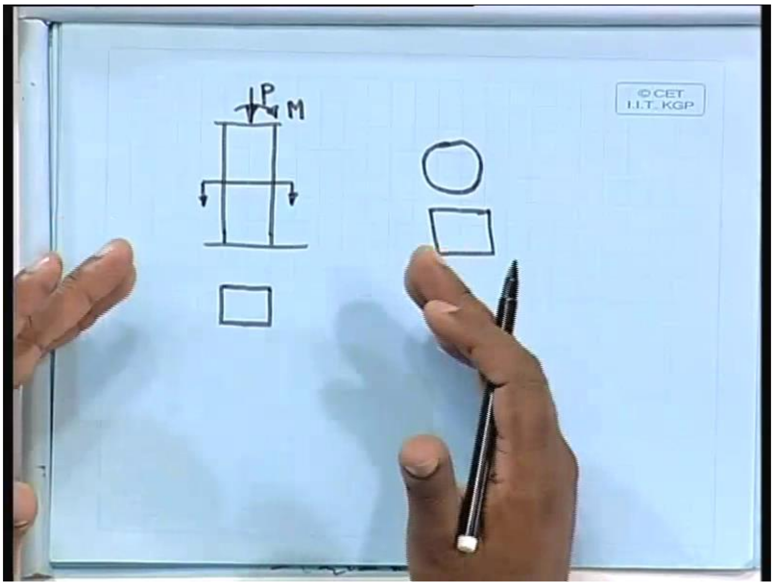
Design of Reinforced Concrete Structures
Prof. N. Dhang
Department of Civil Engineering
Indian Institute of Technology Kharagpur

Lecture –22
Design of columns
Part IV

Well. So, we shall still continue with the design of columns. So, far we have done that, axially loaded columns and last class we have started uniaxial bending.

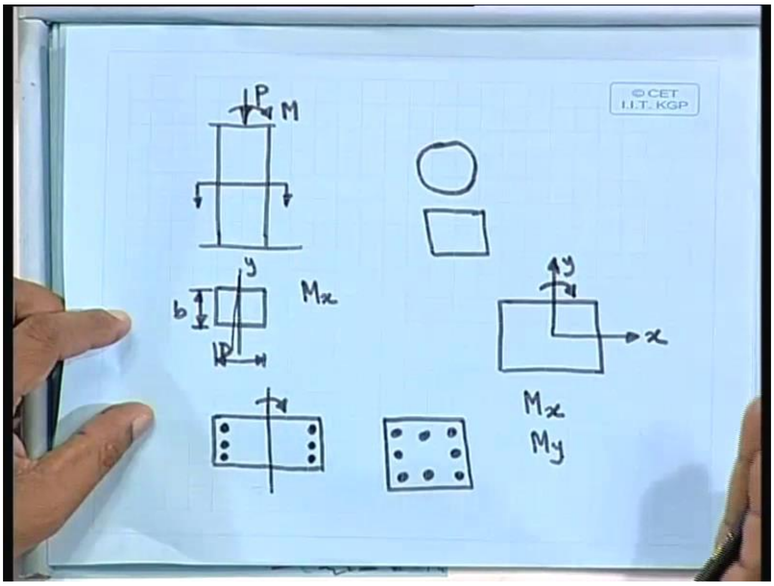
(Refer Slide time: 01:22).



Now, let us see that how that, if there is a moment acting on the columns in addition to besides axial load then, what happens. So, if this is a column load P and moment M. What we can do, if you take a section, we shall get a cross section of the column, not necessarily we shall make this column say square, we can make it rectangular also. If, we have say axially loaded, then we can take it say even we can take it say circular if it is required, square it does not matter, rectangular also. When we are having say bending, so what we can do, we can provide that side, that about the axis there are 2 conventions follow: 1 is that whenever we specify moment, we say that about the axis or we say that along the axis that is that say designation m x.

Whenever we talk say m x, moment about x or say moment, though we are specifying; that means, moment about y, but we are specifying that about x. So, that way also we specify. So, depending on the situation, say you are talking some moment this way.

(Refer Slide time: 02:56)



If this is you would say x axis I can say like this because, this conventions should be followed and it should be mentioned. So, if you take say this is your section; obviously, you can say this is your x axis and this is your y axis. Now, you you'll find out that is; people use to say M x people use to say m y. When you are talking say M x so; obviously, the question comes arises, whether that M x is about y; that means, about y me, I mean to say about this particular axis? But if is acting about y so; that means, as if it is along x. So, other could be that about M x means about x, but it is acting that other direction.

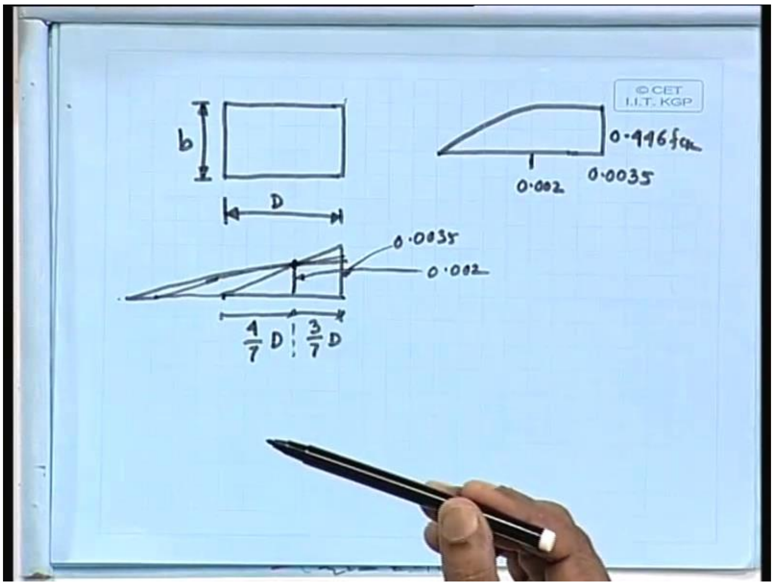
So, this is the convention that we it has to be clear. So, let us say here, whenever we are talking say this M x M y all those things. So, what we can do if we talk, this is your y axis. So, what we can do in this particular case, we can say M x we can say, as if it is along x. So, M x whenever we are talking then, it is say along x. Now, if that be the case what we can do, this is your dimension b and this is your dimension d or objective here or objective here to resistance moment M x or m whatever way and p also that axial load.

So, what we can do we can increase the depth. So, it may be preferable to use rectangular shape; rather than square because, we have to resist this moment, this moment we have to resist, so; obviously, that this depth should be more. And also what we can do, shall we provide the reinforcement along these only? Because then, we are getting the maximum from the because so far, wherever you specify, you put your that reinforcement. So, far axial load concerned there is no problem, but so far the bending moment concerned, what we have to do; obviously, since this moment acting about this axis. So, what we can do, we can provide the reinforcement here; that means, either at this end and the other end that we can specify. Alternatively what we can do if it is required what we can, do we can specify the reinforcement all along.

