Design of Reinforced Concrete Structures
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Lecture - 24
Design of Footings Part I

Well so far done up to design of columns that means, the load that started from the slab then, your through beams it is transferred to the column. And now, what we have to do that load we have to transfer to the ground. So, that is we have to now design the footings or foundation. So, column will transfer the load on the footings and we have to give sufficient area. So, that it will take that it will that it will not cross the limit of the bearing capacity of soil.

So, your geotechnical engineers after the soil investigation they will provide us the bearing capacity of soil that is the basic thing we need. And according to that, we have to design that the base of the footing and also you have to provide the reinforcement. So that, foundation of footing that 1 will not have any crack or it will not say kill. Generally, it happens that when you are having say column here.

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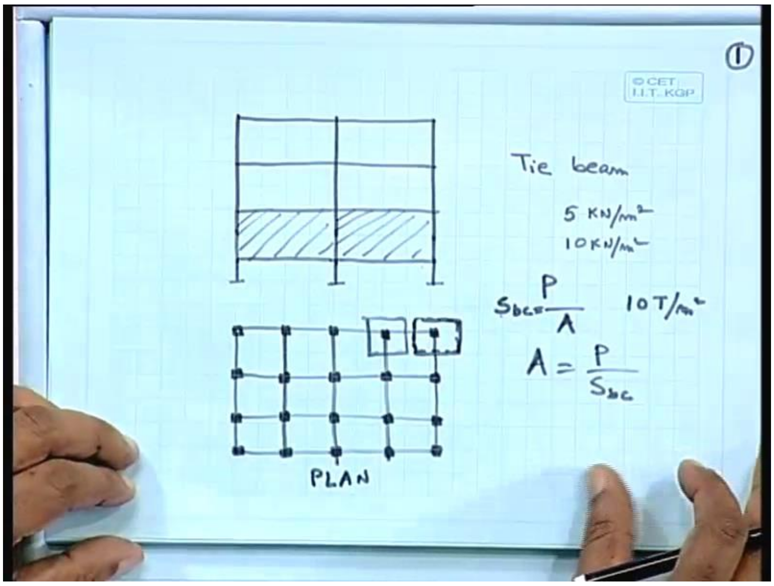

Let us, say column these are the different columns we are talking 1 frame we can go little further, it happens that we can also provide that tie beam. It means we are providing here tie beams, we are not giving any separately we are not giving any say foundation for masonry wall. Wall is generally, it is made of masonry. So, for that we are giving any say foundation what we are doing as if the here if we have the masonry wall, that load will be transferred to again column this masonry wall. And finally, it will come to the ground.

So, it may happen that there are so many ways we can transfer the load depending on the situation it may happen that one. That generally, it happens say it can start with say that 5 simply say 5 kilo newton per say square meter. Then, we can have say your 10 like that this is the beam bearing capacity. So, we can go to the different bearing capacity we can go and depending on the if the bearing capacity is less and load is more on the column then, your footing size will be bigger.

So, if you have plan of a building where we are having so many columns and each of them we have different column position. So, these are the column positions we are looking that say plan of a building and these are all columns. We have to give certain dimension of the footing because, directly that if we simple say 300 millimeter by 300 millimeter, 400 millimeter by 400 millimeter that column.

So, we can consider that 1 compared to the dimension of the building you can almost consider that column dimension is just say a needle. So, that means if we just keep it over the soil it will simply piers. So, because the soil bearing capacity that how much it can take that 1 dependent on that whether, it will piers or not. If it is hard soil or if it is rock then obviously, it will not penetrate otherwise, it may penetrate. So, because of that we have give certain dimension here also and that we shall find out.

Or it is very simple if p is the and bearing capacity say, I can consider say any bearing capacity say Sbc soil bearing capacity if I consider. So, I can find out P by A; A is the footing area so, if I know may say 10 ton per square meter. So, if we have 10 ton per square meter is your say bearing capacity of soil. So, depending on that we can find out say bearing capacity of soil if we know. Then, I can find out what is the area of footing that will be equal to P by say bearing capacity of soil.

So, I can find out the area of the footing that we can find out. And then, whether we shall provide that 1 say rectangular column, rectangular footing, square footing. Or if this area comes say it may happen, this area is coming such a way that if I consider the individual footing then, it may overlap that is also possible. That means, here that whatever area we are getting for this column footing and whatever area we are getting for this footing that it may overlap. Or we are having very little, very small may be say 100 millimeter may be say 50 millimeter gap so, we can avoid that. So, that way we can make it say full whole 1 as it say bridges wrapped 1 we call wrapped type of foundation also we can make it.

So, for bridges particularly, also for say your high raised buildings for that also we have say pile foundations. If it is so, particularly for bridges that we make it say pile foundation also for buildings also we make it high raised buildings not for ordinary 1 say your say 3 storied or 5 storied or 5 storied not like that. But if the bearing capacity is less then, we have to make pile foundation also that is also possible.

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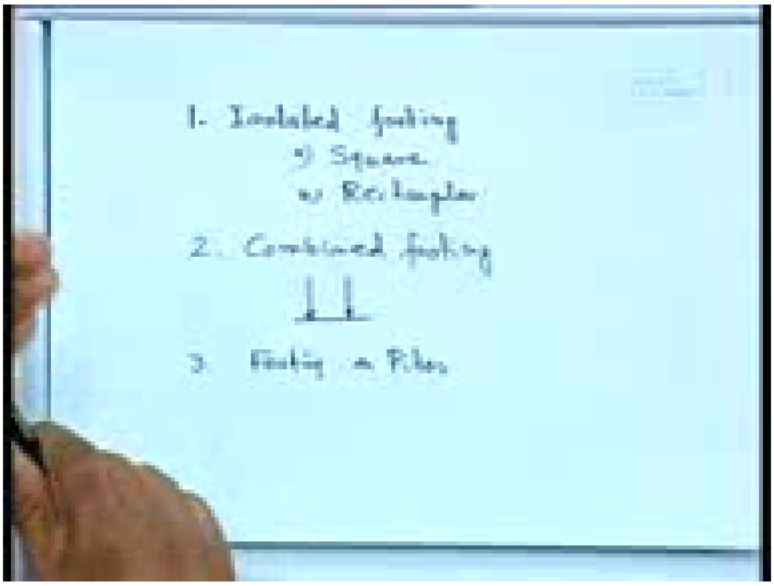

