Design of Reinforced Concrete Structures
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Lecture –25
Design of Footings
Part II

Let us continue with design of footings. Last class, we have started that basic philosophy of design of footings. If you see for any reinforced concrete design, not only reinforced concrete design, for any structures if have to design, so far the governing 1 you have to isolate, that for an element what are the governing forces acting.

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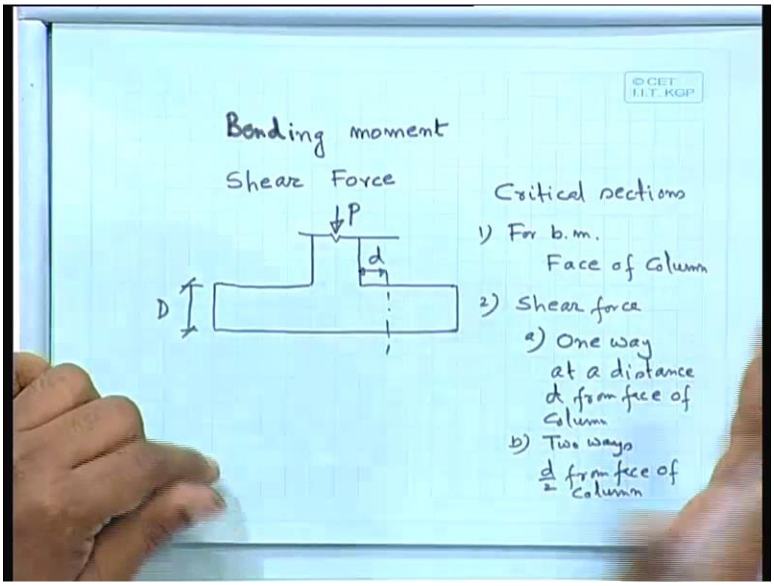

In the footing case we have bending moment and shear forces. So, what we have seen in the last class; if we have a column and we have to provide thus foundation, it may be rectangular, it may be square also. Our objective here is that, we have to due to this axial load say P or due to say your moment, due to your axial load or due to say moment, we have that pressure here.

Now, bending moment; the critical sections. Critical sections for bending moment, it will be in the face of column. That means, either it will be here or we can take it here, so face of column. For shear force we have 2 cases; 1 is called 1 way. So, that 1 will be at a distance d from face of column. So, it will be certain distance say here d, where you have to calculate that shear force and that we have to check. The other 1 is called 2 ways or punching shear. In that case, that is d by 2 from face of column. So, these are the 3 cases that you have to consider. We can start with that bending moment, we can calculate bending moment at this and we can find out.

So, first step, just let us recapitulate first step, that what is the load you have and that should be the characteristics load, is not the ultimate load because; we are not taking the ultimate bearing capacity of soil. We are taking the safe bearing capacity of soil. You can say that is the serviceable 1. So, the load you will take it here, that p that is not multiplied with 1.5 or whatever it is. So, that is the first difference because, otherwise if you multiply with 1.5, your footing size will be bigger, so that you should remember.

So, your column load and certain amount say may be 10 percent you can take for the footing, because footing size already you have not yet decided. So, 10 percent of the axial load whatever coming, you can take it as the shear point of the footing. So, considering that, you can find out the footing size and the serviceable condition. Next 1 you do it to design for; that means, you have to provide the section size. You know the area of the footing, it may be rectangular, it may be circular, it may be square depending on the section.

Now, what you will do; now you have to provide depth of the footing. This depth of the footing you have to provide; that is first 1 that, you have to provide the depth of the footing, overall depth. 50 millimeter we have to provide the clear cover, that you should remember. Then, we have to provide reinforcement. So, reinforcement for this type of thing, you can consider this 1 as a slab. You are not providing any shear reinforcement, no shear, no stirrup. Only we are providing say your slab.

So, here that critical stress for tau c; that will be say less than say 0.35, it should be less than 0.35 that you should consider. Because if it is more than, you have to provide shear reinforcement. But generally in this type of footing, we do not provide any shear reinforcement; there is no provision of that. We could do it, but we do not want to do it here. So, that is why the only alternative we have, that you change the increase the depth. So, that your tau c becomes that, what the shear stress developed that is less than 0.35 Newton per square millimeter.

So, what we have to do, we have to check out of this, we have to start with 1 of them and then you have to check. Generally it is very much say, if you see bending moment shear forces, out of that we will find out the shear force mod. That means: taking bending moment, whatever depth you will get it and taking shear force whatever depth you will get it. Out of that shear force, that depth computed from the shear forces, will be more than the depth computed from the bending moment. That is why in this case, we start from the shear force and then we check for others, that we do.

Compared to your slab or your beam, we generally start with say your bending moment and then we check with the shear. Here depending on the situation, we will find out because, we can start with the bending moment, but later on you have to increase the depth for shear forces, it may happen and that is why we start with the shear force, may be say for 1 way.

