all the lapping in 1 section even then, also we shall not go beyond 6 percent. So, that we do not though we write down specifically that only 50 percent of the lapping will be done at particular section. But even then, we shall not take a chance so, it is preferable that you percent of steel should within 3 percent that should be the or there are sometime we say, within 4 percent sometime we make it like that.

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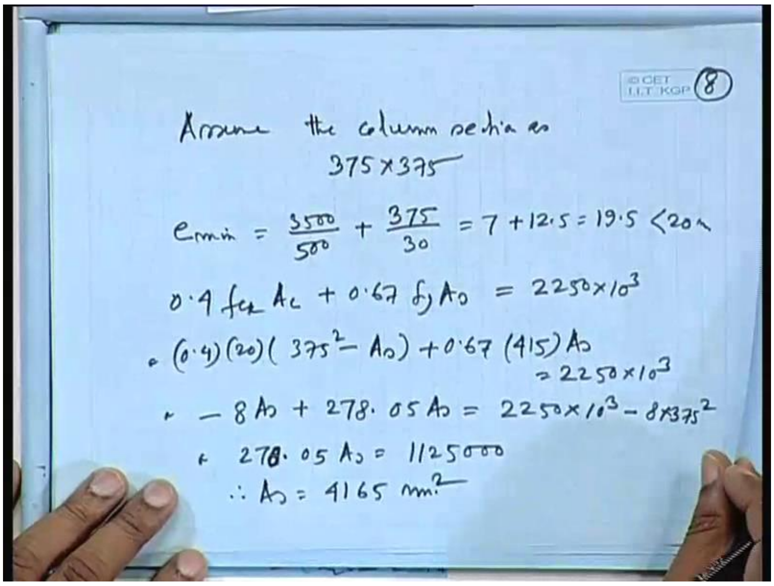

So, let us take the section then, assume the column section as 375 by 375 we shall take that column section as 375 by 375. So, what we can do it hear emin that l by 500 plus 375 by 30 which comes as 7 plus 12.5 equal to 19.5 less than 20 millimeter whatever, the area of steel we can take it as same formula 0.4 fck Ac plus 0.67 fy As equal to 2250 into 10 to the power of 3.

Or 0.4 times 20 times 375 square minus As plus 0.67 times 415 times As equal to 2550 into the 10 to the power of 3 or minus 8 As plus 278.05 As equal to 2250 into 10 to the power of 3 minus or 270.05 As equal to 1125000 therefore, As equal to 4165 square millimeter. So, you’re As area of steel got it as 4165 square millimeter if we have that section 375 by 375. What about the percentage of steel? We can find out the percentage of steel.

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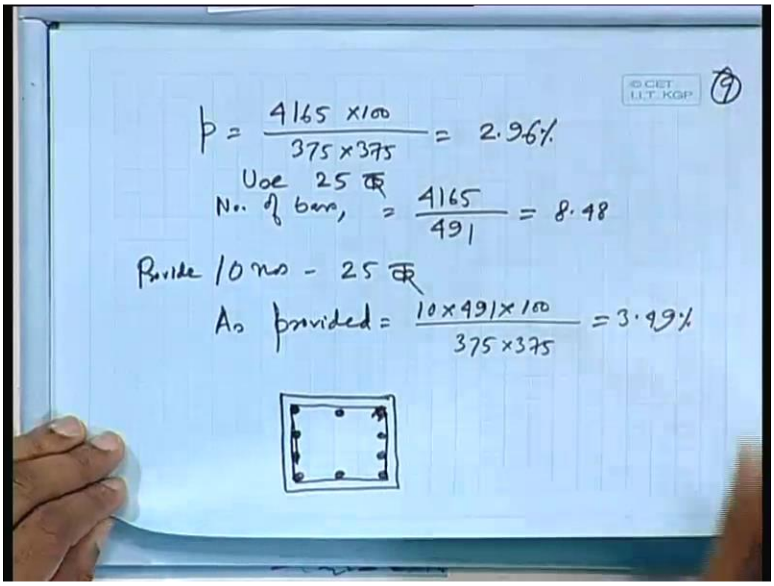

So, p equal to 4165 into 100 by 375 into 375 equal to 2.96 percent. So, you can get 2.96 percent we can get. Number of bars use 25 tor number of bars equal to 4165 by 491 that is the area of for that 25 millimetre bar which comes 8.48 what we can do, we can provide 10 numbers of 20.5 tor. So, area of steel provided equal to 10 into 491 into 100 by 375 into 375 which comes as 3.49 percent. Even then, though it says that it should less than 4 percent because, 4 percent means 4 plus half of that 2 so, 6 percent that 50 percent lapping.

So, in this case alright, but even then I prefer less than 3 percent, it is a designer choice. So, you will find out the reinforcement design or steel design you will find out it is something like that your say different school of thought different philosophy you cannot say this is wrong, you cannot say that is wrong only thing I can say that, it is an idea that it is the philosophy from where we have learnt. It is also sometimes, it happens in the institute itself so, with whom we have learnt that 1 teacher so, that way also it goes.

Similarly, in the industry also with whom you have worked so, that philosophy that actually, you follow that particular 1 that is the idea. So, I prefer less than 3 percent so, that is the idea I usually do it. So, now we can say 10 numbers of 25 tor. So, what about the that say cross section? Cross section the I shall provide here always 4 corners, we can provide here 6 then, we can provide 2.

So, we are having though it is not symmetric, but anyway 10 numbers of bars. Now, we are to provide the tie bars so, if we have to provide the tie bars.

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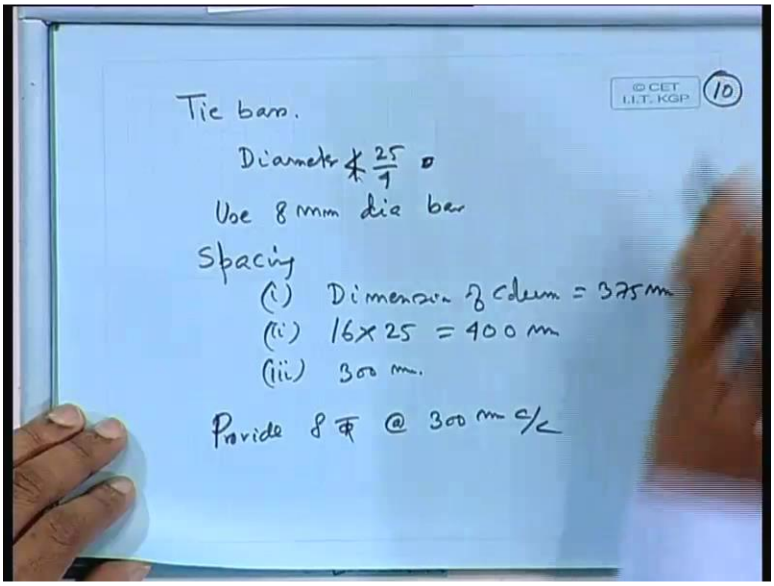

The diameter 25 by 4 so, we can provide use 8 mm dia bar what about the spacing? This will not be less than spacing number 1: the dimension of column say 375 millimeter in this case. Number 2: 16 times the longitudinal bar 400 millimeter. Number 3: our code says 300 millimeter. So, we can provide 8 tor at the rate of say 300 millimeter centre to centre. So, this is the 1 we can provide for tie bars.