Now, 1 case it may happen that is called say isolated footing our objective in this class, just to introduce what are the different forces come in the footing. Then how to design, what aspect you have to consider that is your objective. If you know 1 or 2 cases then, immediately we can do for any other case. So, that is our objective here. So, isolated footing it may be square, it may be rectangular, then we can have combined footing, simple we can have only say 2; the 2 columns the columns are so close we cannot give 1 any isolated footing.

In that case, I can give 1 combined footing; the combined footing may be for 3 or 4 also, but generally we make it for at least for 2 generally we make it here. And what type of that say that, footing size all those things you can find out for combined footing. The other 1 say, footing on piles we shall mainly find out today at least say square footing, but before that let me show you how it comes that piles.

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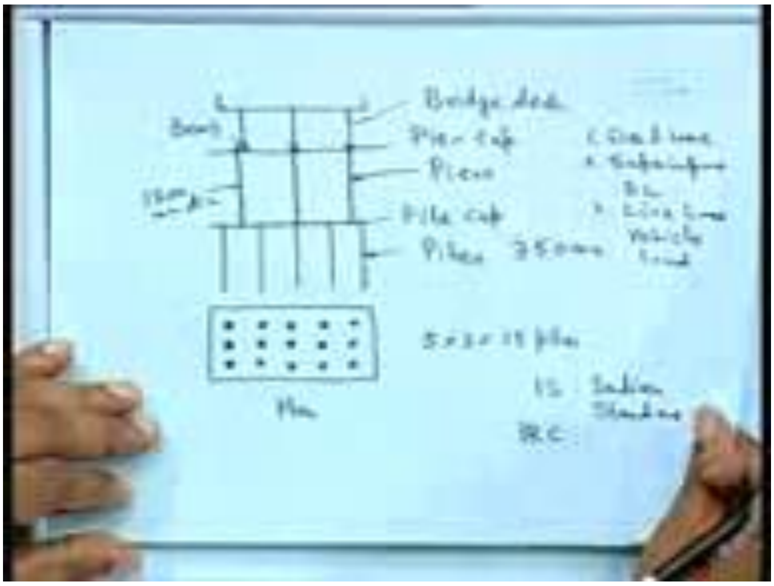

The pile footings it comes generally, say this is the pile that say your I mean to say that where we provide the piles. Let us, say we have provided piles of 3 1 so, there are say 5 into 3 15 piles may be say 20 meter long, 10 meter long those piles. That means, it comes in this way this is the 1 plan I am talking. So, we will have say 1 2 3 4 5 and over that these are called piles each of them may be say 300 or 350. Just give you, some dimensions at least you should know what is the dimension may be say 350 millimeter 400 millimeter that diameter over that this is called pile cap

So, over that we should have I am talking for say bridges over that we should have may be say 3 a big 1 just a schematic 1 I am talking. These are called piers here each of them pier and this is called pier cap what could be the dimension of this 1? It may happen, 1200 millimeter dia, 1500 millimeter dia of the pears. Each of them because, just to give you certain dimension this 1 can come say your 1000 millimeter, 800 millimeter the depth.

Then, this pier cap it can come say 1000 millimeter the depth of the pier cap and over that the bridge deck will come. We will provide the bearing these are called bearing and over that, your Bridge Deck will come this is called Bridge Deck. So, you can understand that now we transfer the load just though it is we are going a little bit out of context.

But even then, I shall tell you and that we shall do it at least for multistoried building later on. We shall analysis as well as, design that 1 and what are the different load cases. Different load cases: come 1 is the obviously, your dead, the other 1 we call it say superimposed dead load. Then, live load in terms of say vehicle load that means, different classes of vehicles here; what happens here, that just for your reference I shall tell you 1.

So, far you know that IS: Indian Standard and another for roads that is IRC: Indian Road Code that IRC those codes are available for say you're for roads. And also, your say for pavement for bridges also. So, those things it is available here as a structural engineer where we are interested. We are interested here that, what is the soil condition say at least we should now what should be the pile length.

The length of the pile you should know then, we shall provide the dimension of the piles may be say 350, 400 millimeter whatever it is coming. So, that whatever load is coming at the top that, load should be safely transferred to the ground that is our objective here. And since, you can understand this 1 that we are having different piles over that your having 1 plate, over that your having piers, generally 3 piers generally we provide. Then, over that we are having pier cap finally, the bridge deck is coming that which is called superstructure.

So, 1 part is called superstructure, the other part is called foundation. So, up to the pier cap that is your foundation I talking this 1 for piles though that is not in our scope. Here in this beginners course, but I would like to say that 1 that how to design. But here also, it is based on your say bending moment, shear force and axial load. In addition, to that we will find out also torsion also so, far we have not covered mainly we have covered say bending moment, shear force and axial. Now let us, come back to our say footing and that 1 say your isolated footing.