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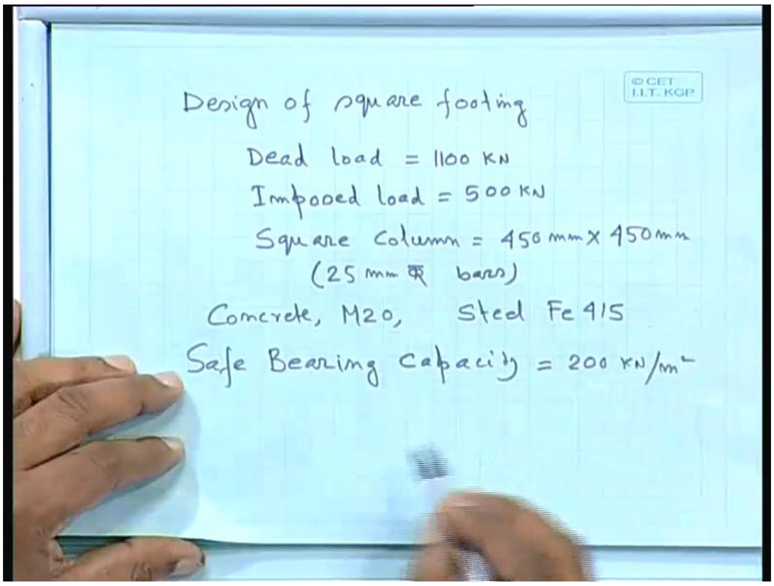

So, this is your whole thing, whatever we have to do and let us start solve, 1 say square footing 1 problem. So, design of square footing. Dead load let us take, imposed load and a square column that which we have to support. Let us take that, this is having say we are not interested for that. So, let us take say 25 millimeter bar provided in the columns, concrete M 20 and steel F e 4 1 5, bearing capacity let us write down safe; so which is coming as 200 kilo Newton per square metre.

So, this is your that your parameters. You can understand that, how that imposed load or live load it is 500 kilo Newton, where dead load which is coming as here say 1100 kilo Newton. So, you can understand that what is the ratio. So, almost it has become more than, that the double that your imposed load. That means this is our object, we have to support this load say 1100 kilo Newton, say that is the main part of the any structure you are going to construct.

So, for that the overhead, you can say that means, here it means say 1100. So, for a structure, if you consider at least for say your bridges, it is 1 of the important part. The span of the bridge, if you take say span of the bridge, if it is say less than your live load or vehicle load because, that is the objective for making a bridge, so, vehicle load whatever is coming and the dead load of the structure of the bridge. For a small span may be say 20 meter or say you can consider say 50 20 30 like that and compared that is your almost say 1 is to 1 something in that ratio.

But if it is more, may be say 100 meter all those things then, you will find out that vehicle load whatever coming, that is very less compared to the dead load. So, that way I can say that because, what I mean to say; that dead load that 1 to support the structure, to make the structure, if it is say 50 50, we can say it is economic or optimum. But most of the cases, you will find out it is not at all possible to make it economic. In this case say here. Finally at the end you are coming to that dead load and live load ratio that is your say almost say 2 is to 1.

And on the basis of that, 1 can estimate that, your say cost other things also 1 can estimate.

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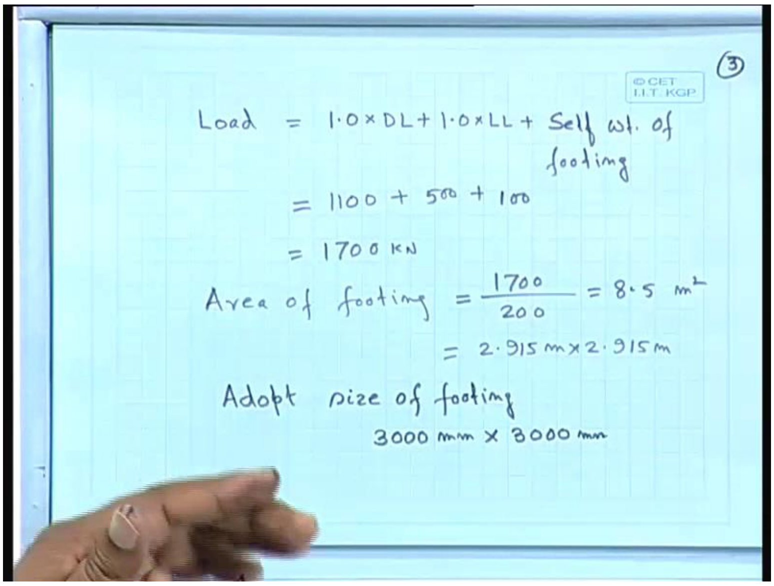

So, load equal to 1.0 times dead load plus 1.0 times live load plus self weight; so which comes as 1100 plus 500. And let us take 100 kilo Newton as self weight; so which is coming as 1700 kilo Newton. Area of footing 1 7 0 0 divided by 200 which is coming as 8.5 square meter equal to 2.915 meter into 2.915 meter. So, we can find out, let us provide size of footing say 3 meter or 3000 millimeter times 3000 millimeter. So, we shall take a square footing of 3 meter by 3 meter.

