Design of Reinforced Concrete Structures
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Lecture -26
Design of Reinforced Concrete Structures
Design of concrete staircases

Well, so today we shall learn how to design stair cases. So, far we have done design of slabs, design of beams, design of columns and design of footings. So, one of the important element for the in any building or structure that is stair cases, because that one only will help us to go from one floor to another floor. You will find out different kind of stair cases. We can say this is our that lecture number 26, which we are going to deliver on the design of stair cases.

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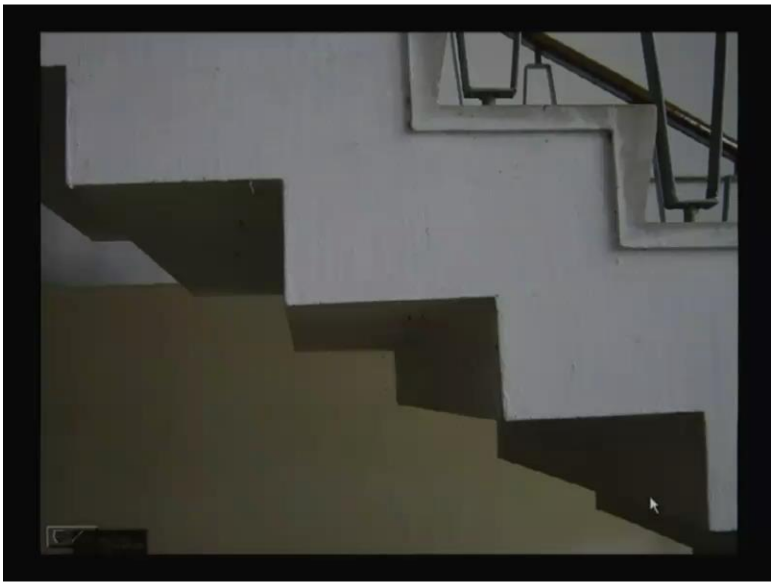

This one type of stair case, you will not find out merely, but this is one type sometimes even in our campus also we can find out few of them. This is the same view; the different view of the same structure. So, here you can find out as if the stair case, you can say as if the bricks one after another it is just kept and you are going from the one floor to another floor.

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This is another type, compare to the other one you can see another type. Here, I think I can show you.

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This is your stapes and were you can find outthe beam, in the back there is a beam and these beam is supporting and I think the last view will be better, yes here there is the beam here and over that all the steps are supported. So; obviously, the past one which I have shown there is one kind and this another one kind of stair cases, which is supported by the beam and over that your steps are there. In that steps you can say easier can cantilever beam again. So, that you can design.

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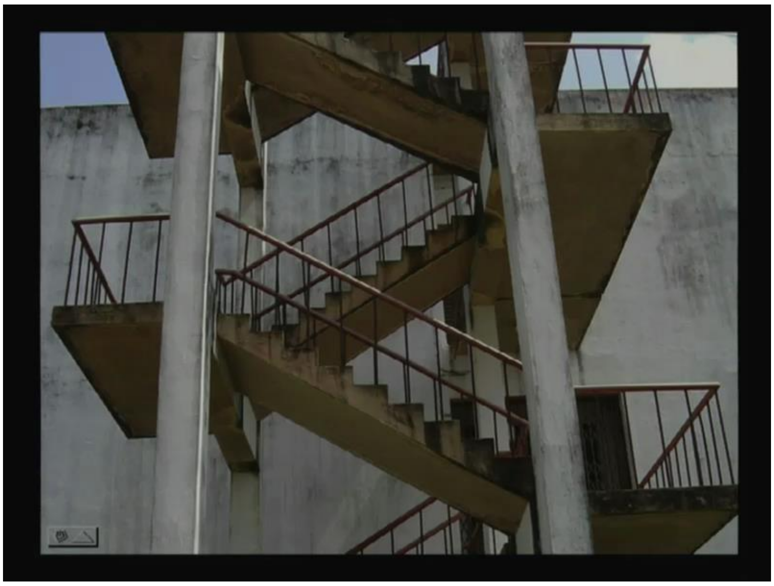

But the most popular one... So, this the other view this 1, we will find out most of the design you will find out this type of stair case, this is the most popular 1 and we shall design this 1. But I shall tell you that how to design the other stair cases also. What you have to find out, what you have to do for any stair case what you have to do and you have find out what is the governing, 1 the bending moment how it is acting about which axis and then according to that you have to design as well as shear force also.