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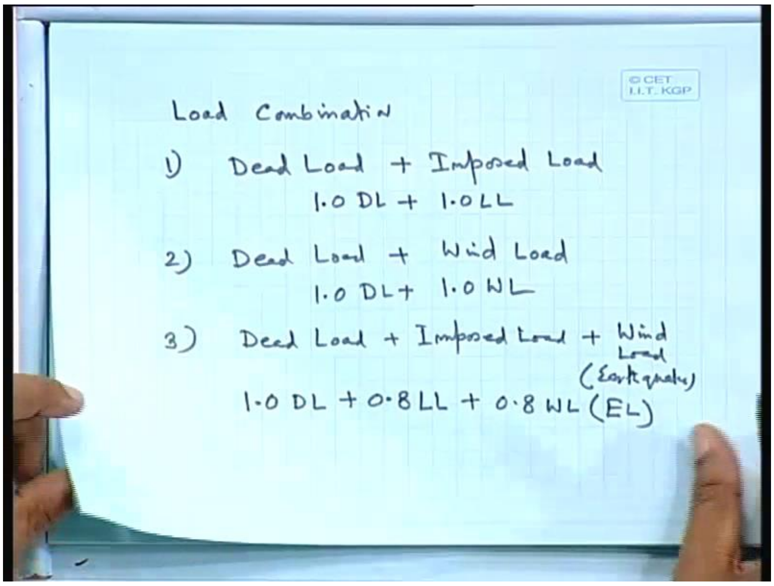

Then, what should be your loads it should have load combination: number 1 dead load plus imposed load. So, it comes please note for calculating size of the footing for size of the footing we do not take that 1.5. Because, we are noting the limit state rather, we are taking that 1 say working stress. Because, the bearing capacity of the soil is given as say you are working stress that 1 that serviceable 1, not the 1 limit state or ultimate bearing capacity.

Because, ultimate bearing capacity divided by the certain factor of safety will give me the safe bearing capacity of soil which is the serviceable 1. So, that is why here we do not multiply with that 1.5 we multiply with say 1.0 that is for dead load plus 1.0 say live load that is 1 case. The other case that, dead load plus wind load which comes as 1.0 dead load multiplication factor 1 plus 1.0 wind load it could be earthquake load also. Number 3, dead load plus imposed load or live load plus wind load or earthquake.

So, it could be earthquake load or wind load which 1 is the governing 1 that we have to find out we check it. So, here it comes as 1.0 dead load plus 0.8 live load we take it when, we consider the live load as well as wind load we take that factor. Or 0.8 times wind load or earthquake load what I would like to say here. These are the whenever, you are doing analysis you have to find out different cases that which 1 is the governing 1.

Then, you have to get different cases for this say your building, we get these are the 3 different load cases we generally get. So dead load, live load that is 1 case then, it may happen dead load also another 1 case also it may happen dead load. And impose load, dead load and wind load, dead load, impose load and wind load or earthquake load. Either, of them we shall take it we generally do analysis and find out which 1 is the governing 1 and we take that load.

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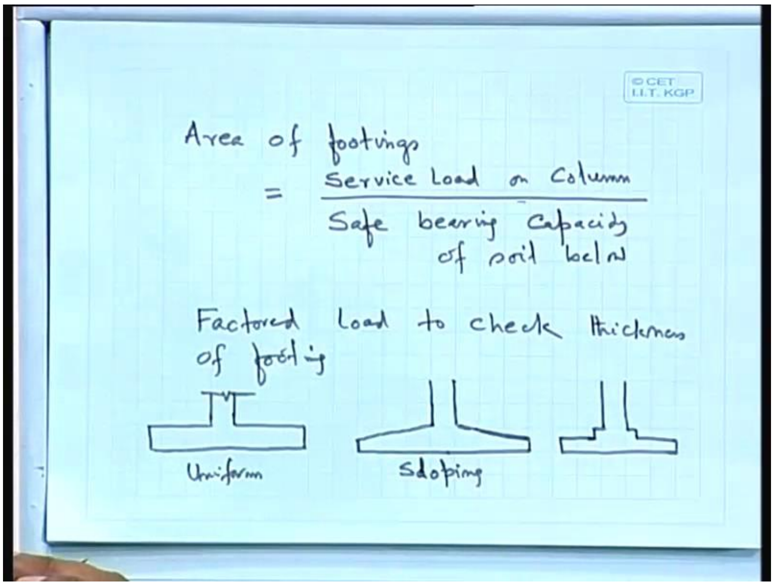

So, what should be the now come back to the area of footings we have to calculate. So, service load on column divided by safe bearing capacity of soil below. So, if we know the service load that means, giving the proper multiplication factor 1.0 this case or 0.8 with the live load and the wind when you are talking. So, service load on column divided by say bearing capacity of soil whatever there on the basis of that, you can get the area of footings.

So, up to this you will get your that service load, but now we have to give your say dimensional thickness of the footing. So, when you have to give the thickness of the footing, in that case what you have to do. Then, we shall go to the factored load. So, factored load to check thickness of footing in this case we can have just simply, if this is your column we can have like this I can make it that uniform thickness.

Then, It is also possible to make it sloped slopping because, I do not want I know that here bending moment here 0 because, after all it is a cantilever 1 I can say. So, bending moment 0 here bending moment maximum. So, I can reduce my thickness. So, this way make it this is uniform then, slopped slopping and the third 1 also possible we can make certain kind of step like this we can provide. That means we can up to certain distance we can provide that 1 say some kind of say pedestal or say step 1. And then, after that we can give uniform or we can give slope also.

So, depending on the situation that we can make it, but this is the very simplest 1 if we can make it because, here only thing here we have to find out, what load cases say what type of say stresses will develop. When, you are talking say your footing what type of stresses will develop. If you look this 1 let us, take this simple 1.