So; obviously, we are not taking the full benefit of this say reinforcement, only it will take the axial load. But if, but for biaxial bending; obviously, we have to specify the reinforcement all along, that all and all the sides you have to specify. So, this is the general case, whenever we are considering that 1 how we shall specify that. Now, whatever code says, how shall we start design? So, far we know that to how to design that axial load loaded column, but how to design that 1 say your uniaxial bending let us say?

So, uniaxial bending means: axial load plus moment about 1 axis or moment about say major axis I can say. So, moment about major axis and axial load, if that be the case then how shall we design? In that case what we do, if you come back to the strain diagram.

(Refer Slide Time: 06:38)



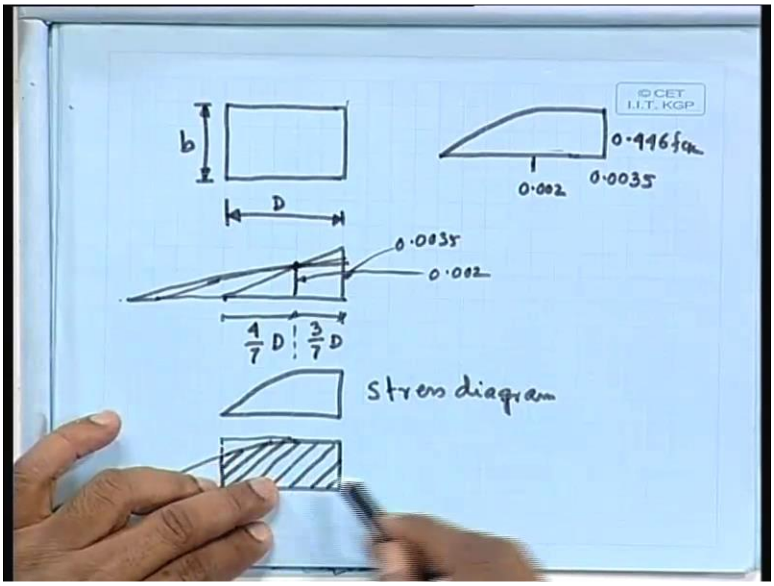
So, this is your b D, I have told that, somewhere if we draw the diagram. So, we have somewhere 0.002 and 0.0035. I repeat once more; this is very important. So, this is your stress and this is 0.446 alpha after the material and all other say you say percent defector, we can get 0.446 f c k. Here what we shall do it, here somewhere we shall get here. So, we shall get 4 by 7 D and 3 by 7 D and we have at this point, we have 0.002 the strain. What happens here; this is your pivot 0.002 and from the highly compressed area because, we are talking this 1 say this is the highly compressed zone this side that compressed highly compressed side are here.

So, what we shall do, we shall start it may happens here something like this. If, this is 0.002 then, this 1 0.0035, note this is point because, this is as per that satisfied and this 1 0.002 0.0035. Our objective here, this case what we shall do? We shall find out 1 case, that it will be pivoted with respect to this point, this line as if I am considering. So, this is your neutral point right now, this 1 will be with respect to this point. So, what we can do, somewhere I shall get like this.

So, neutral axis is going outside the section, this 1 neutral axis is going outside the section. What I am trying to say, the bending moment, we have the bending moment and we have the axially loaded axial load and bending moment. I know this is the critical point here at 0.002 this point. What I am trying to say here, as if with respect to this point this line is being rotated. In other case this is your neutral axis right now. So, if it rotates it will never go beyond 0.0035. So; that means, what will happen, it will try to rotate about this point, at some other point it may happen say like this, what is happening then? It means that, if I start like this, this is your point say line, then what I am doing as if I am rotating like this.

So, your neutral axis is going beyond the section and finally, it can go to infinity I can say; that means, in that case it will be 0.002. The strain will be 0.002; that means, when the neutral axis at infinite distance, then I can say that your strain is 0.002 and at is throughout the section, that is what I mean to say. So, here what does it mean here; that means: it will happen like this.

(Refer Slide Time: 11:20).

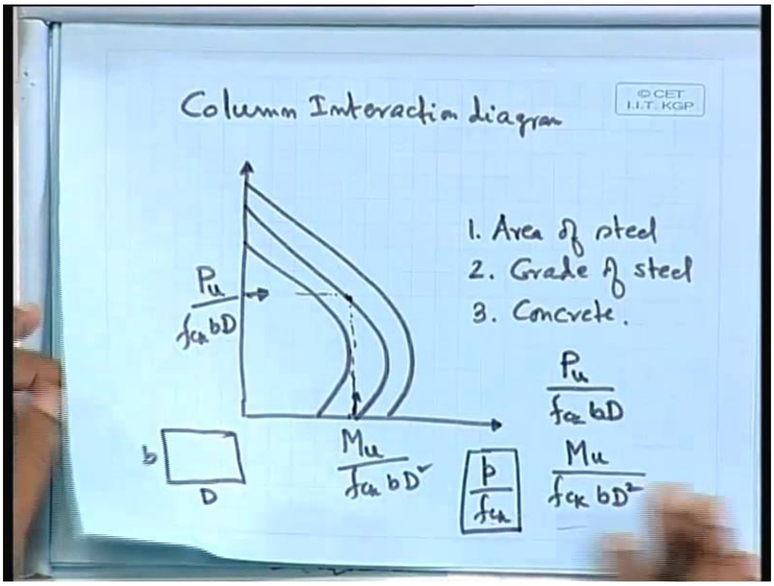


In 1 case, we shall get something like this; this is your stress diagram. When the neutral axis outside the section, then what will happen? It will happen; we shall get the same way this particular 1. So, I am getting which is going beyond this so; that means, I shall get certain portion here. This is your that portion which is acting on the body, which is the part of the column. This portion will no longer acting because, there is no section here. The column is only here; this portion the D, but this portion there is no column. Compared to the your beam problem, there is no problem because, we are taking the whole area, but whenever you are talking column, in that case in certain cases and in most of the cases it will happen that, partial it is partially loaded that is stress block will not be will not get the full 1, we shall get part because, neutral axis is outer the section and this area we have to calculate.

So, what is our objective here? Our objective here that P and M we do not know, because since it is P and M there are 2 parameters. So, we do not know in which case it is safe. Now, what we have to do for we check it for different neutral axis position, we find out that P and M how much moment and how much axial load it can take, that particular section can take. What is the moment of resistance and what is the axial loaded resistance for the axial load, that we calculate for a particular that neutral axis position. And then what we can do, we can find out that 1 and we can plot it and that is called interaction diagram.

So, it is not possible directly, the way we have computed so far; the deterministic way, here we can say little bit iterative.