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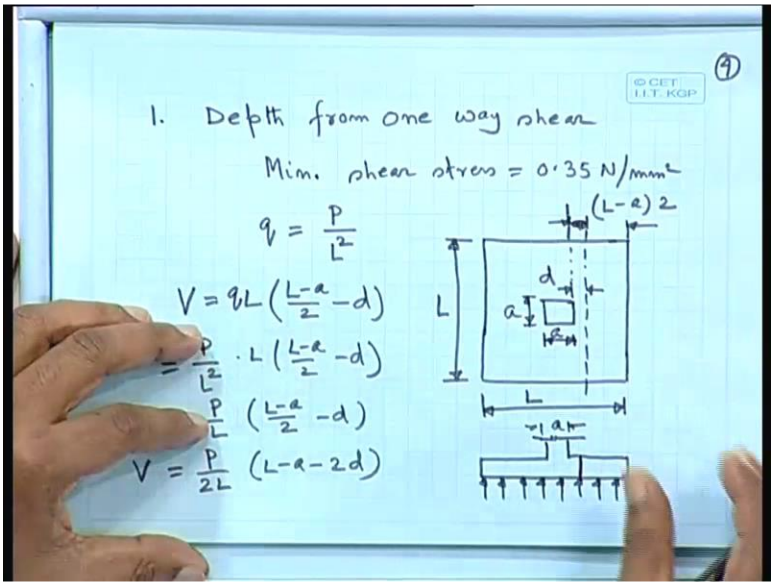

We can calculate depth, so depth from 1 way shear say. We are assuming the minimum shear, though it could be less 0.28 something. But since, we are using say tensile steel, because of that we can increase little bit your, say shear stress. So, minimum shear stress, that is permissible here in our case, that is, 0.35 Newton per square millimeter. Now, q; q is the pressure, that 1 should be equal to p by l square. Let us find out we are taking, so we can take it and we are interested to find out at a distance d.

So, this distance from the face of the column that is d. So, what about this length then? Let us take this length, this is your L and column sides square column a. So, this only will be equal to L minus a by 2. So, what about the shear force here then? The shear force here just let us make it like this. So, L minus a, let us what I can do just to keep it. So, let us make this 1 then you do not have any objection. So, I mean to say this is from the face of the 1; so L minus a by 2.

So, this is your a and you have the uniform pressure and that is q. So, v will be equal to the shear force v along this line, the 2 way we can make it that, 1 we can take unit length or other alternative that, we can take the full length. This is also L, so v will be equal to that q L q L q times L. That means unit steep per meter 1 I can take, times L minus a by 2 minus d. So, I can take it L minus a by 2 minus d that we can take it. So, that is your say shear force.

So, we can write down it as; so this is the shear force, we are getting here equal to, we can write down p by 2L L minus a minus 2 d. This is your the shear force v along this at a distance d from the face of the column. So, we can write down it as, what about the shear force that is permissible? So, that shear force permissible that is here; so, this is your say d, we are taking that effective depth say d here. So, shear force, that whatever shear force developed here, that should be resisted by the cross section here.

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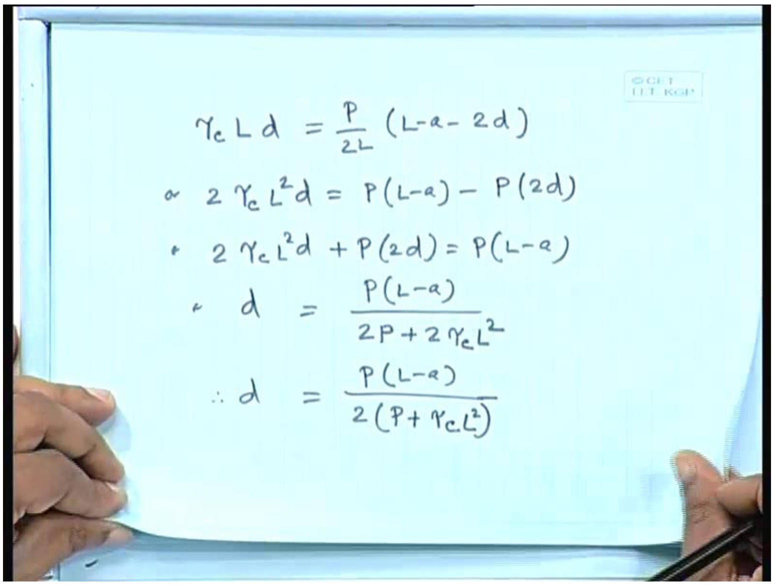

So, that cross section equal to this length times that effective depth times. So, L times d that is the area which is resisting, times that tau c that is permissible. So, that is the shear force. So, we can write down and that should be resisted; that means, so these forces should be resisted by that shear force. So, we can write down as tau c times L times d equal to p by 2L L minus a minus 2 d. Or twice tau c L square d equal to p times L minus a minus p times 2d or tau c square d plus p times 2d will be equal to p times L minus a or d equal to p by L minus a divided by twice p as twice tau c L square.

So, the final form, we can find out it as d equal to p L minus a 2 p plus tau c L square. So, we can find out, we know p, L also you know, a the column size that also you know, tau c 0.35 Newton per square millimeter.