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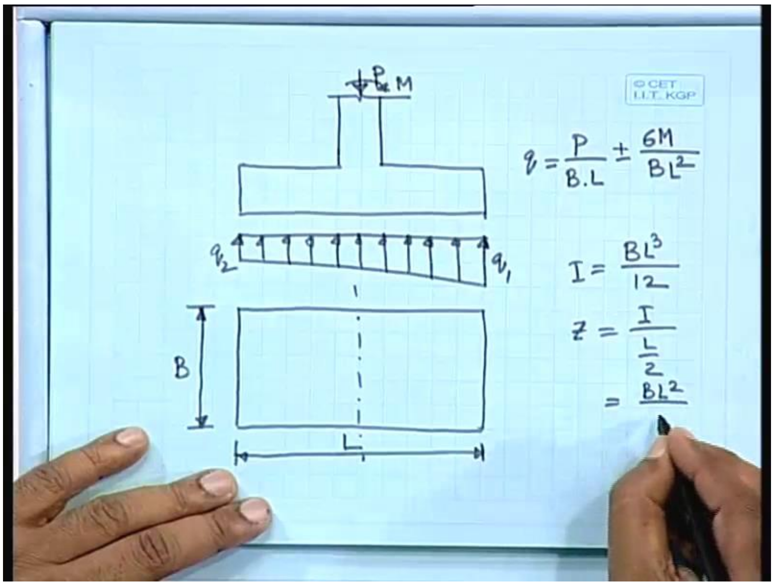

Let us, say the load applied P and moment say M and the plan of the footing let us, say this B that width and this is length L. Since, we are having moment here so, we shall get it will not be uniformly stressed since, we are having moment. So, because of that we shall if we have axially loaded 1 then, we shall get uniform all along. But here since, we are having moment what we shall get we may get something like this.

So, this 1 let us say q1 maximum stressed this 1 your say q2. So, q I can write down here P by B into L and let us say, plus minus M by z; z is the section modulus I can say. So, 6M by BL square I equal to BL cube by 12 I of this 1 with respect to this axis BL cube by 12. So, My by I we are talking L by 2 and here another L by 2 because, with respect to this in other way I can say the z equal to I by L by 2 which comes as BL square by 6.

So, I can get q that is this side that q let us write down q1 or 2. So, q1 will be P by BL plus minus 6M by BL square and this side q2 P by BL minus 6M by BL square. That means, depending on and another way also we can make it we can do 1 trick what we can do since, we are having this 1.

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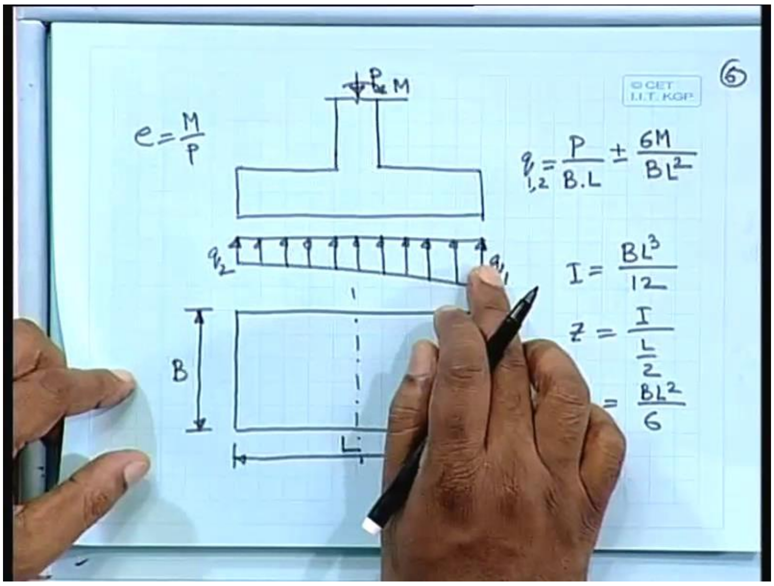

So, that means, say e equal to M by P I would to make it uniform. I would to make this 1 uniform this stress what we can do.

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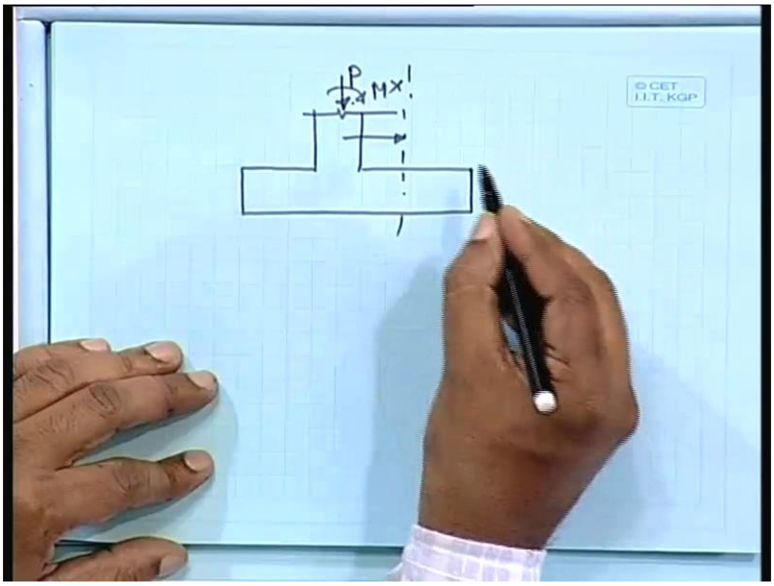

So, we shall do it this we shall have little upset or in other way, I can say instead of having M here. I am not providing M here, what I am doing as if it is at a distance say I should make it here little bit.