(Refer Slide Time: 13:47)



What you have to do, you have to draw the column interaction diagram. So, what we do, we can say as if we are having P and we are having M. So, in 1 of the cases it may happen that, there is no moment, already we have done it. It may happen there is a moment and in another case it is possible, there is no axial load. The interaction diagram, it comes for a particular area of steel. Then we are having say grade of steel, then we are having say concrete. What we do; that means, let us choose a section and then you find out the what is the axial load how much it can take and how much it can take that moment? How shall you find out? I shall find out that, let us assume that this is the neutral axis position that we can take it and if we take the neutral axis position, on the basis of that we can find out, how much moment and how much axial load it can take.

Similarly, I can take another neutral axis position and again I can calculate what the moment is and what the axial load is. So, in this way if you just plot it, then we shall get 1 interaction curve like this and that is for the area of steel, as we have assumed that we are getting a 1 particular area of steel. Now, if you change the area of steel then, I shall get another curve say like this. If, I do again change the area of steel then, I can get another curve like this.

So, if we get it here then what we shall do; if P and M is given, P and M are given that P and M given then, what we shall do then and we can find out from here then, let us say that P is here and M is somewhere here. So, we can find out; that means, if I know the P and if know M because, that is given, for that we have to design. So, if we know that 1 then, wherever it is intersecting, so that percentage of steel we have to take it.

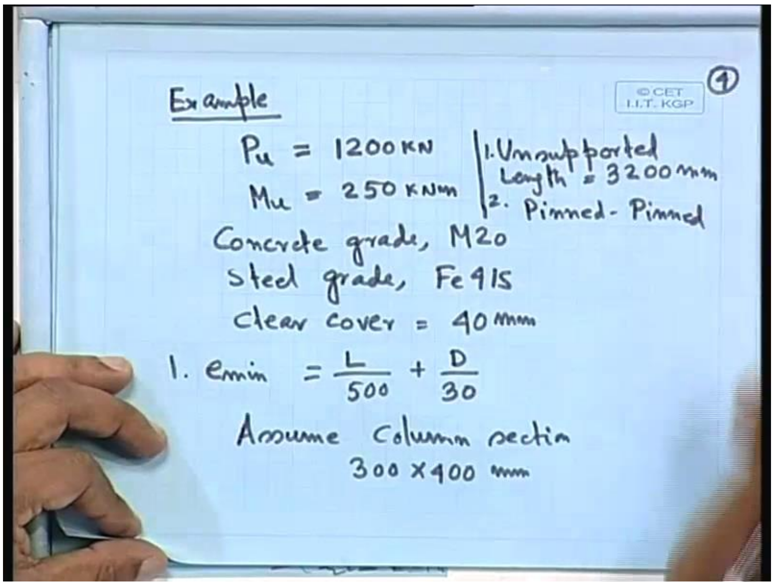
So, this is your, that is why this interaction diagram is helpful. But, what we do and for that that s p 16 that special publication 16, that has given the different chart. What we do it here, instead of that we make it P u, u is the design load and that we divide by f c k b D, f c k is the concrete grade used b is the that width of the width of the column and D is the that you are say depth of the column. So, P u f c k by b D because, I know P u, I know M u also, M u divided by f c k b d square.

So, since I know P u and M u and I am choosing a section, here I am choosing the section; that means, let us try 1 trial section 300 by 300 300 by 400 200 50 by say 300 Like that. Let us choose a section, if we choose and I know that, which concrete has to be used. So, I can find out p u by f c k b d and mu by f c k b d square and that 1 here, instead of this p and M because, there it will be dependent on because these 1 becomes nondimensional. So, that is preferable instead of having some absolute value.

So, this diagram we prefer, instead of giving P and M, we give it give it as p u by f c k b D because, dependent on any f c k we can use it and M u by f c k b D square. Then what we can do, since I can calculate these values then I can find out here wherever you are getting this percentage of steel and that percentage of steel also not given as directly P instead of, it gives as P by f c k. So, if I get that p by f c k then, I can find out percentage of steel, P means that percentage of steel divided by f c k that which concrete grade you are using. So, that way we can find out.

So, let us try 1 problem, then I think it will be clear. Let us try 1 problem then what I mean to say that it will be clear. So, let us take 1 example.

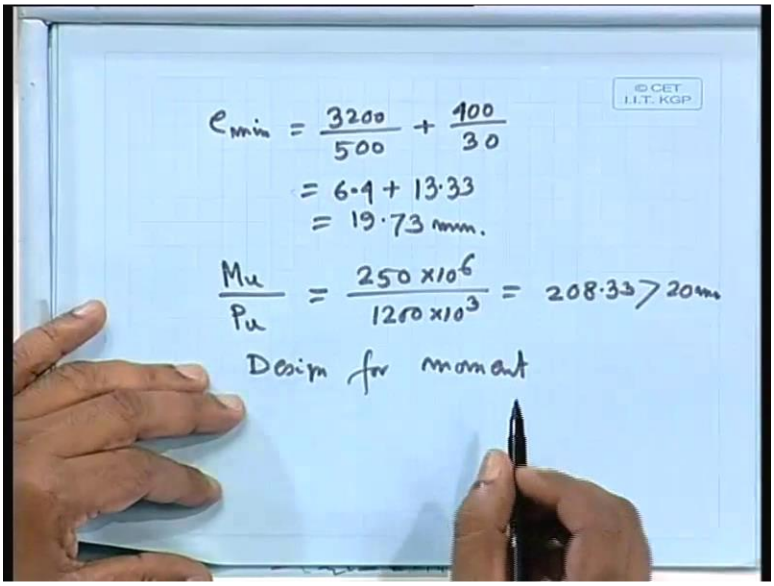
(Refer Slide time: 18:58)



Let us say P u given say 1200 kiloNewton, M u 250 kiloNewton meter, so P u and M u given. Concrete grade M 20, steel grade Fe 415, clear cover 40 millimeter, for column we generally use this clear cover 40 millimeter. Now, what about the emin? Will be equal to when let us take for basically say unsupported length equal to millimeter and it is a pinned-pinned case in both joints are hinged. Let us take this particular condition, so that it we shall get the effective length also, L by 500 plus D by 30 this is the 1. Let us take the column section that could be say 300 by 400 this is millimeter 300 by 400 millimeter.

So, what we can do, we can find out emin.