So, this is your that column design for fca loaded column. But here this is not the end of the column design because, it is not so simple that we can have eccentricity or we can have that moment developed. So, there are 2 possible cases so, we would like to do.

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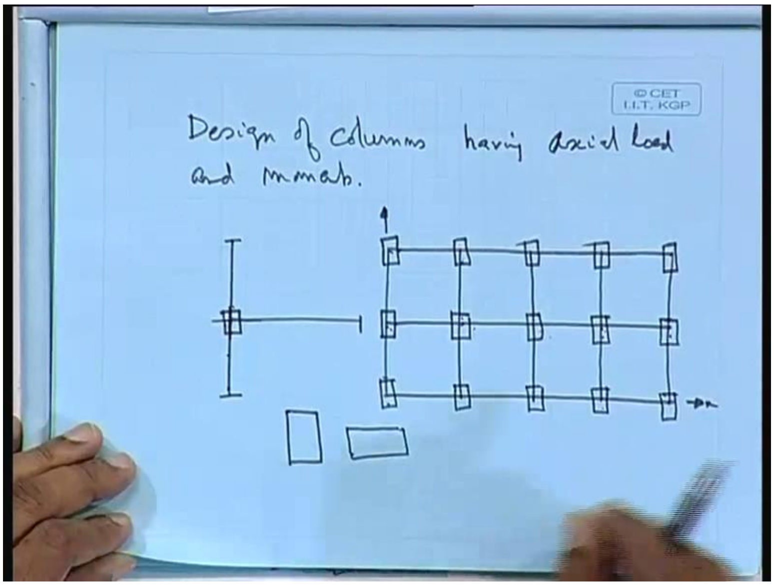

Design of columns having axial load and moment; the moment would be uniaxial or biaxial. If this is your beam say and here is an column if the span is equal loading is equal I can say this side there is no moment, about this side there is no moment. Whereas, about this axis there is a moment of in addition, to that axial load the moment is also here. In this context, I think I can tell you that if there is a plane here the plan I am drawing the plan here.

Then, if the columns are rectangular, this is your column what is the orientation of the column then, with respect to these the orientation of that 1. Because, if we take the whole building say rectangular building type say flanged rectangular. So in that case obviously, we can say it is easier to bend let us say this is a building it is rectangular 1 that cross section plan there are so many rooms.

So obviously, I can say it is easier to bend along this about bend this way, but where as I cannot bend this way I do but it is difficult. If we say wind load or earthquake load due to ground motion it moves like that. So obviously, it will vibrate you can see that it is vibrating like this rather, it is vibrating like this. So, if note this 1 if you observe this so, if rectangular comes if the column is square there is no problem.

Then, if the column is your say circular than here is no problem, there is no orientation problem. But if the column is rectangular the question is whether, shall we provide the column this way or shall we provide the column this way obviously, we shall provide the column this way. Because, the moment of second moment very less to resist that 1 we shall provide the column in this direction, not the other way because, the bending not only the axial load, but bending also there.

So, sometimes it happens that we can find out there are few cases for example: here this corner columns that ends here. That means, here the moment would be about both sides, both axis this column. The moment will be about 1 axis whether, this column moment about the axis whereas, this middle columns you say almost axially loaded you may have due to say your changes span or loading may happen that, there is a the moment.

But in most of the cases, you can find out that these columns are auxiliary loaded whereas, these columns are auxiliary loaded as well as, bending about both axis. This bending about 1 axis whereas, these and these bending about to say the axis so that means, we have 2 more cases: 1 is called uniaxial bending and the other is called biaxial bending. Now, if we consider here that uniaxial bending and we have biaxial bending.

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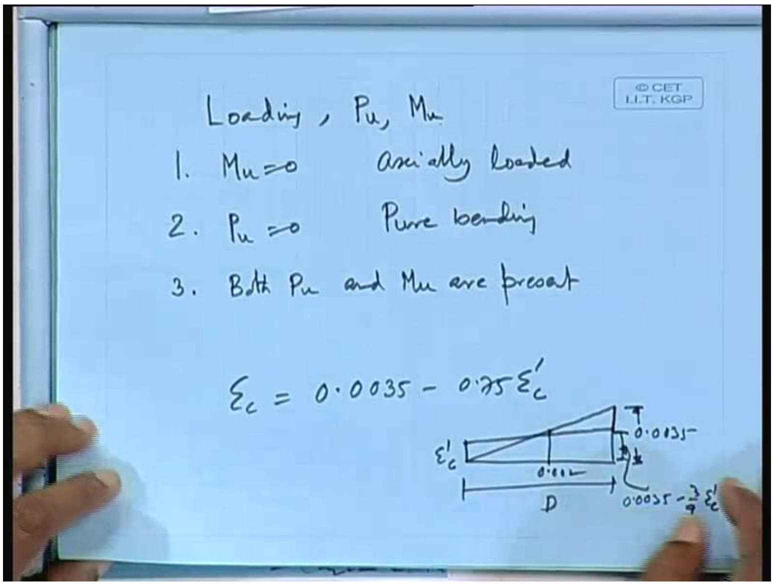

So, how many cases we have that loading depending upon the loading, number 1: what are the loading Pu and Mu say, Mu is the moment ultimate moment, Pu is the design axial load. So, if we have to design this for this, we have to provide the section. 1 case: we can have Mu equal to 0 that means, axially loaded. Number 2: it can happen that Pu equal to 0 that means, it is nothing but purring bending that means it is nothing, but purring bending that bending is your beam problem you can say that it is nothing, but doubly reinforce section.

The number 3: both Pu and Mu are present our code says if it is axially loaded, the strain is 0.002. If it say bending in that case what we shall say, that our code says that in the maximum stressed compression side. They are the strain will be equal to epsilon c will be equal to point 0.0035 minus 0.75 times epsilon dash c I mean to say, if this is the section then, we can find out this 0.0035 this is D somewhere here we have the pivot that is 0.002.

So, I can say the these this 0.0035 is a total 0.0035 minus this is epsilon dash c minus three-fourth of epsilon dash c will given me this 1. So, this value will be 0.0035 minus three-fourth of epsilon dash c or nothing, but 0.75 dash c. This garbage required to find out the strain as well as to find out the stress. So, we can find out the strain and then, we can find out stress what we do here. Because, it is very we say for example, Pu and Mu is given, now what should be percentage of steel that we do not know.

So, what value of Pu and what value of Mu; that means, if Pu moved that is not mean that Pu and Mu there is no linear relationship. That means, you should certain kind of trial and error and we have to find out at what percentage of steel both Pu and Mu satisfied. For what percentage of steel and section say if I take, certain section 300 by 300.

So, for that section if we start then, we have to find out and then let us take say 1 percent percentage of steel. For that, we can find out we can use this formula we can find out the strain and all those things. And then, we can get the Pu and Mu and then, we can say it is perfectly alright that is the thing we generally do it.