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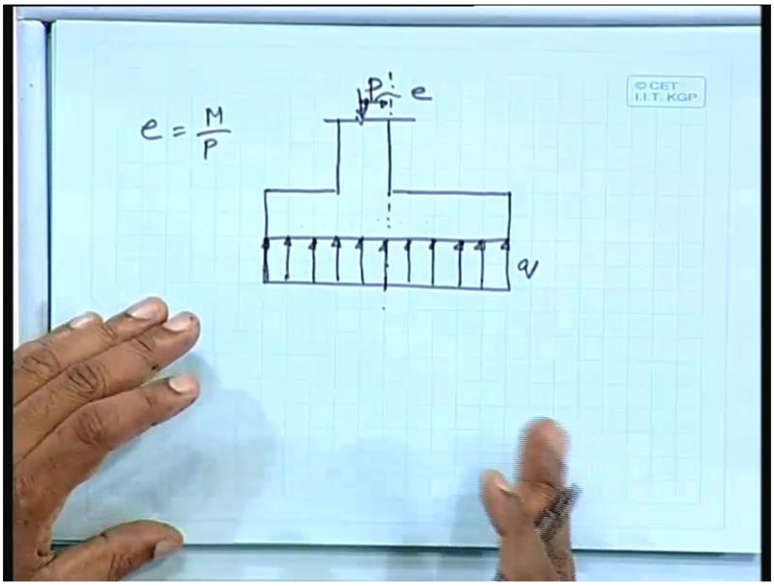

Let, make it clearly then we write down. So, I want this your P and let us say, I can have as per my this drawing so, I can have this is your e. So, e equal to M by P and then, what we shall get; we shall get the uniform. Uniform soil pressure that q this way also we can make it. So, this 1 way generally we have acquired this 1 we generally, keep the central line of the column and the central line of the footing same.

Generally because, this way makes it that we should not have any that in this case you are getting uniform soil pressure whereas, in the other case, the 1 I have told in this case we are getting that 1 side maximum and the other side less. So, it means that if we get P by BL plus minus 6M by BL square see in 1 case it may happen that, I shall get this side 0 that q2 equal to 0 I shall get depending on the value that e.

So, I can get q2 equal to 0 1 case it may happen if we further we go. Then, also it may happen that, I shall get only certain portion, but not fully it is in contact that is also possible.

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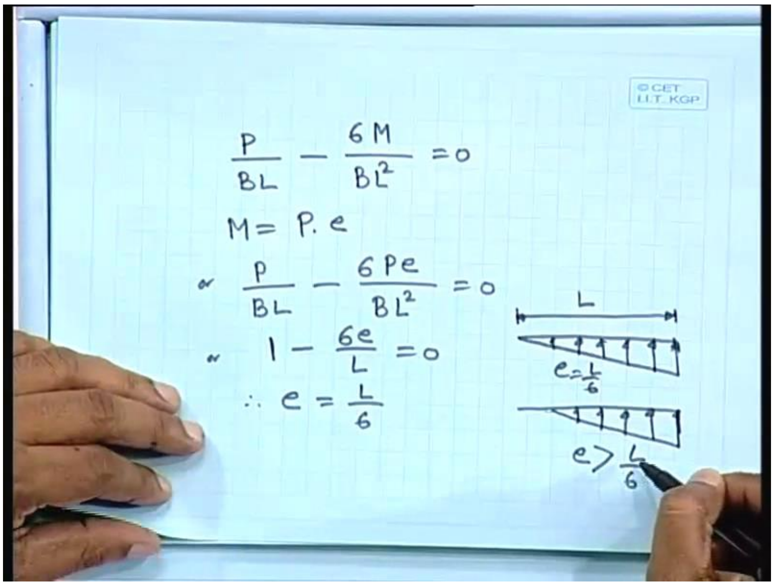

So, if we write down here P by BL minus 6M by BL square equal to 0. So, what shall we get here M equal to P times e the other way I can write down M equal to P times e. So, I can write down or. So, equal to e equal L by 6 that means, if we get e equal to L by 6 in that case what will happen, it will happen that you will get only on 1 side. That means, if this is the length L of the footing so, in 1 end we shall get 0.

So, if the P or e exceeds that L by 6 value then, what will happen we shall get we may get certain lengths say this. That means certain portion not in contact with the soil, this is if e greater than L by 6 this means, e equal to L by 6. So, these are the different cases we only consider that e equal to L by 6 greater than L by 6 all those this so, generally we have.

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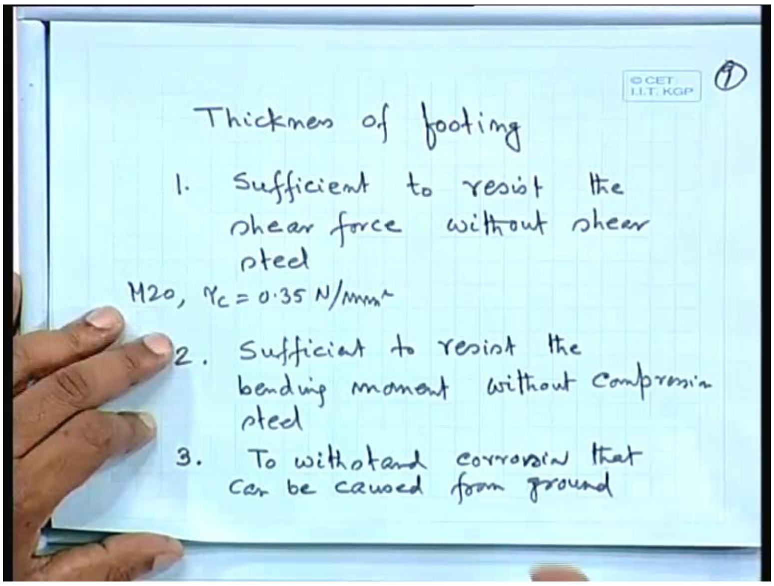

So, let us come back the thickness of the foundation or footing what should be the thickness of footing, how shall be what is the governing criteria. It should be sufficient to resist the shear force without shear steel. So, our case here that we have to provide the thickness of footing such that, it will resist the shear force without shear steel. That means, stirrup we do not provide any stirrup. That means, in this case for M20 grade of concrete we have give; that means, your tau c for M20, tau c equal to 0.35 Newton per square millimeter.

So, that means, that value shear stress should come less than 0.35 Newton per square meter minimum critical 1. If I say just for your let us, check it that will be available that is your say 0.28. But depending on that is your 0.28 that is the minimum, as per Table 19 of IS: 456. But if we know the area of steel the area of tensile steel depending on that, we can take that is say 0.35 that is why i have told 0.35.