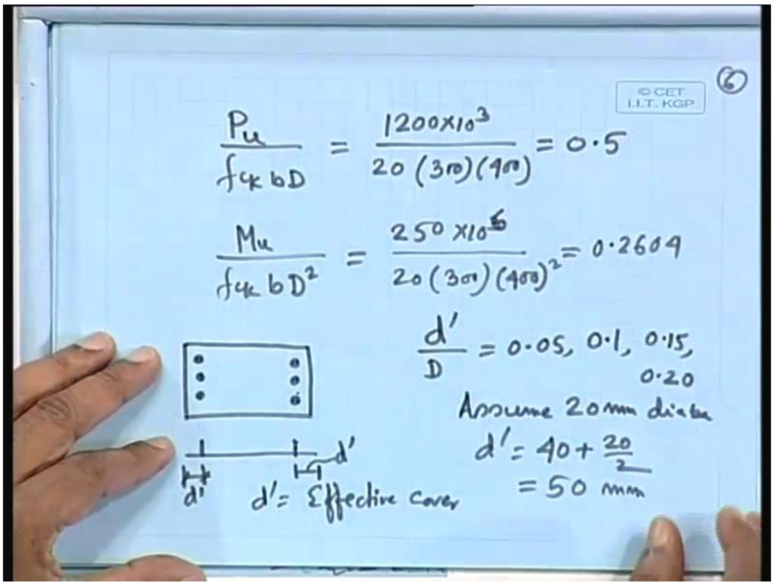
(Refer Slide Time: 21:08)



I do not know I have taken 300 or 400, but I may have to change because, I do not know right now, we are thinking that it may work. We can also choose other way also that, we can assume that P on the basis of P also; you can find out and then, but anyway you have to try with something. So, let us try and then D equal to you have 400 by 30 and which comes as 6.44 plus 13.33 or 19.73.

So, let us find out design for M, what is the M Mu by P u? Mu by P u equal to 250 into 10 to the power 6 divided by which is 208.33 which is greater than 20 millimeter. So, we have to design for M, even Mu is specified even then if you check it that M u by P u is less than 20, then we can simply go as you say your axial loaded column, but anyway it is quite high, so you have to design for moment. So, what we shall do it here, Mu and P u. So, let us find out P u by f c k b D P u.

(Refer Slide time: 23:12)



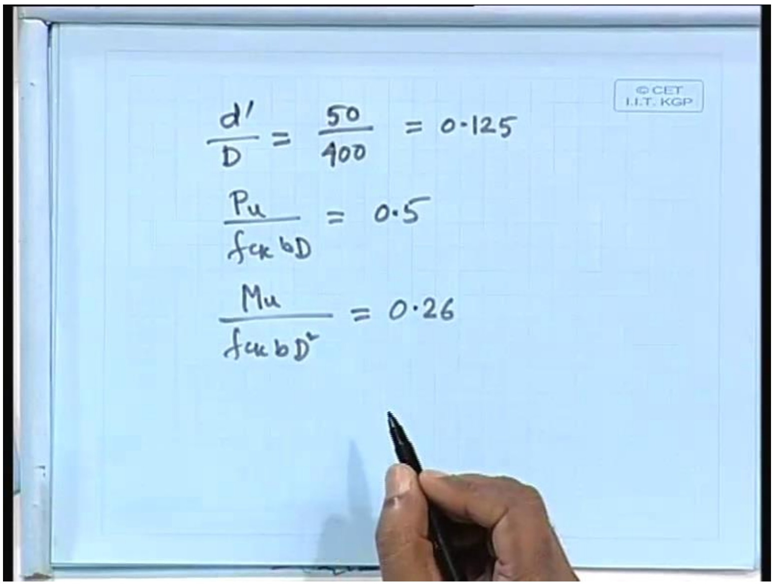
P u equal to 1200 into 10 to the power 3 divided by 20 times 300 times 400 which comes as 0.5. M u by f ck b D square equal to 250 times 10 to the power 6 divided by 20 times 300 times 400 square which comes as 0.2604 or 0.26 simply we can take it. What about the d dash? Our code says that, is it not only dependent on this P u by f c k b D Mu by f c k b D square. Since, it is dependent on let us say, we shall provide the reinforcement along this. When your calculating moment or moment of resistance, what is happening here, the strain the strain in the steel or in other with the stress you have to compute on the basis of the strain, let us say these strain also you have to find out and then you have to accordingly, you have to find out the stress and it is at a distance d dash. What is d dash? d dash is the effective cover.

So, d dash is effective cover. Our code says that we shall not take this P u by f c k for just only 1 chart, instead of that let us make it for different because, that this depending on the d dash, your strain also will change in the steel and. So, your stress also will vary. So, let us make few cases and our code gives that d dash by d, there is a special publication they have computed d dash by D that is for 0.05 0.1 0.15 and 2.0.

So, since we have to calculate d dash, let us say we shall provide assume 20 millimeter dia bar. So, d dash will be equal to 40 that clear cover plus 20 by 2 which comes as 50 millimeter. So, d dash that is 50 millimeter because, here also again I have chosen that 20 millimeter dia bar, I do not know for that 20 millimeter will be sufficient because, it may happen that, I have to increase or decrease that 1 depending on the say your area of steel computed.

So, we are taking here also, initially also I have taken a section I do not know, but anyway that is a trial section. Here also I am trying with 25 millimeter dia bar.

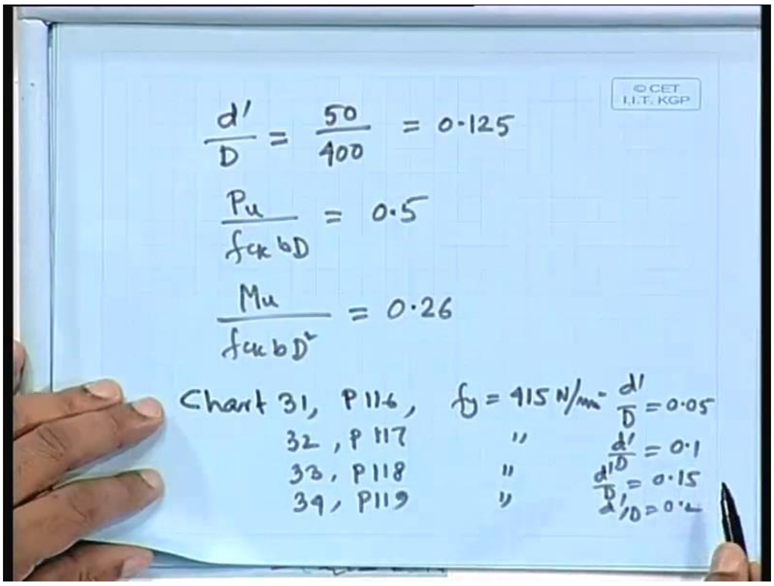
(Refer Slide time: 26:26)



So, d dash by D equal to 50 by 400 and which comes as 0.125. Now, let us show what you, we have we have d dash by D, then we have P u by f c k b D which is equal to say 0.5 that we have computed, M u by f c k b d square that also we have found that is point, let us say 0.26 only, let us take 0.2604, though we have computed, so this particular 1. So, we have to find out the area of steel and this from the special publication, what we can do we are having so many. If, you see this side actually it is written that steel grade here it is, fy 415. Just only to mention this 1 let me tell you.