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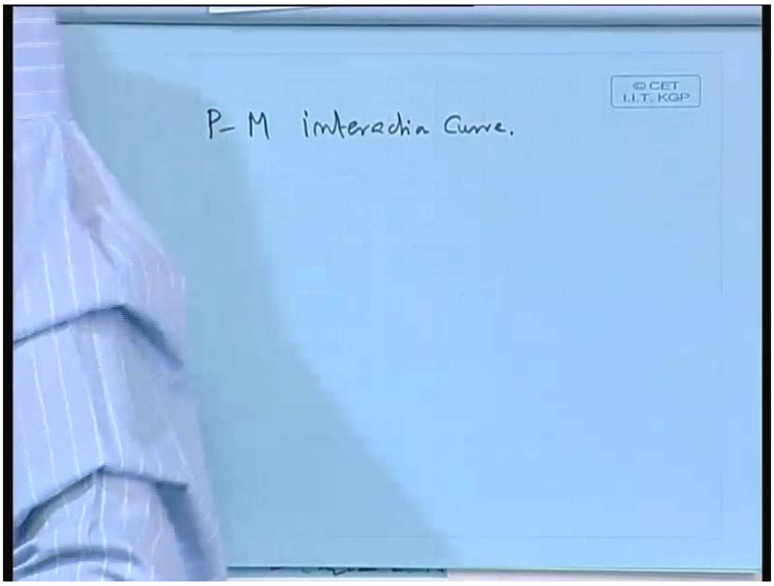

But here what we generally do, that is called interaction curve P verses M interaction curve. So, that 1 you can get it I shall show you anyway, just to tell you.

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Actually, I have already referred this 1 that design aids for reinforced to concrete IS:456-1978 of course, this is SP 16 the special publication SP 16.

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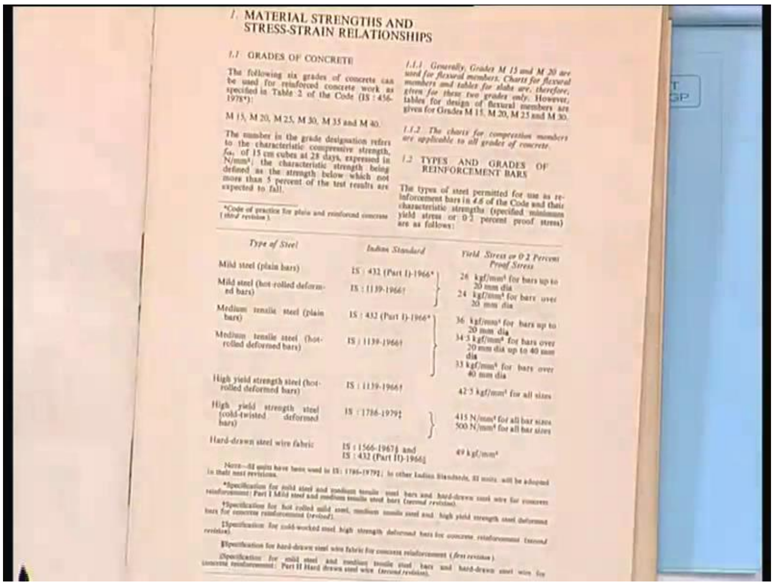

Where you, find out lots of charts and tables all those things you can find out even nowadays.

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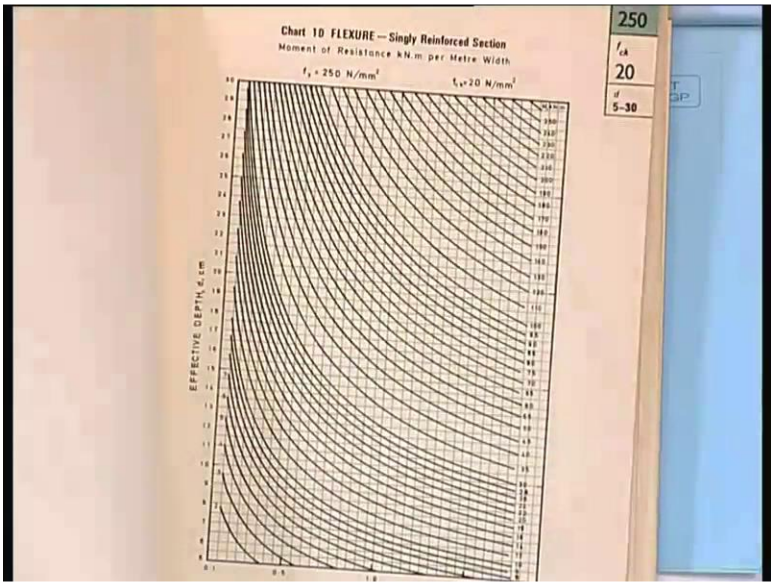

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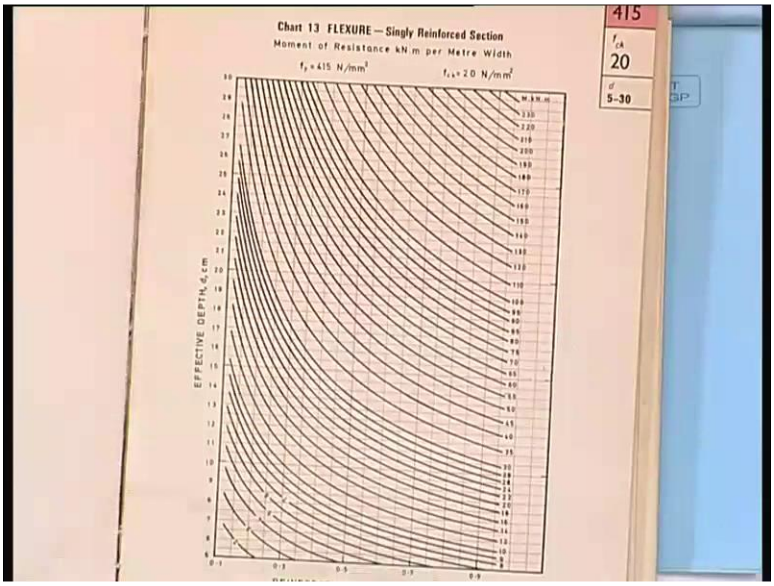

one can write a simple small program and can generate all those things. For each table all those things 1 can generate that 1 you say. 1 small program it is not very big 1. So, what we shall do it here what I like to show I shall come in detail.

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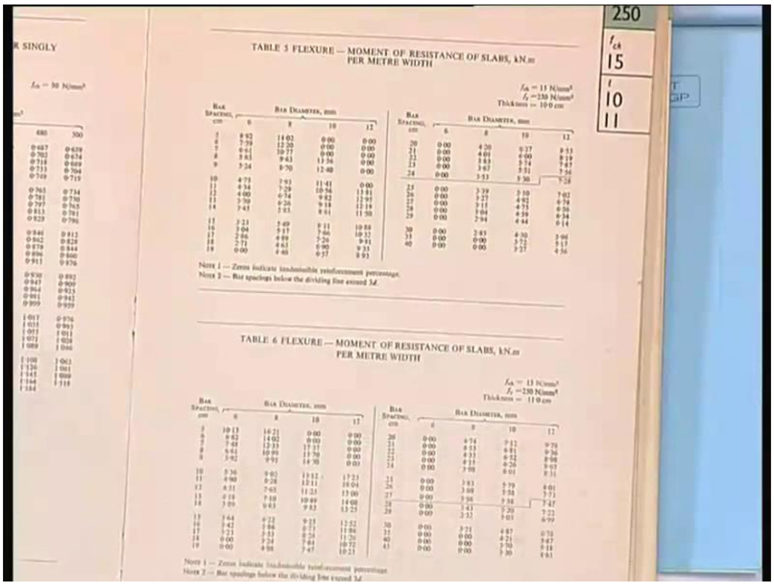