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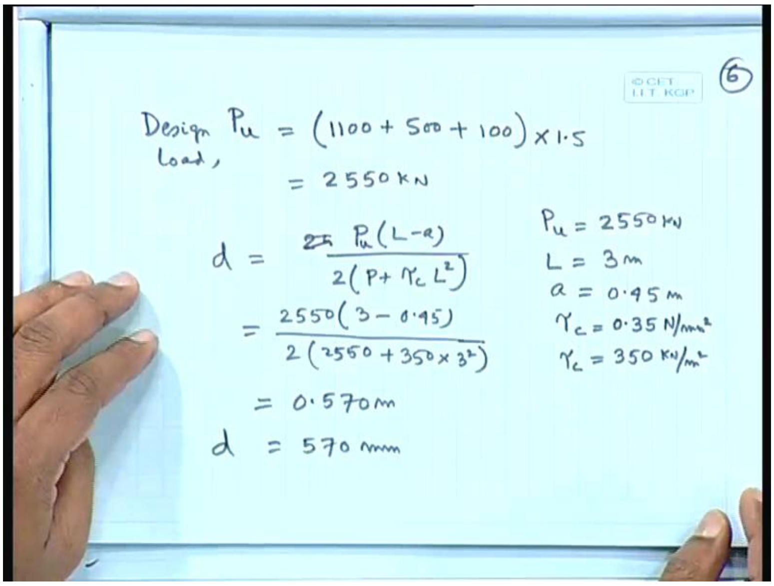

So, we can find out the depth. What about P u that design load; 1100 plus 500 1100 dead load, 500 live load plus self weight times 1.5 equals 2 5 5 0 kilo Newton. We can write down now d will be equal to, let us make it like this p times L minus a divided by twice p plus tau c l square P or P u we can write down here. P u 2 5 5 0 kilo Newton, L 3 meter, a 0.45 and tau c 3 5 Newton per square millimeter equal to 350 kilo Newton per square meter, that is your tau c.

So, we can write down as 2 5 5 0 3 minus 0.45 divided by 2 times 2 5 5 0 plus 3 5 0 times 3 square, which comes as 0.570 meter, d equal to 570 millimeter.

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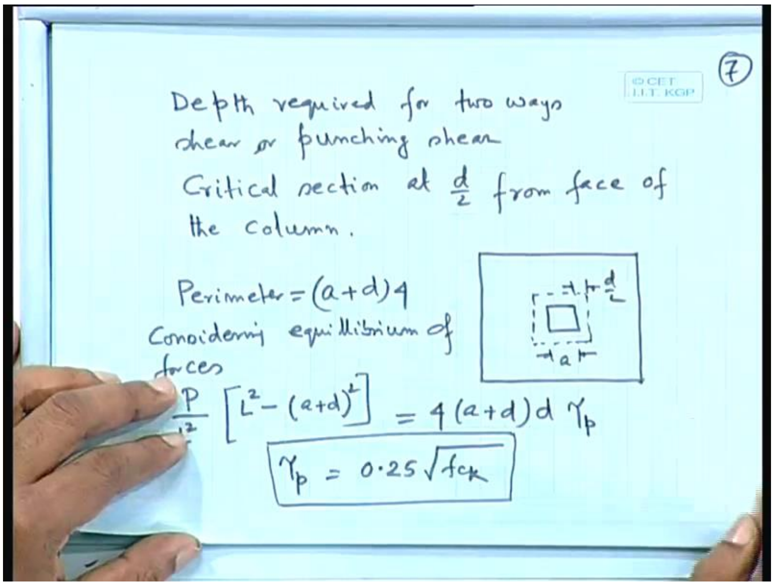

So, d equal to 570 millimeter, that we are getting here. We can check with the 2 ways shear. So, depth required for 2 ways shear or which we call it say punching shear. So, critical section at d by 2, from face of the column. Let us draw a figure here. So, this is the critical section and this is at a distance d by 2. What the perimeter? a plus, this is a, so a plus d by 2 d by 2 d times 4. So, you can write down here, if we consider the equilibrium forces.

So, you can write down q or p by L square L square minus a plus d whole square. We are taking this portion, we are taking tov. So, we can say this portion will be equal to 4 times a plus d that is the perimeter times the d, d is the effective depth because we are talking this 1. Note that, whenever you are talking say which 1 will your resist? It will resist this 1. So, we are taking the perimeter, this is your perimeter which is here for this is rectangular, but we are talking say square. So, 4 times a plus d times the, not the overall depth it should be effective depth. So, that cross-sectional area we are talking and then, remaining portion whatever they are that 1, whatever forces are coming that we have to take.

So, 4 times a plus d d that is for we are getting it here and we have to take times. But here it is for punching shear. So, tau p equal to, our code says it should be equal to 0.25 fck. So that means, this M 20 grade concrete, we know what is the allowable punching shear. So, what we do it here then? We can now calculate, we instead of doing that we can simply put the value of d here, d equal to 0.57 already we have got it.

So, now when we have got the 0.5, now on the basis of that if we know this portion can check, what is the value of that d we can find out. And if that d is less than 570 here in all case, then we can say it is alright. Otherwise you have to increase it, other alternative could be that again, we can make it that full from these all those things from there also you can calculate d. Since, already we know that 570 millimeter. So, that we can keep it here and we can check whether that d is coming less than the 570 or not.