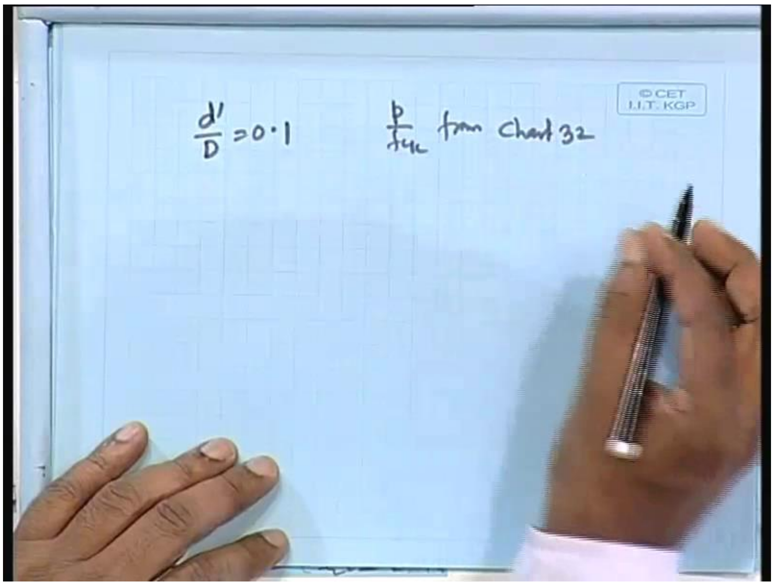
So, we can get it here from chart 31 note down chart 31 just to make it for reference.

(Refer Slide Time: 27:47).



So, chart 31 page 116 this is for f y 415 Newton per millimeter square and d dash by D equal to 0.5. Similarly, 32 33 and 34, so 32 the same 1, this is in page 117 page 118, page 119, this is for same 1. Only change is that d dash by D this is 0.1 d dash by D 0.15 and d dash by D 0.2. So, we are having these 4 charts specifically for f f y 415 f e 415 and for different d dash by D. What we can do, we have 0.125 d dash by D. Now, 1 can say that 0.1 and 0.15. Let us find out from these 2 charts, what are the values.

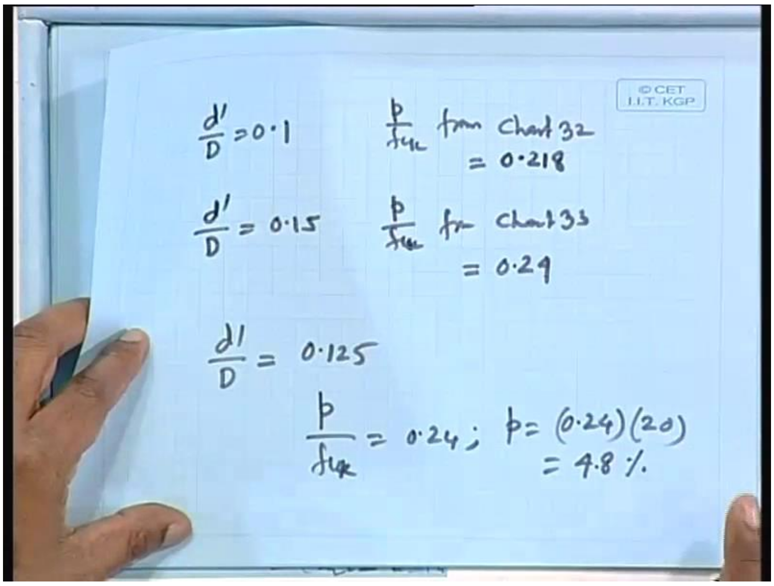
(Refer Slide time: 29:08)



So, if D dash by d 0.1 p by f c k from chart 32 will be equal to, which comes as it is difficult, but anyway just let me tell you, this is the 1 that chart how it comes. You can say all of them these are all coming, this is from say 0 0.02 0.04 that is p by fck percentage of steel divided by the grade of concrete. So, different 1 we have now we have, what is the value we have got that is 0.5 and 0.26 and this is for d dash by D equal to 0.1. Generally, it is written here d dash by D 0.1 and little away that is your say here that for 415. It comes in that in this fashion.

So, what we can do it here, we can find out 0.5, this is 0.5, just to tell you this is 0.5 and we have 2.6. So, 0.26 is somewhere here. So, wherever it cuts, it will cut somewhere this value and that value we have to take it that p by f c k. So, which is coming as here 0.5 this is 0.5 and I have to 2 6, just to tell you that how it is coming. So, somewhere it comes somewhere here and as per my that is actually it comes between 0.2 and 0.22, note just to refer this 1 because it may be difficult, but only to tell you that chart 32 and you have to find out p u by f c k b d in this direction, M u by f c k b d square in this direction if you just get you will get a point you will get that p by f c k if it comes in between. So, you just from the highest you find out that that what is the value. So, if you get it.

(Refer Slide time: 31:33).



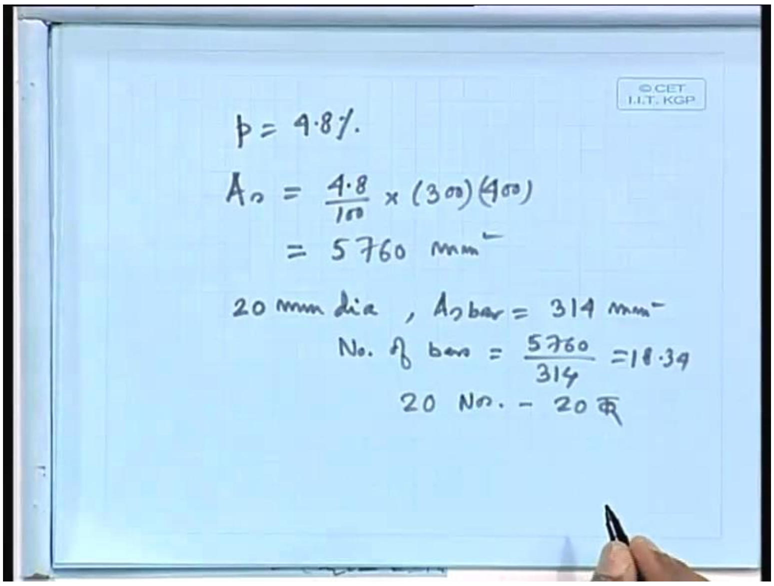
So, I have got it here p by f c k equal to 0.218. Similarly, the other 1 also d dash by D equal to 0.15 and p by f c k from chart 33, which comes as 0.24 because, d dash by D

0.1, d dash by D 0.15. Now, 1 can argue so which 1; obviously, if we do not interpolate; that means, because our d dash by D which we have computed that 1 equal to 0.125 dash by d equal to 0.125. So, if you do not interpolate then; obviously, we have to go that chart for d dash by D equal to 0.15 because, percentage of steel here more.