So, this is your 1. So, you can say this portion is continually work, this is 1 column and this is another column, which is supported by the 2 beams; 1 this side and this side and this slab, this is the 1 you have. I think that is all I have the photograph so for concern. So, but I can say here; there is 1 stap here, you can see those staple all the steps. So, you have to consider the dead load of the steps also, weight of the steps also and this is called waist slab. So, how to design this 1; if you like to say that I should not consider this, the last 1 I have told the steps 1 after another, but here we are assuming this stapes are supported by this slab. So; that means, I can design that slab.

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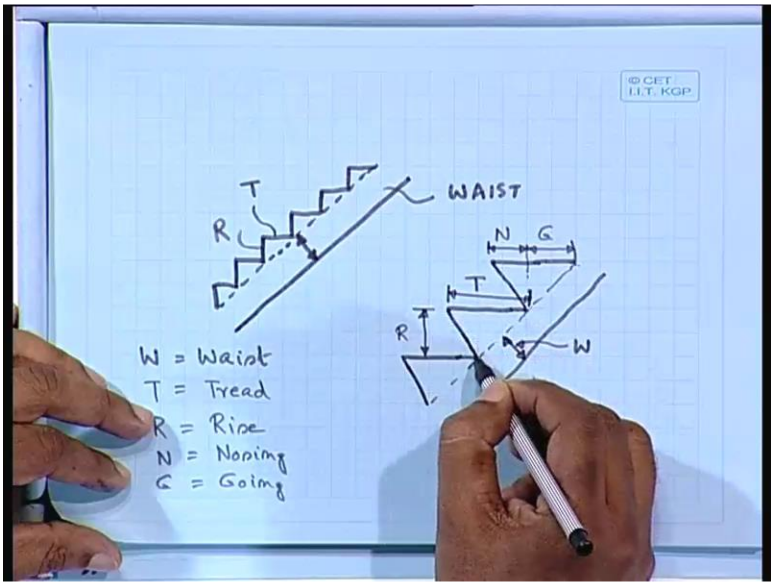

If I know draw that figure we can say; so this is your slab which we have to design. Over that, you have these steps, these are the steps. So, what we have to do; we have to design what about this depth, this is called waist. There are two things: 1 is called rise R and this is called tread T. So, we have if we make it very very different one, in the sense, I can write like this, sometimes we can project little bit; so let us make it some kind of projection and then I can go again this kind of steps. Yes like that it will go.

So, if we move and then you have; it is supported these steps are supported by this slab. So, what we have; I can say different components that dimension, this is W which is called waist. Then 1 is called from here to here we have trade T. So, W waist, then T tread, then we have R rise and we have certain portion; this is called nose N nosing and this portion is called going. So, what we are assuming here; in this case we are assuming that we shall take the dead load of these steps we shall take, but all the things will be supported by these waist slab. This is the most common 1.

The other case is that as if you are having 1 say your beam like these; as if you are having one, you having one beam like this and what you are doing here then above that there are steps are like this; that is first one I have shown you. So, that design will be different compared to this one. So, this is most common one. So, let us see how to design this one.

So, now the first question arrives is what is the length of that dimension of the rise and tread, nose, going what is the dimension off that? That is first 1 we have. Generally in residential building or factory building, generally what we can do; we can increase little bit that rise, whereas the public building that one we make it say 150 mille meter, but whereas in the residential building we can say 160 170 millimetre we can go. But also another 1 we can say and this height arise and tread and there should be some kind of proportional. If so far that concern at least though I should not tell it here, but you should note down that, our subway in our that in Kharagapur station; they are steps it is the steps little wider, not little quite wider then the rise and we feel little discomfort actually only. So, that type of composition should be there so that we cannot feel any discomfort.