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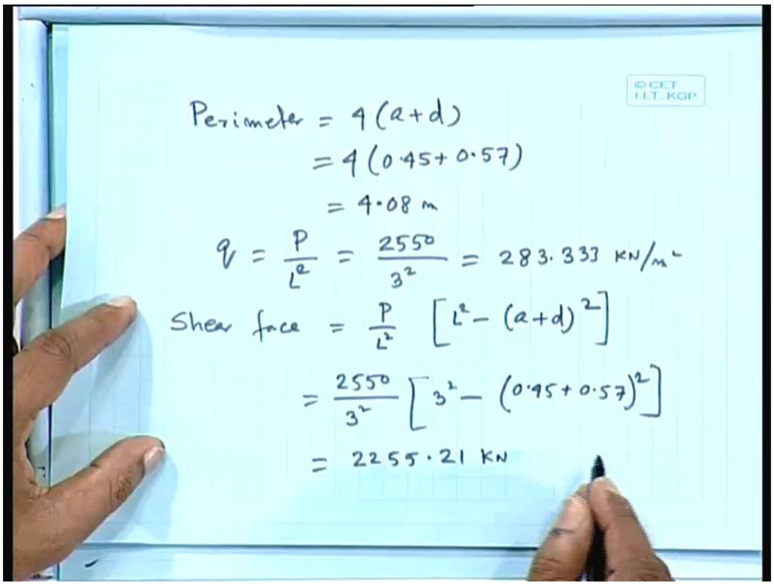

So, perimeter equal to 4 times 0.45 plus d equal to 0.57 we have got it, which comes as 4.08 meter, q equal to p by L square equal to 2550 divided by 3 square equal to 283.333 kilo Newton per square meter. Shear force p by L square L square minus a plus d whole square equal 2 5 5 0 divided by 3 square. So, 3 square minus a equal to 0.45 plus 0.57 whole square which comes as 2255.21 kilo Newton. This is the shear force. What about the permissible shear stress? Permissible stress 0.25 root f c k equal to 0.5 root over 20 equal to 1.118 Newton per square millimeter.

So, we are getting this value; tau p equal to shall I write down once more here. Let me write down here p by L square L square minus a plus d whole square equal to 4 times a plus d times d tau p. Therefore, tau p equal to p by L square L square minus a plus d whole square divided by 4 times a plus d times d. So, we can write down here as p by L square this part already we have done, that is the your say shear force which is coming as 2255.21 divided by 4 times, a is 0.45, d is 0.57 times 0.57.

So, we can find out tau p, that is equal to here we are getting 0.969 less than 1.118 Newton per square millimeter. So, indirect way we are doing. The other way you can do it that, directly you can compute that, you put the value of tau p and then you find out the d, the way we have done it for 1 way shear. But here since already we have got it, so it is better to check it with this value say tau p. If it is greater than the 1.118, then have to increase the depth.

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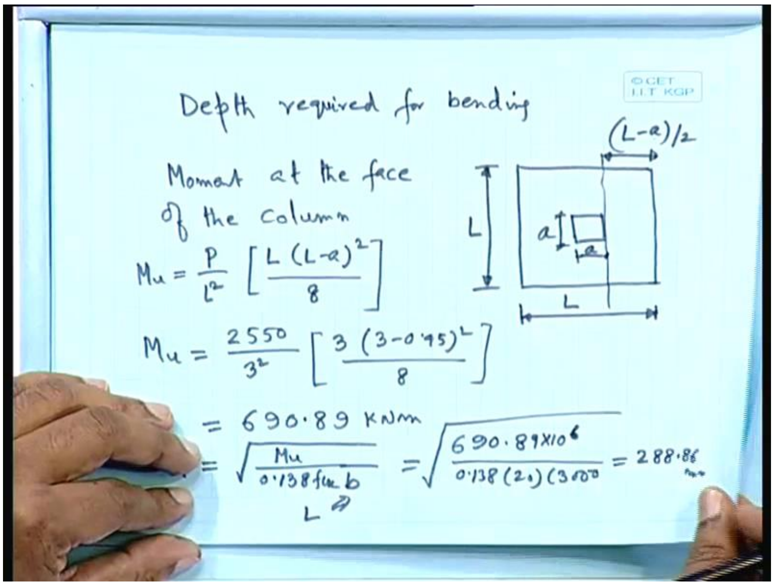

Now what about depth for bending? So, here where we have to calculate, we have to calculate the moment at the column face. So, this 1 will be equal to, this is your L and this is you’re a; so L minus a by 2, Moment at the face of the column, we can write down it as M u. So, p by L square times L s a square by as per this which is coming as. So, this 1 L minus a by 2 double L square by 2, L is here L minus a by 2. So, we are getting here this much. S

So, M u equal to 2 5 5 0 divided by I can take it here, so let us write down 3 square 3 times 3 minus 0.45 whole square by 8, which comes as 690.89 kilo Newton meter. This is your M u. Therefore, we can write down d here itself; d will be equal to the same formula M u by 0.138 f c k times say b, b is here nothing, but L because, we are talking that L here. So, 690.89 into 10 to the power 6 divided by 0.138 times 20 times 3000 and which comes as 288.86. You can understand that it is very less.