So, let us take this 1 itself let us do not interpolate. So, let us take this particular 1 say chart 33 and we can find out because, that we can we will be in the conservative side because, we are not doing any interpolation. So, what we are doing. So, we are just simply taking say from d dash by D 0.15. So, we shall always take the higher 1 and then, we shall get that 0.1225. So, let us find out how much is getting it is 0.24. So, we can find out p u will be equal to p by f c k equal to 0.24 therefore, p will be equal to 0.24 times 20, which comes as 4.8.

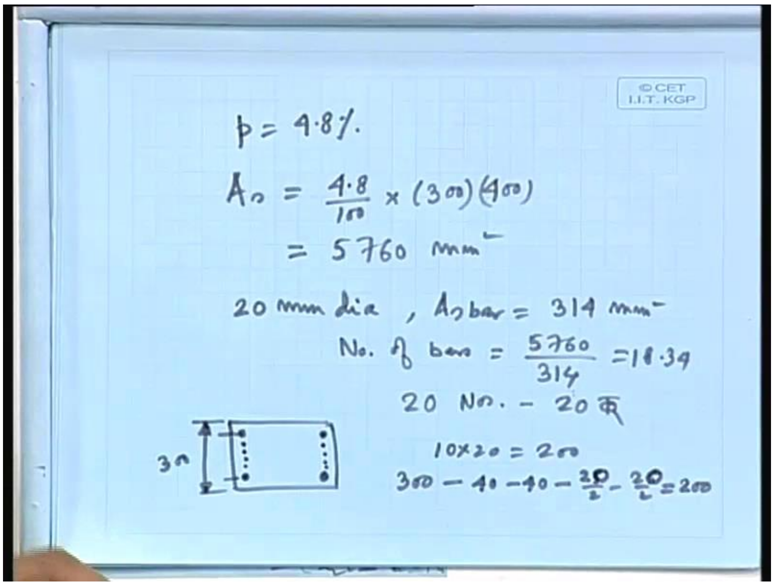
So, if you get this particular 1, say 4.8 percentage. So, it is quite high, I generally do not fit for this much of steel. Let us find out what is the difficulty, how it can happen that 1.

(Refer Slide time: 33:36)



So, 4.8 percent so p equal to 4.8 percent, let us find out that what is the difficulty we will face. So, area of steel equal to 4.8 by 100 times the section 300 times 400 and which comes as 5760 square millimeter, area of steel that 20 millimeter dia bar, that which we have assumed that we shall provide, area of steel of 20 millimeter bar is 314 and number of bars will be 5 7 6 0 by 31 4 18.14; that means, at least we have to provide 20 numbers. So, 20 numbers 20 torr that we have to provide.

(Refer Slide Time: 35:35).

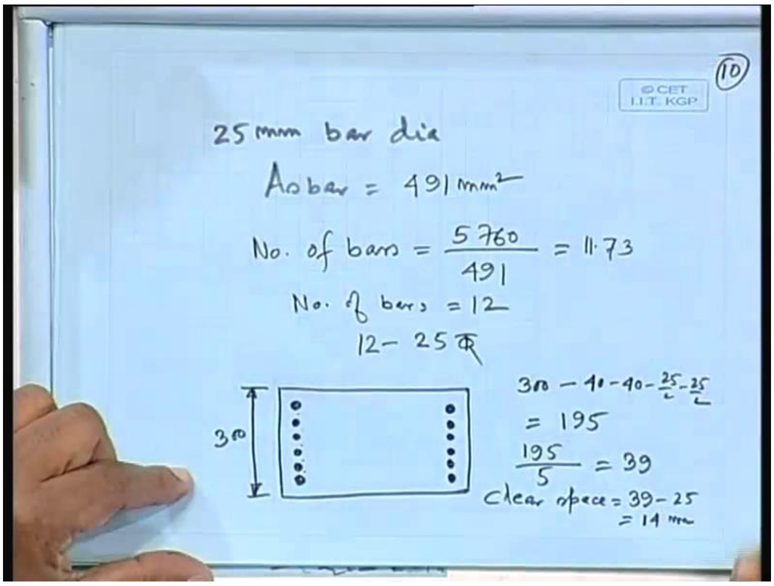


Let us find out and we have assumed because, we have taken a section. Note, we have taken a section, we have taken a section, I think you could you find out that, we are providing the reinforcement in only in the 2 sides, not all through. So, this 1 we have chosen; that means, now we cannot provide that all through that this 20 number bars, we cannot provide in all through. So; that means, what you have to provide, we have to provide the reinforcement along this. So, 10 numbers this sides, 10 numbers this sides like this.

So, what are the difficulties here? Let us assume that we shall provide 10 numbers. So, 20 times 20 10 times 20 it comes here; so, 10 times 20 which comes as 200, 10 times 20 which comes as 200 millimeter. So, that means, how much you have to provide here? This distance this is 300 and that is called detailing. Whenever you have to provide the reinforcement detailing you have to consider.

So, if you have provide here 300; so 300 minus clear cover minus clear cover, we are coming to center to center. So, 25 by 2 minus 25 by 2, which comes as 20 by 2, so which comes as; 40 plus 40 80, 80 plus 20 100, so, which comes as 200. So; that means, the bars, simply we have to provide along that, we shall not get any space. So, while that course aggregate, all this aggregate should go; that means, how shall you do the concreting? That is that difficult point. So, always you have to consider that, this particular 1 you have to consider. Let us assume that we shall provide say 25 millimeter, the bar diameter say 25 millimeter. If we provide 25 millimeter, then also is there any difficulty, let us find out.

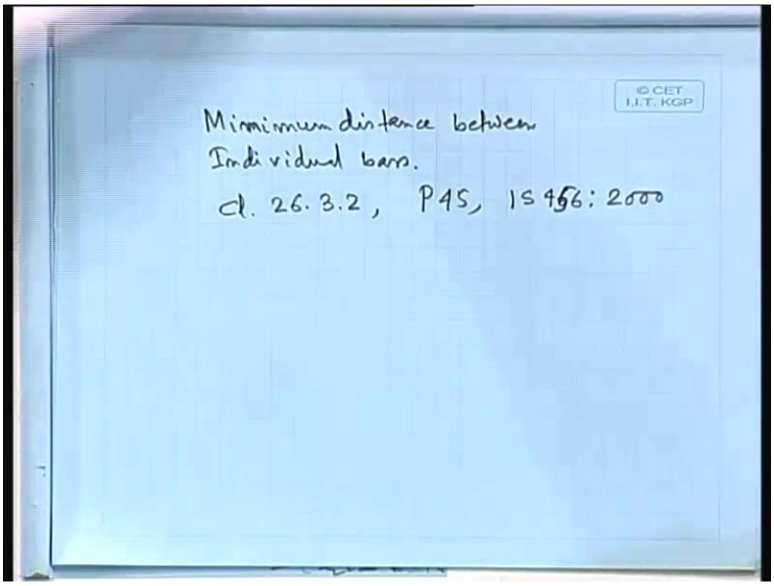
(Refer Slide Time: 37:21).