So, let us come and also compared to say your general load general load, if you compare that, balcony it may be crowded that because, your rooms whereever that 1 say load or the balcony it would be crowded more. Similarly, you say the stair case also, the frequent chance that may be crowded. So, that is why more compared to the standard load on the rooms. So, here the first thing that, what is the dimension of these rise and tread and second 1 what should be the loading and these two things should be consider in our calculation.

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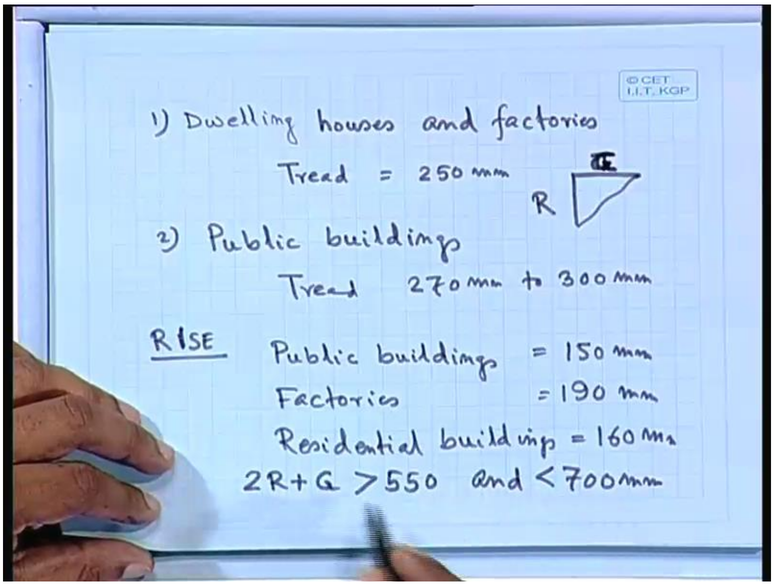

So, you can say number one that dwelling houses and factories. So, if you consider this 1, the tread 250 millimetres, whereas in the public buildings it will be in the range of trade of 270 mille meter to say 300 millimetre so, the horizontal portion. What about he raise? So, for public buildings it will say 150 mille meter and factories we can go little higher 190 mille meter and residential building is 160 millimetre. So, this is your rise and this is your tread. There is a popular formula; we can write T as G tread or total that we are talking so G also we can consider there.

So, now 2R plus G that 1 should be greater than 550 and lesser than 700 millimetre. We can take it 2R plus G the rise plus going, so that you can take 600 millimetre that we can take. This is called residential building, for any building you can take it, but only you are changing. So, residential building you can take 2R plus G is equal to 600. But anyway, you can find most of the cases in 150 mille meter and in 160 mille meter rise or we can say 250 mille meter or 260 mille meter per tread that general you can consider. And it is also dependent on your on this formula.

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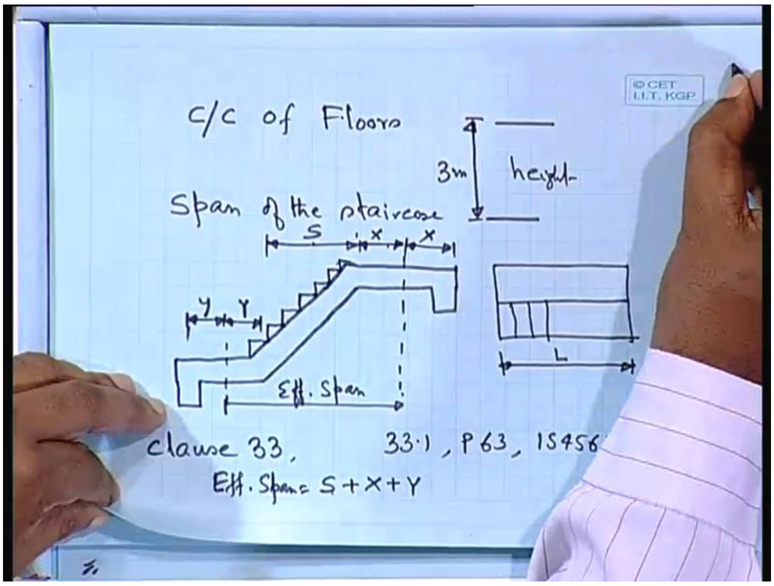