So that means, as if we are giving certain say tensile steel on the basis of that, your critical stress of the shear stress that is actually we have to find out. So, that is why i am telling say 0.35, but as per Table19 for M15 0.28 M20 also 0.28 M25 0.29, but that is less than equal to 0.15 percent. But if we provide say 0.25 then, we are getting 0.35 0.36 like that. So, we can take say 0.35 Newton per square millimeter.

Now, also it should be sufficient to resist the bending moment and here also we impose, another criteria without compression steel. So that means, shear force without shear steel that means, there was no stirrup and bending moment without compression steel. That means, only we are providing 1 side the tensile 1. So, in footing we shall get the tensile 1 at the bottom that 1 we shall get it.

So, here we are getting that also without compression steel we shall do it. And also we can note another 1 number 3, that to withstand the corrosion that can be caused from ground. So, at least you should have these 3 cases at least you should have for that you have to provide the thickness.

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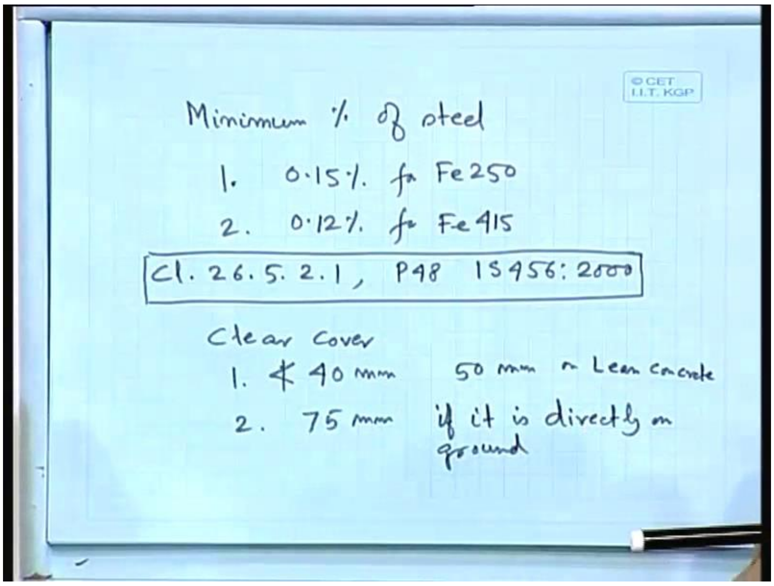

So, what about the minimum percentage of steel? In this case, we shall use that slab that whatever we provide the minimum reinforcement for slab that is 0.15 percent for Fe 250 and 0.12 percent for Fe 415 and these we will get in just for your reference clause 26.5.2.1 of page 48 IS 456 : 2000 the same clause for slabs. What about your cover? Generally, we provide say 40 millimeter not less than 40 millimeter.

So, let us say 50 millimeter we shall provide 50 millimeter if we have certain say lean concrete. That means, we are providing not directly on soil or say 75 millimeter if it is directly on soil. That means, if we provide that so if then, you have to provide 75 millimeter. Generally we provide say sand then, we are having lean concrete then, you provide that say foundation.

So, 40 millimeter or 50 millimeter let us say we shall provide for clear cover when, you are providing with on lean concrete. Otherwise, if it is directly on the soil on the ground then, we have to take say 75 millimeter. Now, let us come now I think what we can do instead of coming say let us, take 1 problem I think that could be easier.

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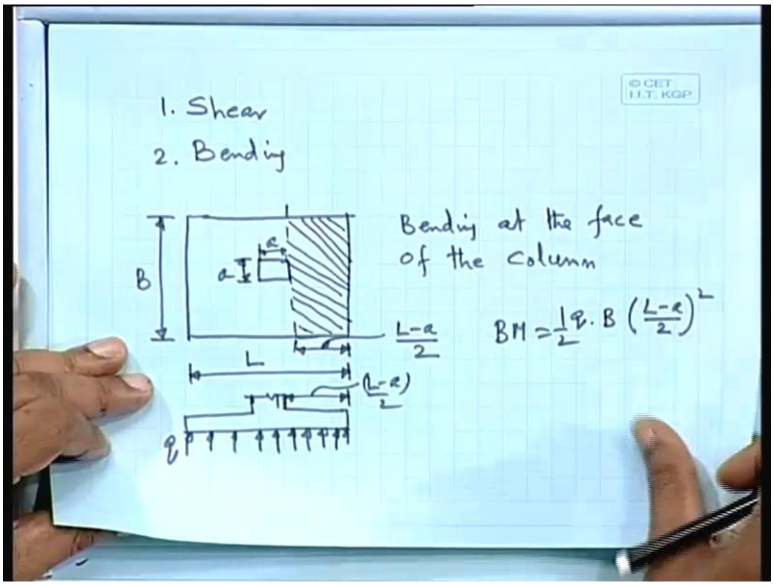

That we can do it, but before that let us take that we have shear and bending we take it say if this is the plan of the footing. The bending we consider at the face of the column. So, bending we shall consider at the face of the column. That means, if this your length L, this is your say B, a is the say column and let us take this is square. So, this length is equal to L minus a by 2 so that means, we shall take this portion L minus a by 2.

So, we shall take due to bending we shall find out the bending moment at this position and which will be taken care of as you say your cantilever beam. So, if q is the load that means, in other way if it comes this. So, this your say q and this length is L minus a by 2. So, bending moment will be equal to q times that is B this way and L minus a by 2 whole square.

So, I shall get this particular 1 here times half, this length we shall get it here. So, this is will be your that whatever the bending moment we shall get it, we shall get this bending moment here. And we have to check that thickness of this 1 we have to check it with this bending moment. So, for footing we have to check the bending moment due to the soil pressure whatever your getting.