So, 25 millimeter bar dia. So, area of steel of each bar equals, this 1 will be 491. So, area of steel that 1 will be 491. So, how much steel, number of bars so 5 7 6 0 divided by 491 and which comes as 11.73, number of bars; that means, 12 at least you have to prove it. So, 12 numbers 25 torr. So, whatever is here 1 2 3 4 then 4 more, now we have 300 minus 40 minus 40 minus 25 by 2 minus 25 by 2; so we get here 195. Now, 195 divided by 1 2 3 4 5 there are 5 gap, so 39. So, if it is 39 millimeter, so clear space how much will be the clear space then? 39 minus 25 equal to 14 millimeter. So, clear space between the 2 bars, we are getting 14 millimeter, so far so good at least I can say compared to that.

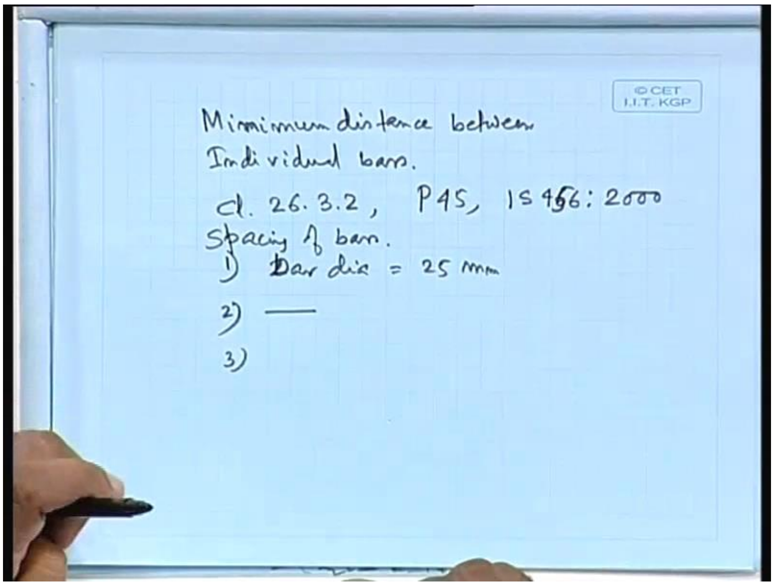
Let us find out what are our code says. So, let us find out what our code says and that we shall get it in class

(Refer Slide time: 40:08)



Minimum distance distance between individual bars. Our code says in class 26.3.2 page 45 I s 4 5 6 2000. Our code says, let me read it; the following shall apply for spacing of bars a, the horizontal distance between 2 parallel main reinforcing bars shall usually be not less than shall usually be not less than the greatest of the following. So, whatever we shall get it, out of that we shall select the maximum 1 and that should not be less than that value, so the diameter of the bar if the diameters are equal. In this case diameters are equal, so which is here say 25 millimeter we have taken, but even then that our calculation is still wrong because, d dash by D that 1 also changed all those things, but for the time being let us take 25 millimeter.

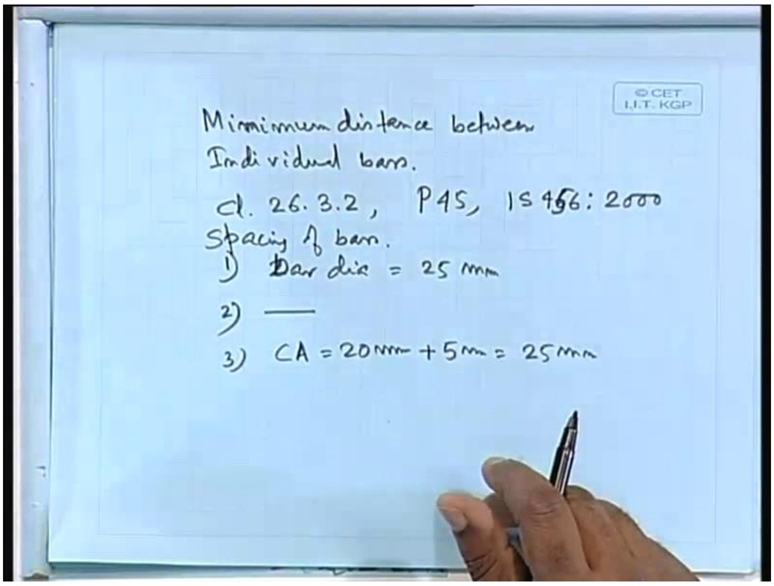
(Refer Slide time: 41:46)



So, spacing of bars, so we are getting bar diameter, let us write down bar diameter 25 millimeter. Number 2: the diameter of the largest larger bar, if the diameters are unequal. Sometimes we provide say 16 millimeter 12 millimeter 20 millimeter 25 millimeter. If the all the bars are not equal diameter, then we have to take the larger 1, that we have to take it, that case does not arise here. Here that case does not arise because; you are providing the 25 millimeter 1. Number 3: 5 millimeter more than the nominal maximum size of course aggregate. So, whatever the course aggregate you are providing. So, you add 5 millimeter more; that means, in our case course aggregate maximum size generally you provide 20 millimeter, the size of the that maximum course aggregate size that is 20 millimeter. So, you have to make 20 millimeter.

So, course aggregate that 20 millimeter, we generally provide say 20 millimeter downgraded generally we described, the aggregates that mean it means that the

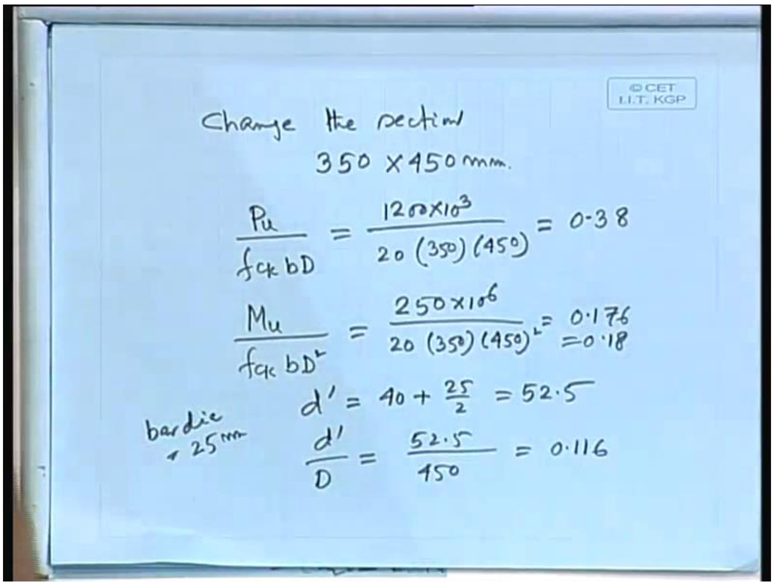
(Refer Slide time: 42:53)