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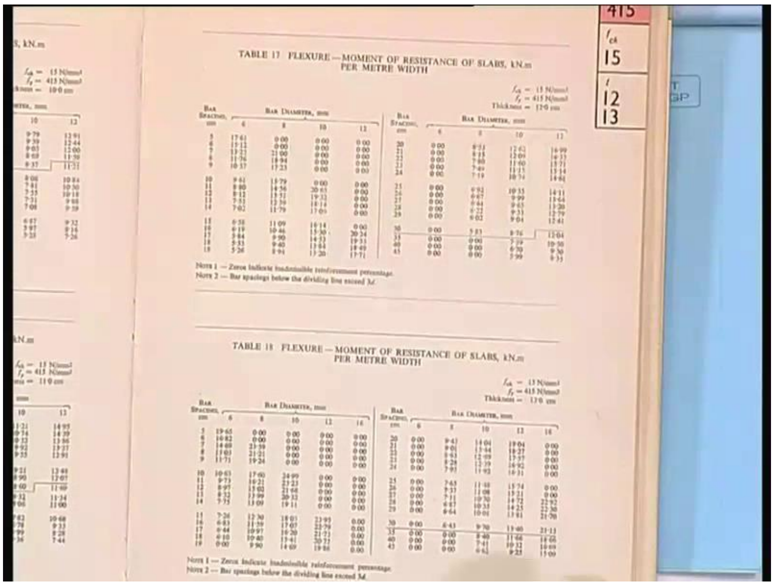

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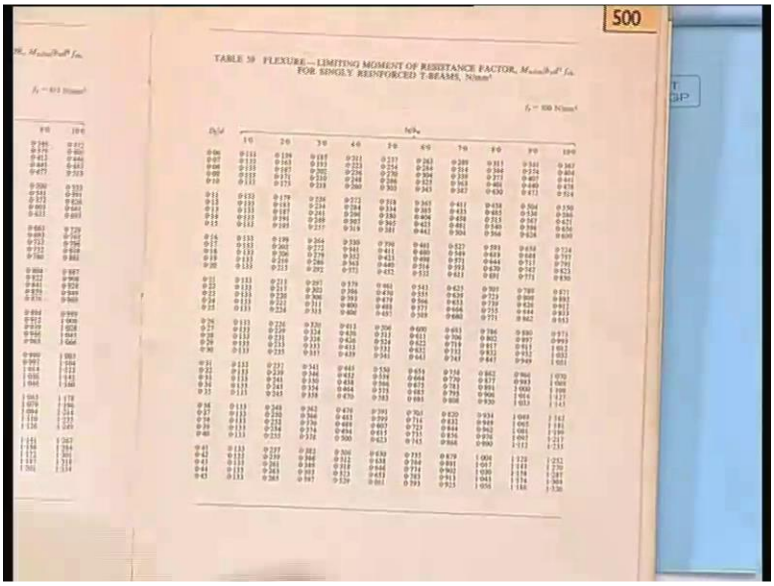

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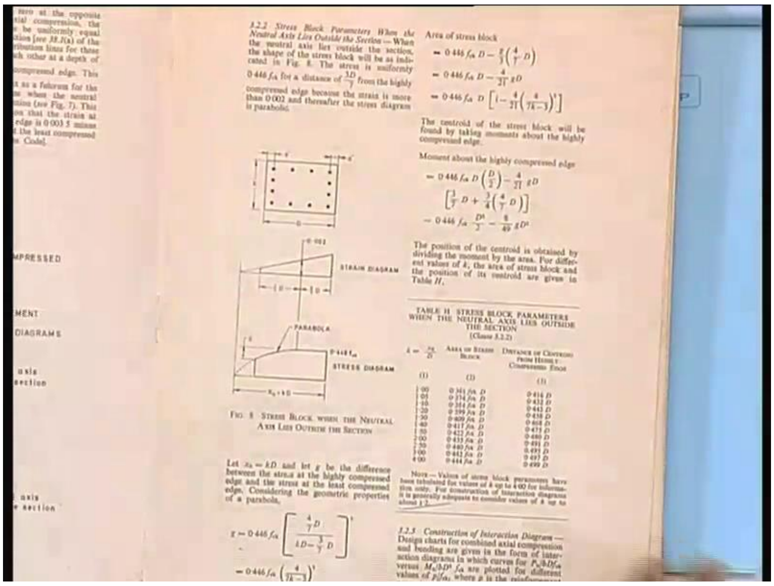

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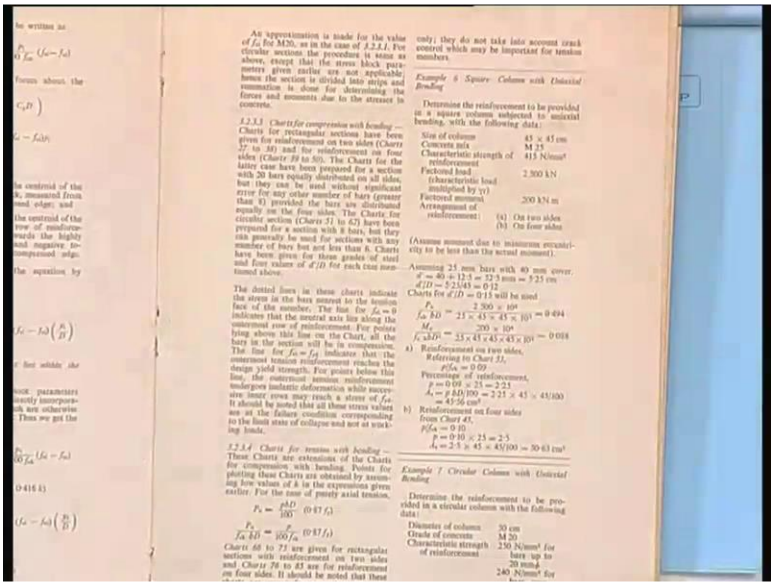

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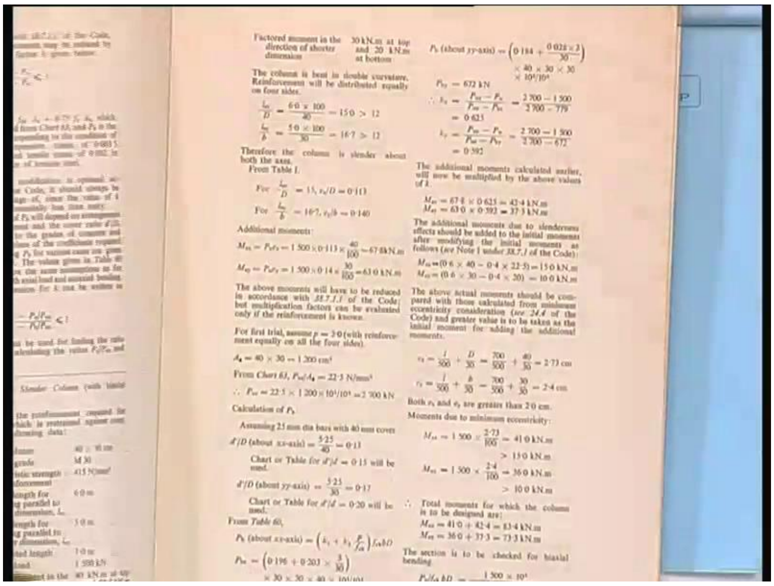