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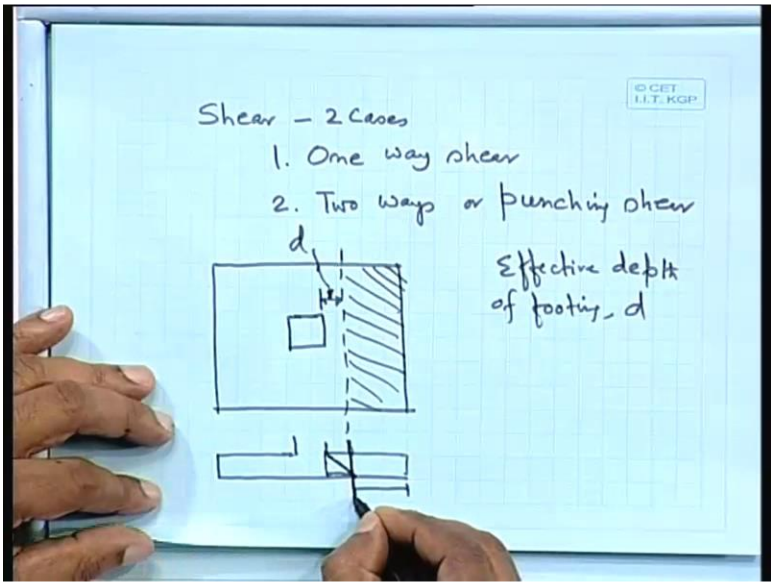

Next 1 we shall get it so that shear, we have 2 cases: 1 we call it 1 way shear, the other 1 is called 2 ways or punching shear. What about this 1 way shear? 1 way shear means, if this is the column position if effective depth of footing d. Then, we have to take a section at a distance d. So this your d that means, shear force we have to compute where this section compared to the bending moment.

So, we are getting the shear force at this section which is at a distance d from the face of the column, not immediately on the face of the column which we have done it for bending moment. Here we have to find out at a distance d that means, in other way I can say as if we are having 45 degree dispersion of the load. So, we are going 45 degree dispersion of the load. So, we are going to that up to say d; that means we are calculating the section here.

In other way, I can say as if we are having we are going here this your d and this is your d. So, I am going; that means, I taking this section this is 45 degree so, this your effective depth d. So, we are calculating here at this section and this is called 1 way, either we can compute here or we can compute here, but if it is rectangular obviously, you have to take the longer direction, not the width. Because, that there the shear force obviously, will be less. What about the punching shear or 2 ways or both ways?

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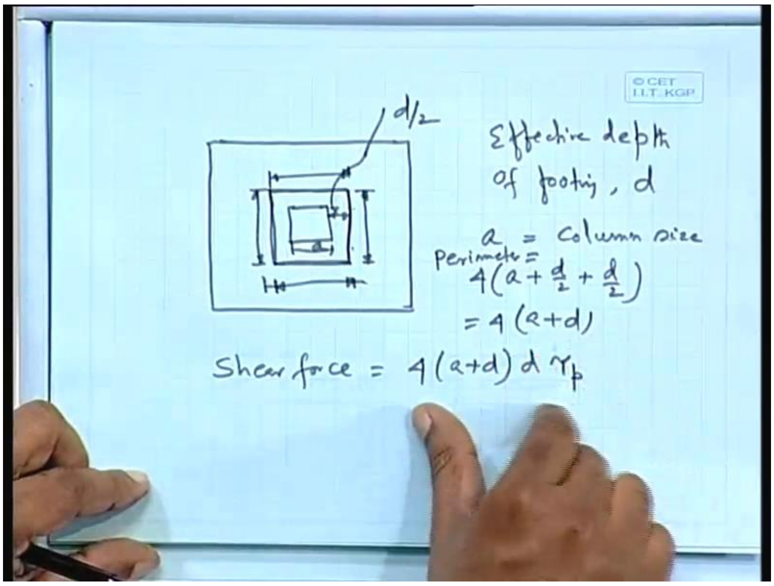

It means, if this is a column position. So, we shall go all along in all side and this 1 will give you at a distance d by 2; d is the effective depth of footing. What does it mean? What we are doing basically? We are doing here because, punching means simply it will piers that means, as if this portion we are applying load like this. That means, as if this portion simply break and it will just simply insert that 1.

So that means, having that 1 say plate and it will just simply your are piercing through that that is called the punching shear or 2 way shear. Or both ways, all sides your are having. So, what is the effective area that means, what is the area which is actually concerned with the shear if this is the length this is also. So, a column dimension say square. So, we shall get 4 times a plus d by 2 the total perimeter. perimeter equal to 4 times a plus d by 2 plus a plus d by 2.

Because, this is the a and d by 2 this side d and by 2 to this side and 4 times if it say square. So, we shall get the perimeter of this 1 that is 4 times this 1 which comes as 4 times a plus d. What about the shear force? The shear force will be equal to total shear force 4 times a plus d times the depth d please note we are talking the Perimeter this is the perimeter.

So, what about the area; area means along the I can say like this area means this 1. Because, this is the 1 say if this is your say d by 2 we are putting the I can say this is the column say, your that calculator that we are putting here that is the column. And we are going say at the distance d by 2 in all sides. So, we shall get the perimeter that we can compute. So, this dimension if it is rectangular so, it is a and it is small b say. So, a plus d by 2 d by 2 and this side may be b plus d by 2 d by 2 we can go. So, we can get the perimeter and we have to find out that which will resist the shear.

The shear will be resisted by this area because, if this is the depth of the footing shear will be resisted by this area. So, these area what will be the shear this will be the depth. So, perimeter times the depth that we shall get it. So, that is what I have written here 4 times a plus d we are talking say square footing so, 4 times a plus d times d times the allowable punching shear.

So, that is say tau p; tau p is the allowable punching shear. So, this 1 will be given that 1 say shear force and that should be equal to or greater than whatever, the your say column load. So, that should be equal to that means, not only column load including that also we have to add the self weight of the footing. So, self weight of the footing plus the load whatever is coming from the column.