So, if we start with this 1, then we have to calculate and that is why it is better always, you can find always start 1 way shear so far, the footing concerned. So, d required from the bending point of view only 288.86 and you are from 1 way shear, we have got it 570 millimeter. So, we have to provide that say 570 millimeter.

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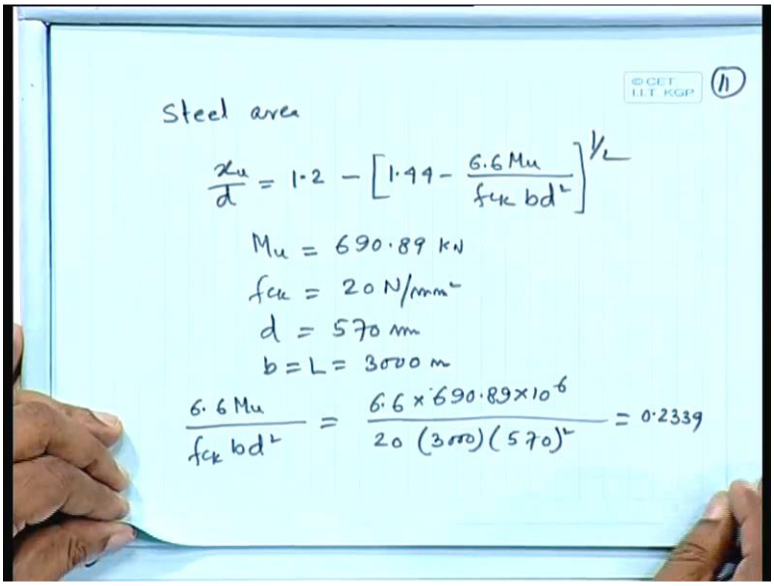

Now, we have to provide the steel area. So, we can find out that the same way; x by d, we can find out what x u by d 1.2 minus 1.44 minus 6.6 e m u by f c k b d square, M u equal to 690.89 kilo Newton, f c k 20, d 570, b equal to L equal to 3000 millimeter,6.6 M u, let us break it separately fck bd square equal to 6.6 times 690.89 into 10 to the power 6 divided by 20 times 3000 times 570 square equals 0.2339. This part is 6.6 M u by fck bd square; so 0.2339.

So, what about x by d? x by d we can calculate as, we can put it back here x u by d.

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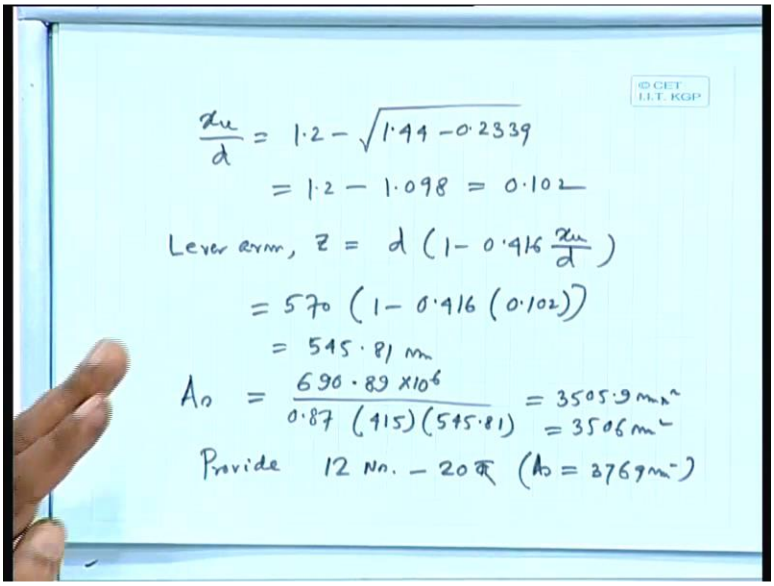

So, we can find out x u by d here. So, x u by d equal to 1.2 minus root over 1.44 minus 0.2339 whereas, 1.2 minus 1.098 equal to 0.102. So, x u by d we have got it as 0.102. So, lever arm jet equal to d 1 minus 0.416 x u by d equals 570 1 minus 0.416 times 0.102 equals 545.81 millimeter. Area of steel say a s here due to moment 690.89 into 10 to the power 6 divided by 0.87 times 415 that f y times the lever arm 545.81 which comes as 3505.9. We can write down 3 5 0 6 square millimeter, provide 12 numbers 20 torr, which comes as area of steel 3769 square millimeter.

So, here 1 thing you note, I have written 12 numbers 20 torr, you can mention like that. But if you make it say here, instead of taking the whole length, I have always consider that length equals 3 meter. 1 way you can do it, the same thing you can do it, that bending moment or shear force you could compute, for say 1 meter length. When we are talking this 1, we can go to the say 1 meter length. In that case, we have to provide that say 20 torr at the rate of certain spacing. Whenever you are talking say 1 meter, but here we have taken the full length and that is why I am giving the specifically, I am specifying the numbers.