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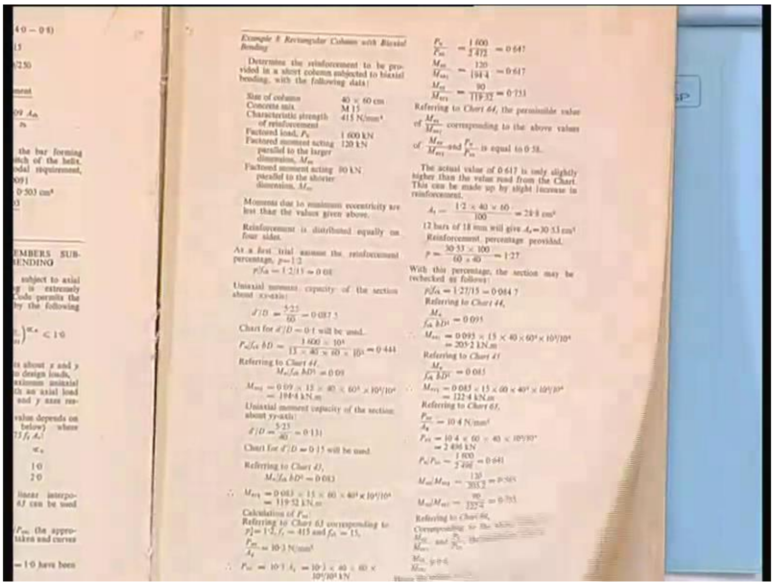

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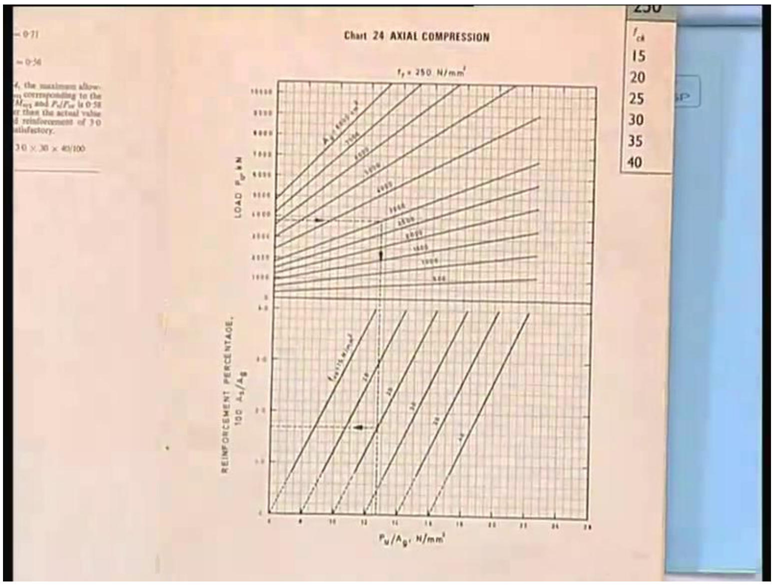

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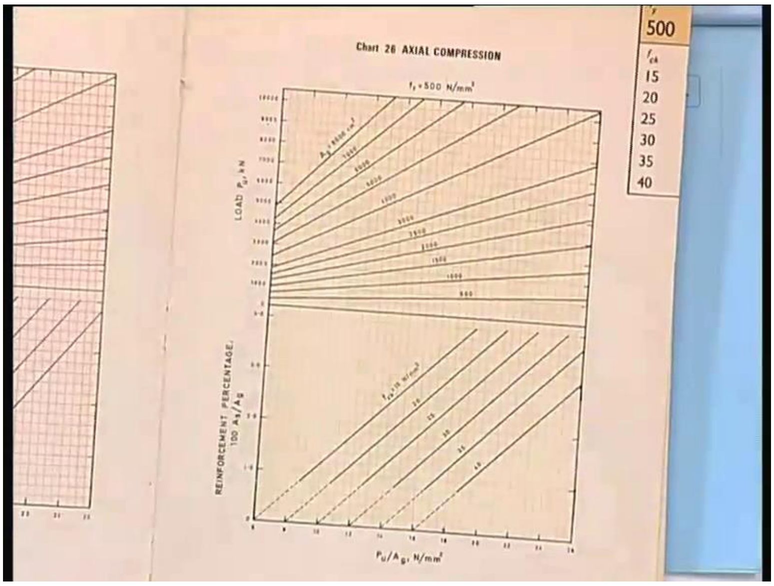

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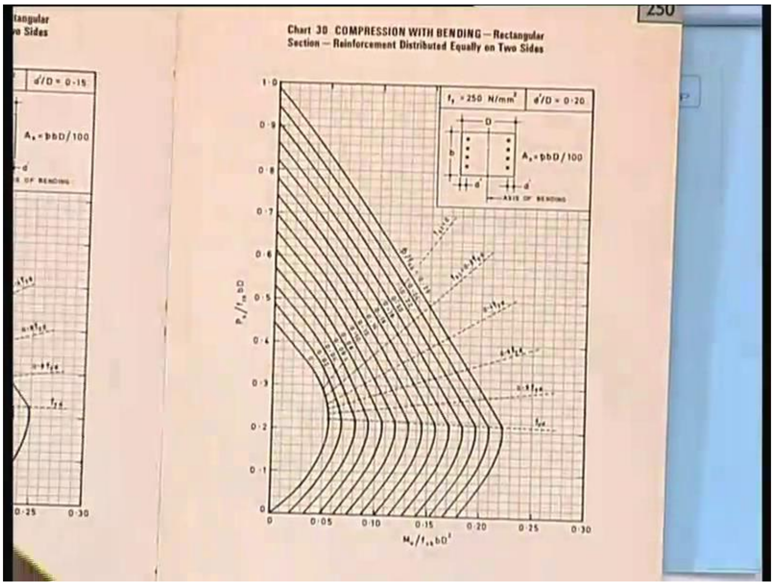

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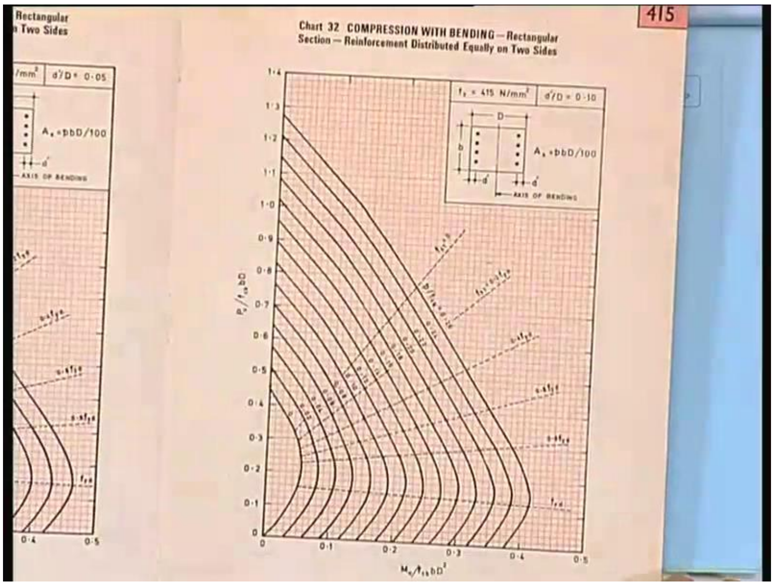

Let us, take I think we can show you these 1 anyone of them . So, we have like this chart what we can do let me, see whether available here 1 second.