We can also say were it is dependent on the centre to centre of that floors. That means: if we have means this is one floor and this is another floor. So, what is the distance this height; that is is very very important. If it is 3 meter, accordingly we shall distribute. Similarly, we have the length that size of the room, were you have to accommodate. So, if this your height and this is your length, so you have to accommodate here. So, depending on that, how many steps that you provide; that also it depends. So, it not necessary that we shall keep it with in that range; that means, we can 250 millimetre and the other one within say 1 mm the range say 150 millimetre. So, you can go little higher little less 5 mille meter 10 mille meter that does nott matter. So, but also this is depend on two things.

Now, next part is that span of the stair case. So, we have to calculate the dead load, live load and and we have to find out the span. So, from that we can calculate the bending moment as well as the shear force. So, what we generally do; there are few cases. Let us say this is your beam and it is supported like this. This may be one case. So, what about this 1 and what about and here the steps are here and the steps may be constructed by bricks. So, when we have the solution to the dead load of the steps. So, what about the effective span? These 1 we shall find out in clause 33 more physically 33 point 1 page 63 of IS456 2000.

So, the effective span which we taking here for this case, this one upto this one we say x and this one we can say y. And clause this your effective span as we say is the distance. Our code says if x is less than 1 and less than, y also less than 1, if x and y that means: if x and these 1 of another y, then u take s plus x plus y; that effective span, but if x is greater than 1 and y also greater than ,1 then you take plus 1 because, if x greater than 1 meter, then take 1 meter, then y is greater than 1 meter you can take 1 meter, otherwise if it is less than 1 then you take that x only. So, here I can say though I comes, taht this is your effective span I can write down it as s plus x plus y, but code says this is our effective span, which we will get it in this clause.

So, our code says that if x is less than 1, then you take it as x only whatever value you getting you say 0.75 meter you take it 0.75 meter, 0.8 metre also you take it, but if it say 1.2 meter, then you take it as 1 meter, similarly for y also. So, it should be these 2 values; that means, it should not be more than x plus 2. So, that means, now I know what should be or effective span. So, I know the effective span I calculate that your load.

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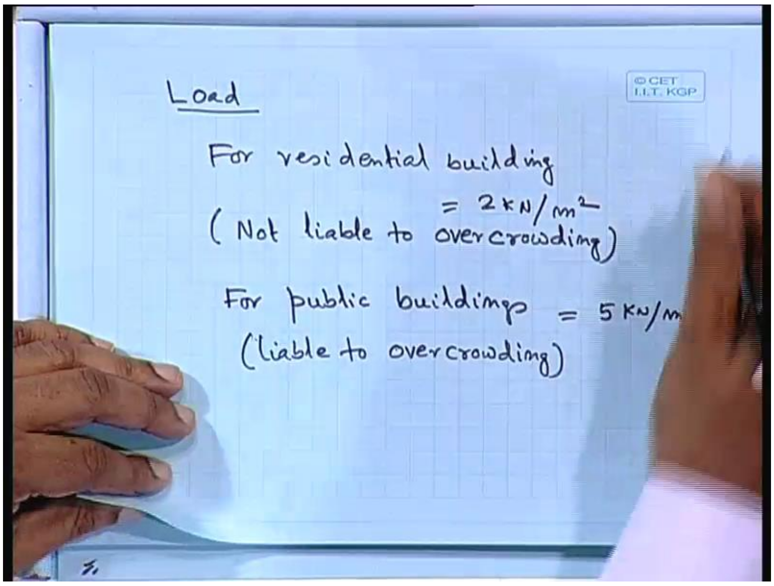

What about your load? For residential building; so for residential building we shall see that 2 kilo newton or square meter and there is a restriction not liable to overcrowding. That means, the staircase will never be over crowded. But public buildings they are that balcony and your staircase, that is, that it is very very frequent that regular features that it will be over crowded. So, for public buildings, it means: liable to over crowding and we can say 5 kilo newton per square meter. So, this is your live load. So, you have to calculate the dead load and then we have to calculate the live load.