Other alternative that 1 that, instead of taking that whole 3 meter length, take it as if that we are taking 1 meter and for that we are calculating the area of steel. So, in that case, it is customary to provide in such a way; that means, 20 torr of certain spacing that will. That is why in the slab, whenever we have design slab, we have taken 1 meter width and that is why we are providing at the spacing. But whereas, in beam that we are taking the full width, we know the definite length and that is why we are providing the numbers.

So, however, it is applicable that, you know the full length those things, will specify the exact numbers. But however, you are only calculating on the basis of the unit area or unit length then, you specify the spacing.

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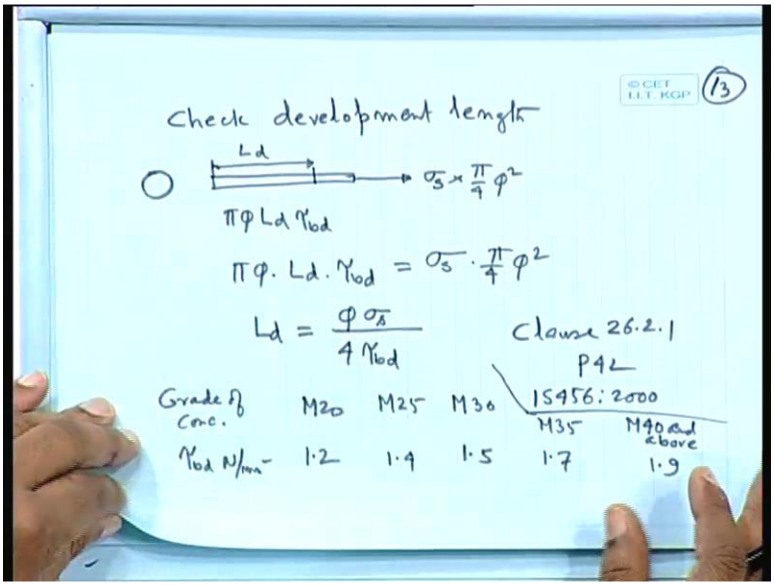

Now, we have to check certain development length. So, what we can do there is; 1 thing we can find out here that, if this is the bar what we generally do here. This is the permissible stress is sigma s. So, acting on this pie by 4 pie square. So, sigma s is the permissible stress, say for pulling you can say and times pie by 4 square. So, that is the 1 that force that is developed, force that is permissible. You are pulling a bar, so how much is the permissible that you say force? That only be the cross-section area times sigma s.

Now, I am just trying to pull it like this; that means, here if I just like this and you are trying to pull it. So, what should be the development length; that means, there is also, there is some developed, due to I say pressure like this. So, that 1 should be resisted it should resist the pull. So, what I mean to say to now length. So, here if this we call it say L d, this 1 if we call it L d. So, what is the area? Area will be equal to then pie fi, that is the pie fi, this 1 times this length times the bond.

If, we call it say bond stress whatever, so there is tau b d. So, if the length is say for example, how much I have to do it. So, what is the surface area of that 1 say cylinder, say surface area of the cylinder is equal to pie fi times the length, whatever I am just holding and then permissible stress that is the tau b d. So, in our case it is, I can write down at here pie fi times L d times tau b d equals sigma s times pie by 4 fi square.

So, we shall get it here L d or development length equal to pie sigma s divided by 4 tau b d. So, L d equal to pie sigma s by 4 tau b d, which comes as now, I can refer a code clause page number 43 and 42. So, you will get it in class 26.2.1 page 42 I S 4 5 6 2000. Now what about tau bd? So, grade of concrete and tau bd that, design bond stress for M 20 it is 1.2 M 25 1.4 M 30 1.4. So, like that we have, M 20 M 25 M 30. There is M 35, I can note down here M 35 that is, 1.7 M 40 and above it is 1.9. So, you can note that it is maximum 1.9 and M 20 for our case it is 1.2.

Now, this is valid for because, we have taken this 1 that surface. This surface we have taken that is a plane. The surface we have taken plane, are not the revved 1 say different bar. So, what is code saying, that for different bar, you in case which 60 percent, whatever L d we will get it. So; that means, for that L d will be reduced. For plane bar mile steel bar, whatever you will get it and then for, so your bond stress will be increased by say your 60 percent. So, you multiplied with 1.6.

So, in other way, L d will be reduced by. So, divided by 0.6, we have to consider that way we can consider. So, generally it is say tau b d 1.2 times 1.6 and you can find out. In addition to that, it is easier to pull rather than push. So, in that case, for compression you in that further you increase by 25 percent, the bond stress you increase by 25 percent. So, for plane 1 surface, it is just it is given 1.2 and also for pulling for tension tensile. If it is compressed for different bar, you increase this by 60 percent, so multiplied it with 1.6.