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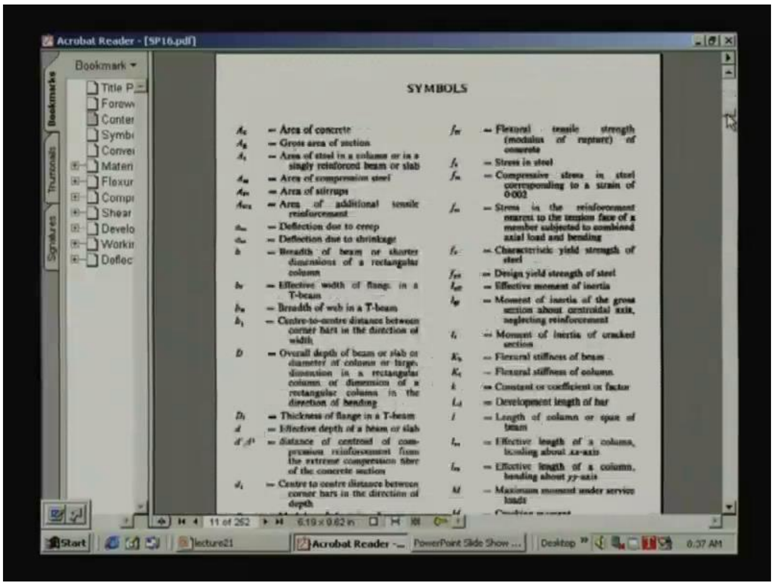

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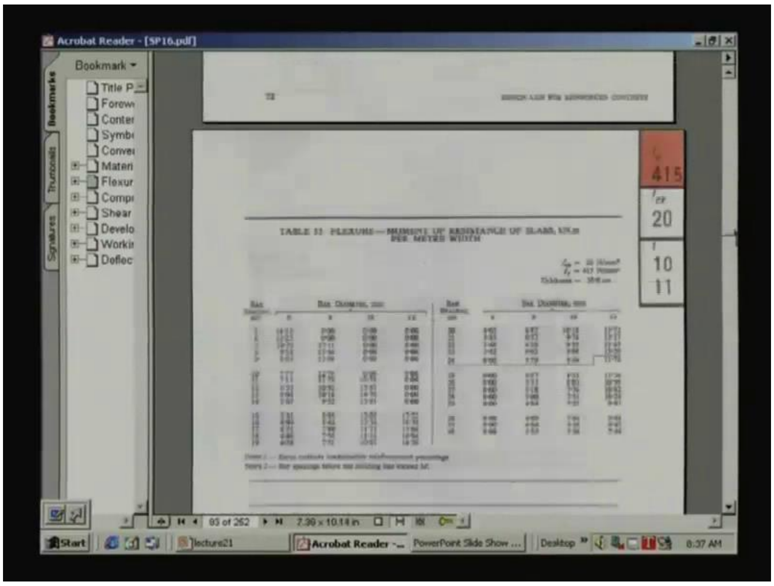

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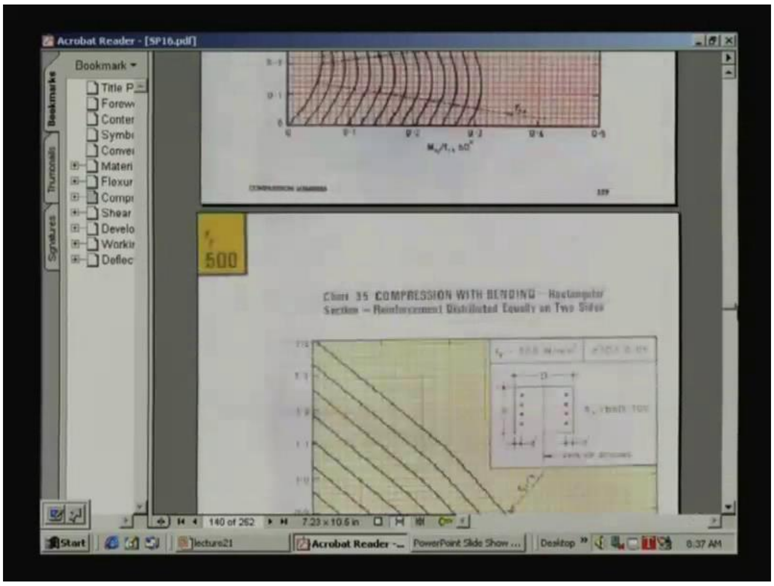

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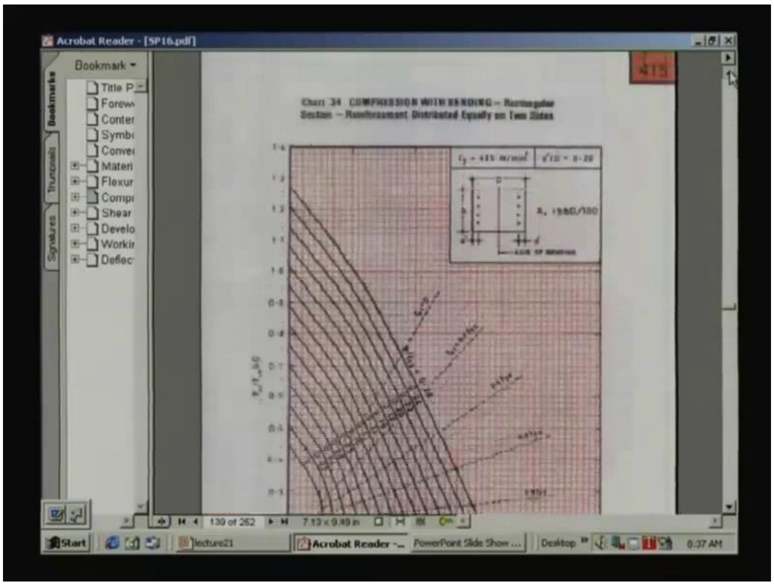

I can do it I think it may be better right.