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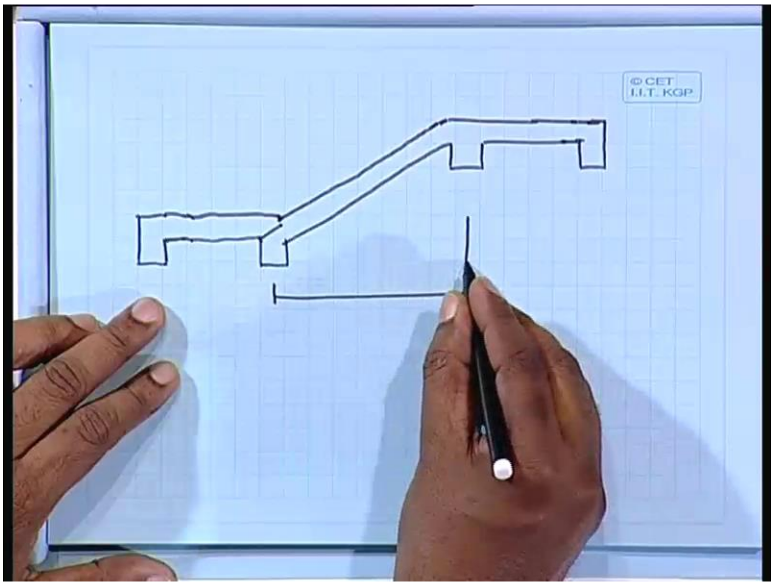

So, let us come on more case. The first 1 I have told you this is one case that I have told you, it is also possible one I have shown that is like this; it would be something the stair case is something like this and either it may be cantilever the case which I shown it here ; that means, it may have something like these also. So, in this case this is your 1 type. In this case what will happen the effective span here because, it will not have 1 such thing. So, effective span only enter to center distance between because, it was supported by these 2 beams. The first 1 we have shown that it is supported here; there is no beam here.

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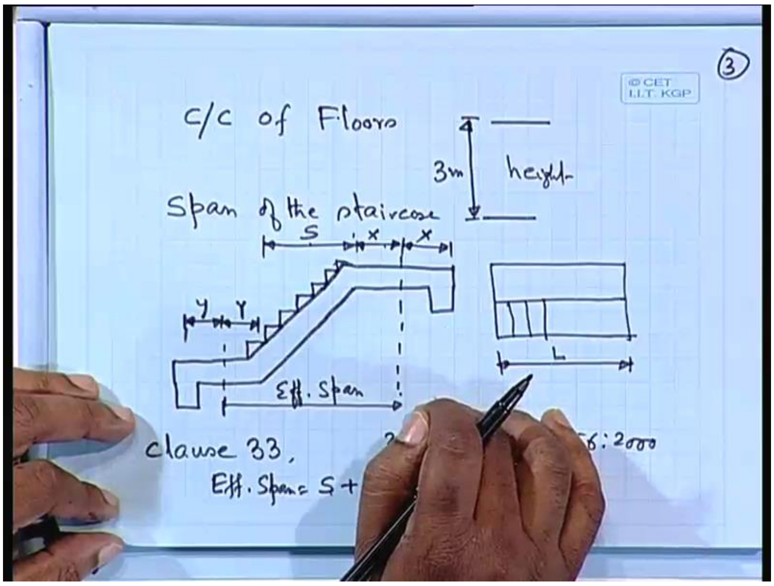

Please note; I think you have remember. So, this is the case where there is no support here, it is only supported only in these 2 beams. It may be supported in walls also there is another case.