Course aggregate will never be more than the 20 millimeter. So, 20 millimeter plus 5 millimeter, so which is coming as 25 millimeter. So, what is the spacing then? Out of that; obviously, it has come 25 25 both, but out of that if which 1 will be the maximum that you have to choose and it should not be less than that. But in our case what happened? In our case we have got it only 14 millimeter; that means, with this section we cannot provide; so we have to increase the section. So, that also you can find out here also. I have told you that percentage of steel p 4.8 percent, whatever you have got it here 4.8 percent that is that itself is; that means, you need not go to that level, just to for your academic I have written here, but in actual practice here itself, I just why I restrict that 1 say may be 3 percent or less than 3 percent.

So, if you restrict that 1 immediately those things could be taken care of. So, we are getting 25 millimeter. So, what we shall do then? Then we shall change the section. So, let us change the section.

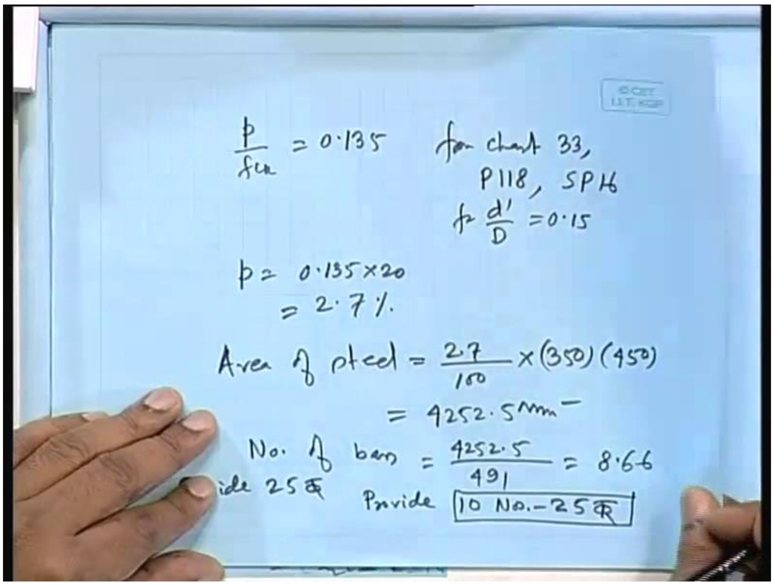
(Refer Slide time: 44:30)



So, let us take, so 350 by say 450. So, we are taking the section say 350 millimeter by say 450 millimeter that section we are taking. So, what will be then p u by f c k b d? That 1200 into 10 to the power 3, so which comes as 0.38 M u by f c k b d square 250. So, it comes as 0.176, let us say 0.18. What about d dash? d dash equal to say 40 millimeter, let us take bar dia because, we have seen that 20 millimeter is not the good choice. Let us take 25millimeter, so 25 by 2. So, we are getting here 52.5, so d dash by D equal to 52.5 divided by 450, which comes as 0.116.

So, what we can do then here, that section we can take it that chart. The chart we can take it here. I think the chart corresponding chart, we can take it here. Let me find out that 1 in 20. So, 0.116 that is d dash by D and we can come. So, 0.15 directly we can take it 0.15. So, what is coming here at 0.15? Your 0.38 and 0.18 just to let me take it here because; it will be difficult, but only for your reference I am talking, so which comes as here say approximately, I can say 0.135.

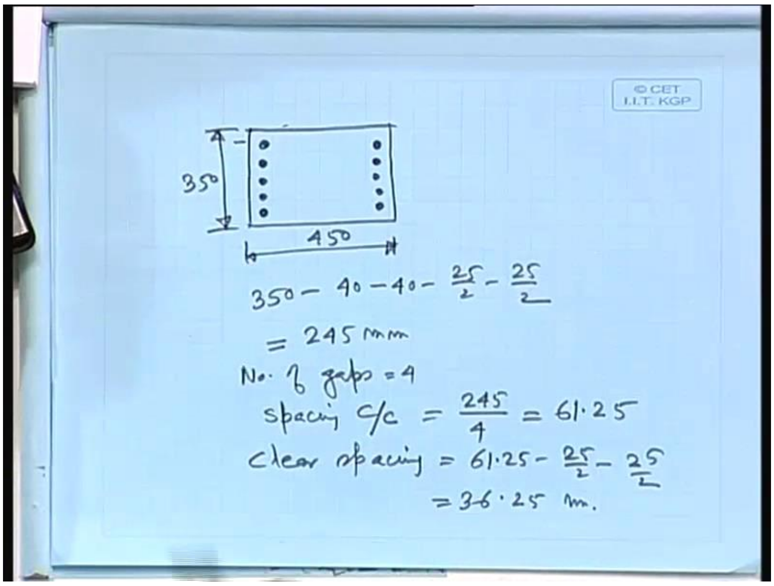
(Refer Slide Time: 47:55)



So, p by f c k 0.135 from chart 33 page 118 for d dash by D equal to 0.15, for d dash by D equal to 0.15 that we have chosen, I am not doing any interpolation. So, I am this will in the conservative side. So, p to equal to 0.135 times 20. So, 2.7, at least it is less than 3 percent. So, area of steel equal to 2.7 by 100 times 350 the section I have chosen and times 450 which comes as 2.7 into 3 5 0 into 4 5 0 divided by 1 0 0. So, 44252.5 number of bars, let us take say 25 torr, so 4252.5 by 491; 8.66. So, we shall provide 10 numbers 25 torr.

Now, let us check the torr that we have got that class, whether we have violated or not. That we have to always check.

(Refer Slide Time: 50:03).



So, we can find out now, we can find out now here 1 2 3 4 5 6 7; so total 10. So, we are getting here; this is 350 and this is 450. So, 350 minus 40 clear cover this side, so this 1 also d dash minus 40 minus 25 by 2 minus 25 by 2, so which comes as 105 245 millimeter. How many gap, number of gaps? 4 So, spacing center to center 245 by 4. So, 61.25, clear spacing, so 61.25 minus 25 by 2 minus 25 by 2, so we shall get it here 36.25. So, which is as per the code now it is not violated.

So, we have enough gap because, we have to provide that 1 say course aggregates. So, that is why it is very important you say, reinforce concrete design that, you would say clear spacing, all those that is detailing that we have to specify it. So, let us conclude at least this 1, this particular class today now. We shall continue in the next class.

So, thank you.