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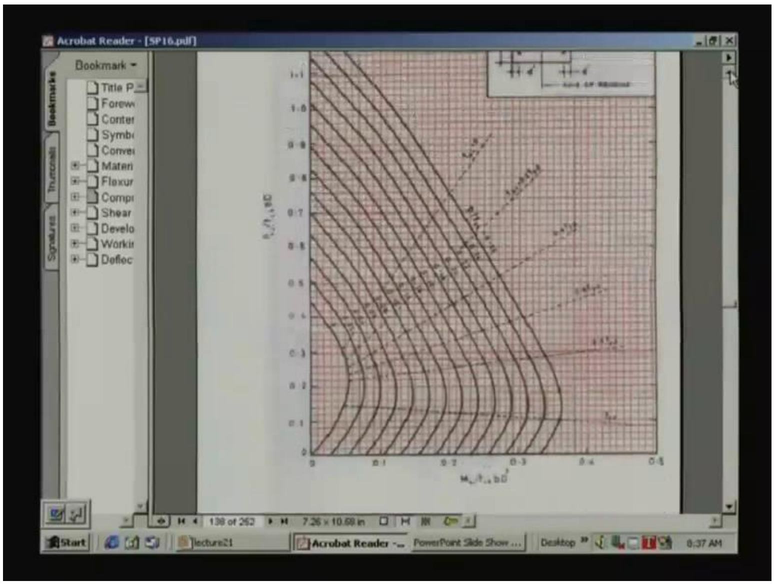

So, the same thing it will be now, available in our library also online.

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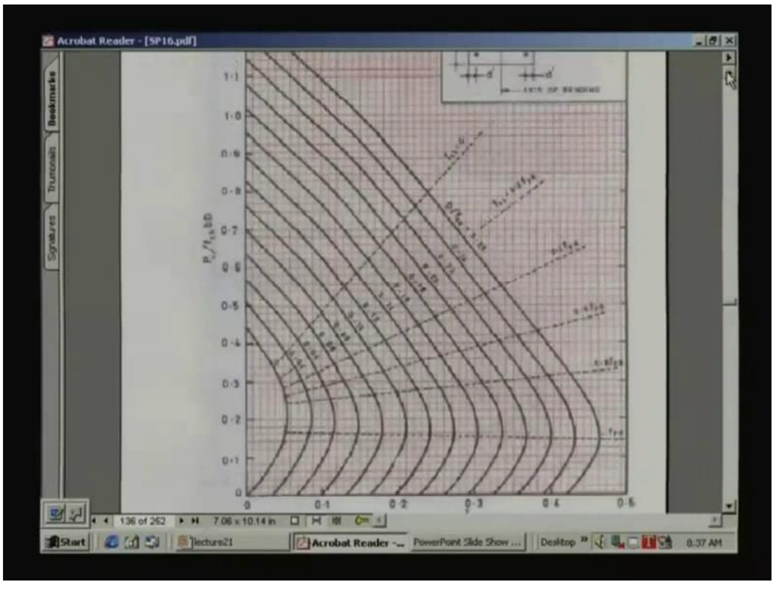

So, you can see the same thing now, available here this is for this is called interaction curve.

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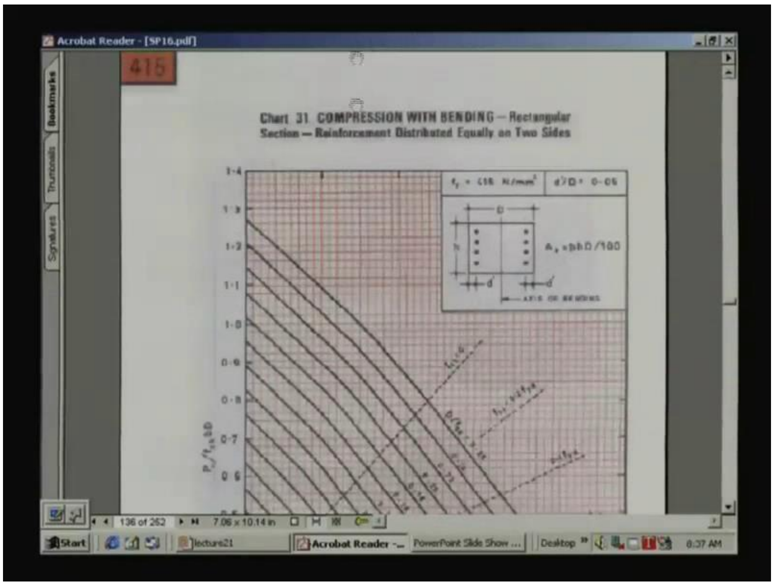

What we do, this is say there is 1 chart just to tell you in the later class. So, here what happen here this particular 1 this is for fy say 415 what will we do it, we make it here.

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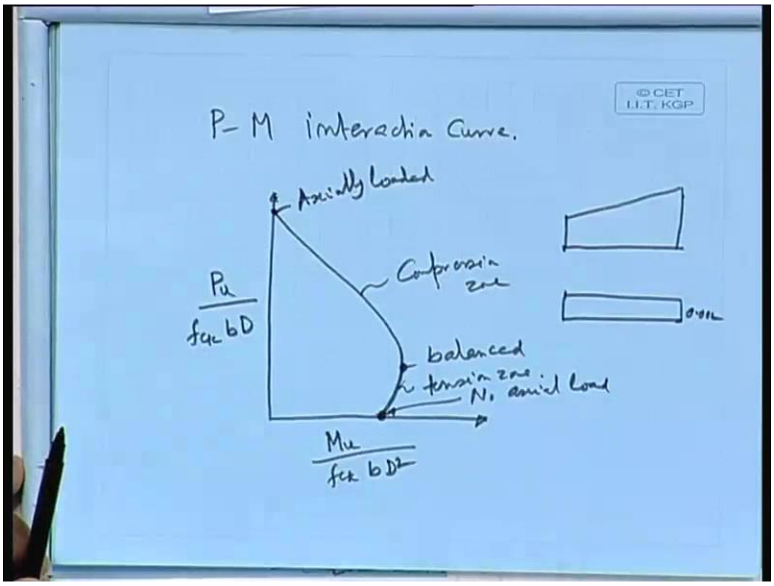

Here, write down by pu by fck bD Pu is th design load axial load fck bD and Mu by fck bD square this for a certain percentage of the steel. I can get different curve for different percentage of steel. What about this point? B ecause, there are few salient points this point axially loaded, that is certain point here that is balanced, this point no axial load, this side is compression zone and this portion is tension zone.

So, depending on the neutral axis position we can find out there is 1 case say you are axially loaded that means, it is uniformly distributed that 0.002 the strain is 0.002. Then, we have 1 case where there is no axial load that means, it is simple beam problem and neutral axis is the within the section somewhere, we are having the balanced section then, we are having say tension zone.

Finally, the neutral axis is going out the section and where you are getting purely compression zone. That means, that even the distribution of say that 1 here it may be something like this, the strain this it can go like this something like this. So, what we can do we are starting somewhere here like this 0.002 is the strain. Then, somewhere you are getting 0.0035 minus three-fourth of this side so, like that it will go.

So, this is your interaction curve this SP 16 provide you this so many curves. So, what we have to do depending on these charts depending on the d dash by d means that clear that effective cover.