If it is a compression, then you further multiplied with 1.25. So, that 1 will give you that 1. So, that tau b d tension

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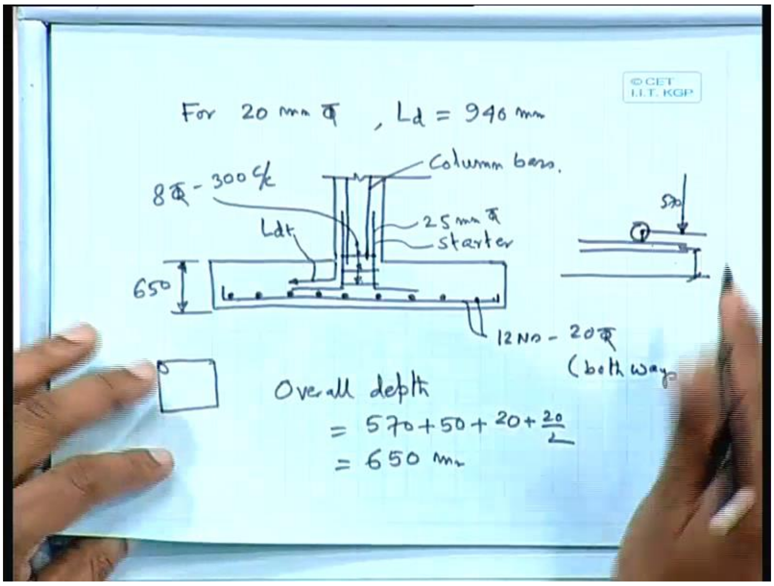

So, for 20 millimeter torr L d equal to say 940 millimeter. We can get this 1 in s p 16 also. Whatever I am trying to do all the problems, I am trying to do it, from the first principle using equations. In other way, but when the design of is most of the cases we use say s p 16 that is special publication 16 can do it. So, from that we can find out this chart 20 millimeter torr l d equal to 940 millimeter, that also we can take it.

So, what about the, then your say what about your say putting that your, what is called that, how shall we provide the reinforcement? The reinforcement we provide here. So, there should be main reinforcement and that should be in both ways and I can say this 1 we have used how many we have got it 12 numbers. So, 12 numbers 20 torr both ways. We can provide this 1 say 25 meter torr that, we can provide it here. So, this is called starter. The starter bar we can provide and this 1 will be your say the development length. This is your length in development tension.

So, we shall get this development in how we shall go and then we shall provide the column bars. The column bars will go from the other bar you are providing. And at least you have to provide 3 links here 3 1 2 3 at least you have to provide and that 1 should be equal to say 8 torr at least. If it is not specified, at least we have to provide say 30 millimeter center to center, at least 3 tie stirrup, we call it here tie that we have to provide the ring type. It comes like this to hold this starter works and later on that that column bars will start. This is your column; column bars, this is your column bars. So, this reinforcement you have to provide and what about your overall depth?

Overall depth equal to say 570 plus 50 plus this 1, we are getting 50 plus 20 and plus 20 by 2. We are taking this 1 because, the other way also we have to provide, say 1 way you are getting, we should not stop it here because, for that is the 1 570 minimum. So, if we take, if this is your 1 side bar, the other side we are having this 1. So, the center line of this 1 and this is your clear cover. So, this length is equal to 50 plus 10: 60. But effective depth, for that we have to take it this 1, because this is the 1 that effective depth we have to consider. Because other way also it may help. So, that is why this is effective depth.

So, 570 plus this 10 the 20 by 2 plus 20 plus clear cover. So, we are getting here 650 millimeter.

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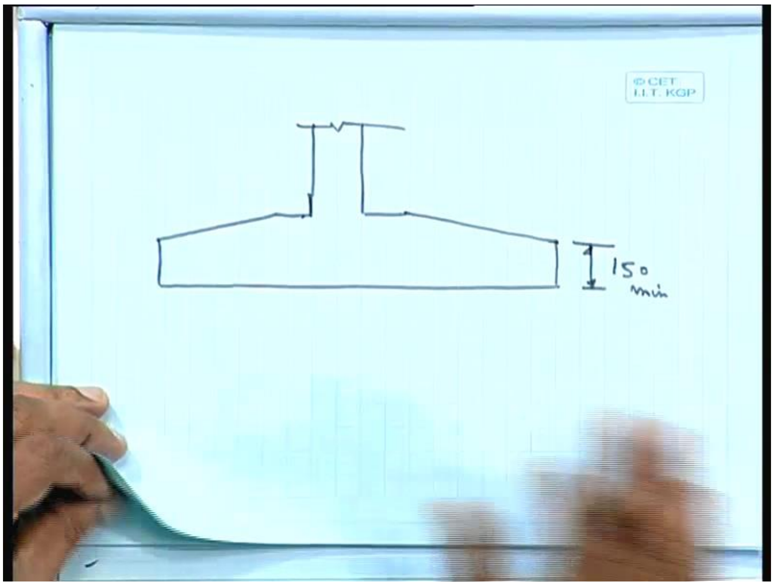

So, overall depth that is 650. Now, we can make it other things also we can do it, but this 1, we have to we are talking say square footing with this type of thing we are talking. Because, we can reduce this 1 also, we can further we can reduce it. So, that also, but anyway we have not so far, we have not considered that in our calculation, but we can further we can reduce it say like this.

So, we can find out and it should be minimum 150, 150 is the minimum we cannot go beyond that. So, 150 is the minimum that we have to provide, if we make it slope. So, again we have to calculate that effective depth, all those things here and that is a separate issue. That here we have considered that 1 constant depth throughout.

So, I think we can stop it here today.