Then, from there whatever, you are getting say total load, design load that 1 from there you will get the shear force that is the shear force that should be equal to or less than this value. Then, you can say it is safe.

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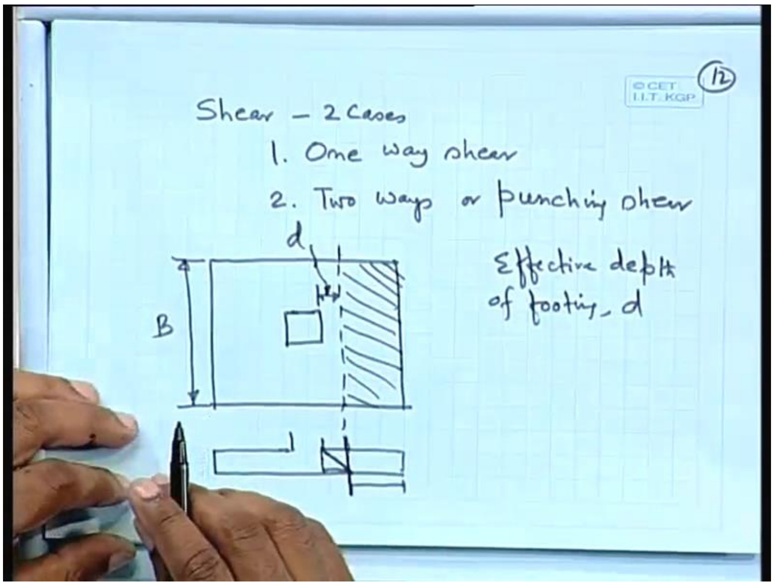

So, if I now since I have come to this 1 let us, come this 1 here if this your B or L. So, if I now since I have come to this 1 let us, come this 1 here if this your B or L. Let us, say this your B then, in that case what will happen here. I can find out the shear force here also shear force here. What will be the shear force here? Again, here B times the d and due to this load.

Because, that you have to resist this portion what about shear force will come due to this load, the left side at this section that we have resist. Here again, we are talking that 1 say the vertical section the 1 section overload whatever, we consider. That section we have resist so, depth times this length that you have resist. So, these are the different cases we get here. This 1 I mean to say that since, I am taking say d is the distance I can say as if this load dispersed at say 45 degree.

So that means, if this is your d this 1 also will be d. So, that is why taking that 1 say at a distance say d; that means, in the other way I can argue that as if we are taking a section and as if your having say 45 degree load dispersion that we can say. So that means, if you have to design the your say thickness of the footing we are having 3 cases: 1 case is the bending, another case shear; shear having 2: 1 is called 1 way shear and another 1 is caller say punching shear or 2 way shear.

On the basis of that, only we can provide the thickness what we generally do, we generally find shear in that your footing that is mores. So, we can calculate depth that generally the usual procedural in design you calculate depth from any 1 of the 3. Either shear from punching, shear from way or bending you can calculate the depth and you check for other whether it is satisfied. So, that is the usual procedural here what we can do, you can find out the depth from 1 way shear and then, we can calculate for others.

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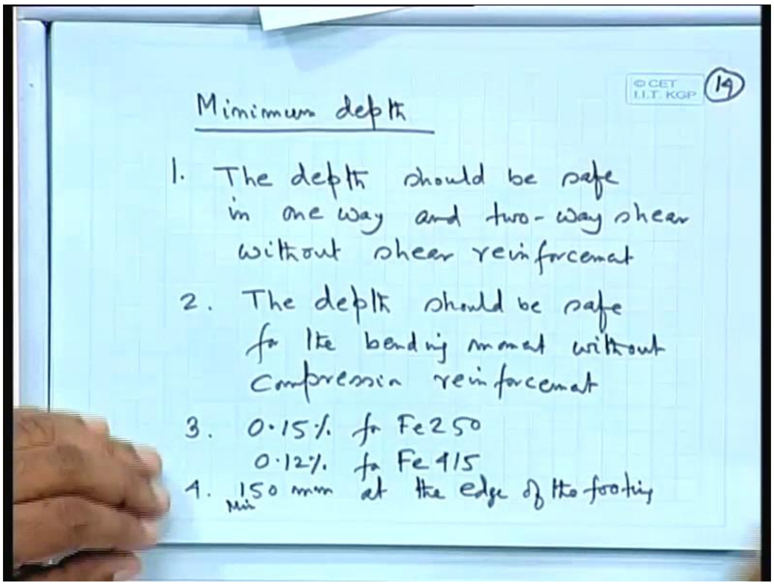

So, let us check here I think we can start solving 1 problem, but before that I think we shall actually we get time. So, we shall take may be say let us keep it for the next class. So, let us at least tell say minimum depth so, let us at least write down depth should be safe in whatever I have told just let us, just simply enlist it. The depth should be safe in 1 way and 2 way shear I have already told.

But let us, just write down without shear reinforcement. The depth should be safe for the bending moment without compression reinforcement. So, we can take this 1 and I have already told 0.15 percent for Fe 250 0.12 percent for Fe 415 as well as 500. So, this depth we have to provide and also we can say 150 millimeter at by the age of the 150 millimeter at the age of footing that should be the minimum depth.

So, I can write down here 150 millimeter the age of the footing. So, and but 300 millimeter if it is 1 pile foundation 300 millimeter that is the minimum. This 1 I am talking minimum. So, minimum 150 millimeter at the age of the footing if it say minimum say 300 millimeter if it is on the pile. So, I think I can stop here today.

So, next class we shall solve problem at least 1 square footing and because, our main objective here that we have to finish it that all the different components this footing because, we have done slab, we have done beam, we have done say columns and we have done say your now we are doing footing and 1 more we have that is your say staircase.

So, that at least for at least building we shall have all the components. Then, only we shall we shall start with at least 1 multistoried frame, multistoried building we shall design for all the components starting from the analysis and then design.

Thank you