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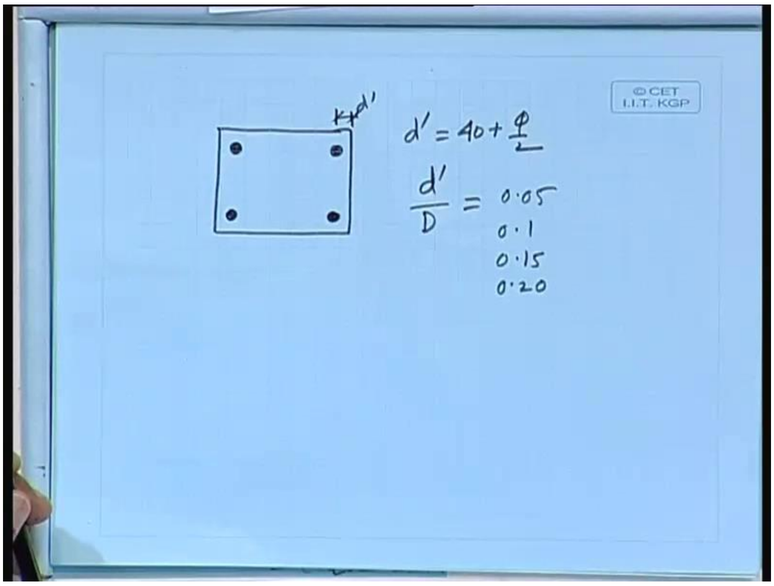

So, what we do here so, it says what is does d dash means equal to 40 millimetre plus pie by 2 diameter of the bar pie by 2. So, d dash by d depending on different d dash by d, we can get different strain that why we are having different d dash by d it starts with 0.05, 0.1, 0.15, 0.2.

So, we can have different charts see chart 31 for Fe 415 d dash by d like that. Then, we can have the other 1 d dash by d 0.1 this is for 0.15 and this is for 0.2 what we can do? Let me, show you what we shall do.

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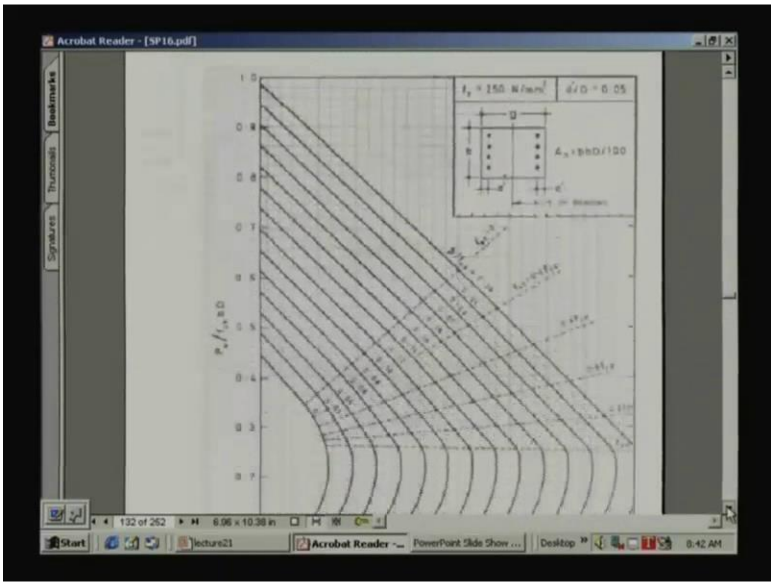

So, let us take a particular chart it depends on that is for mile steel this for fy means mile steel. Since, we are using say Fe 415 so, we have to use a Fe 415 what we shall do it here I think I can yes, what we do it here, 1 sec this is the case I can show you 1 example then, it will clear what we are going to do, what we shall do.

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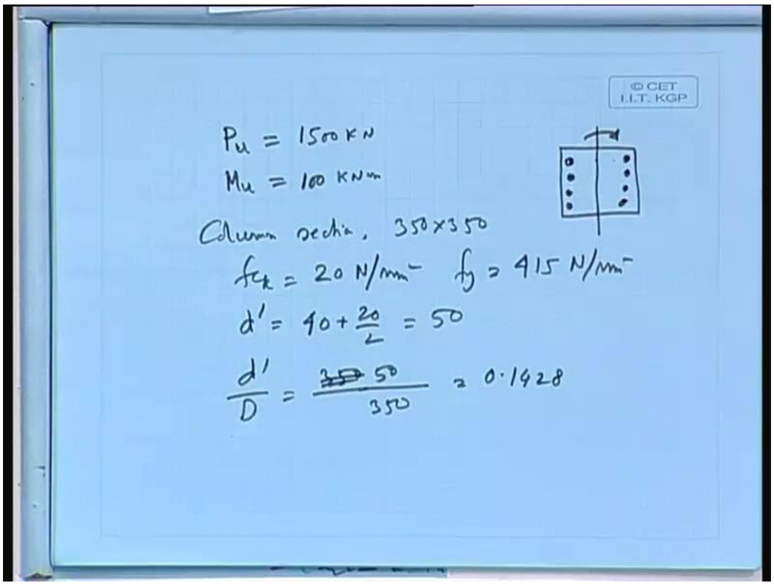

Let us, take Pu say 1500 Kilonewton and Mu say 100 Kilonewton Meter we are getting this value. And let us, assume a section from a section say 350 by 350 fck 20 newton square millimetre fy 415 newton per square millimetre d dash let us, take d dash here 40 plus 20 by 2 20 millimetre slab so 50 . So, we are getting this 1 say 50 so, what about d dash by d? d dash by d will be 3, 50 by 350.

So, we can get 0.1428 d dash by d 0.1428 what we can do though it is not correct we can interpolate of course, but we can take the table per chart this chart. Because, this is it says d dash y d equal to 0.15 what we should do we can take d dash by d for 0.1 and also we can take d dash by d for 0.15.

So, here we are getting 0.1428 which is coming closer to 0.15. So, we can let us assume that we shall take this 1, but actually we should interpolate this 2 charts, what shall we do this here. So, d dash by d 0.15 this is the section it is unixial about these line these axis the moment applied since, the moment is applied about this axis that so, that’s why I am providing the reinforcement about this.

The thing that here, this is your section moment is applied about these axis. So, we have to provide the reinforcement along this then only we will get the maximum benefits. Because, it should be as far as possible it will be far away from the neutral axis. So, instead of providing here we provide like this for uniaxial bending we are talking uniaxial bending. That means, the bars can be provided along this 2 lines is it clear?

Then, we are having say moment Pu and Mu when you are having Pu and Mu, if we do not want to provide the reinforcement uniformly distributed in all 4 sides, instead of that I would like to get the maximum benefit here what I am interested here. We can provide the reinforcement along these 2 axis only 2 sides only. Because, this 1 whatever moment will be produced due to these wherever, you provide this reinforcement it does not matter if it is axially loaded, but when you are talking say moment.

So, these bars if you provide say far any from this 1 then, it will take the maximum moment. And that is why we are providing that in 2 sides only, we are providing only reinforcement. But it is biaxial bending then, there we have to provide in all 4 sides. So, what we can do if you have d dash by d equal to 0.1428 I can take this section and I can take the I think what I can do just to going to computation.

So, what I shall do here say this is if the reinforcement think it is not over anyway, what I can show you if the this is your Mu by fck bD square what I shall do, I shall take along this line this is 1 axis which I shall get it Mu by fck by bD square I shall get along this. And Pu by fck by bD I shall get along this.

So, shall get a point so, I shall get 1 line and from there what are these are for different value of p by fck this is for different value of p by fck and then, we can find out the w can calculate the percent of steel. So, I think I shall do it in the next class I shall do it that will example the specific example, how we can do it that 1 and if it possible if the time permits.

Then, I shall show how to make in the computer because, that 1 it is very simple 1 it is not a very difficult problem 1 can do it. Because, all the charts everything 1 can simply make it on his own all those things you can make it let us, finish it today.

Thank you