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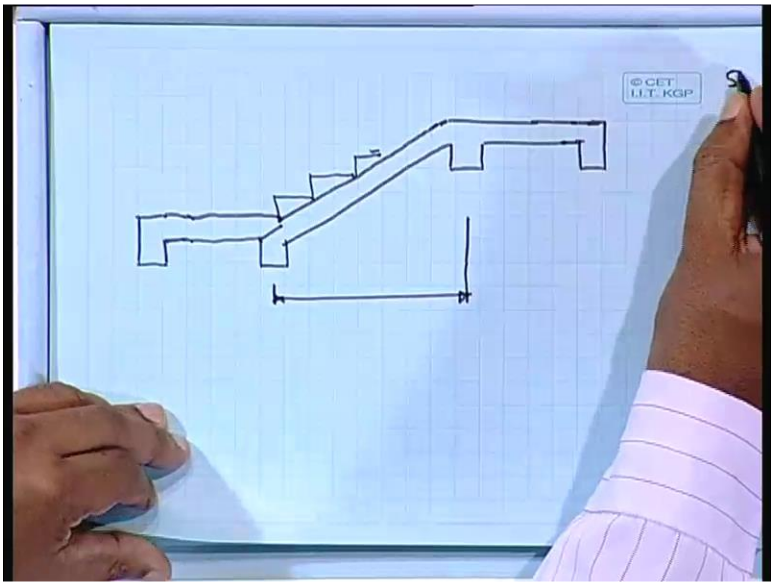

But there is other possible case here which I am talking that is these one, but here the effective span will be this one center to center distance and where you will have the staircases like this. So, let us calculate dead loads.

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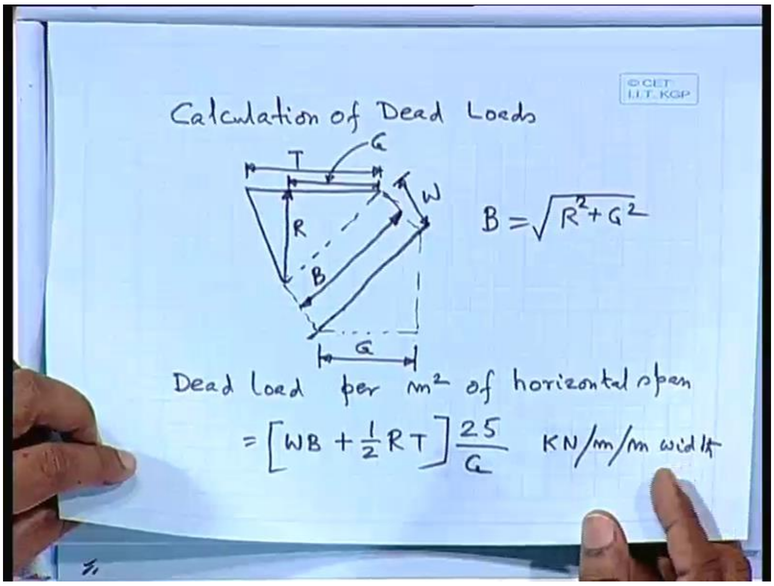

So, those are your one step we can take it, this is the 1 unit of the step, which is have been say your worst slab W B and then we have rise R: this is your rise R, the T: the thread and these portion is going. So, we can say the other way, these portions have same as that going only. So, this is your going and here also that would take it. So, this is coming as going the same position.

So, if we take this 1 what about your B then? B will be B means this 1, B will be equal to R square plus G square. And dead load per meter square of horizontal span horizontal, span means: along this that 1 will be equal to, the weight of this 1 W times B and we are talking say per unit width. That means; we are taking the width of the stair case 1 meter. So, W B this is your W B times 1, times the unit weight of the concrete plus this triangle which is half times R times T, R is the that it was the height and T that base you can say times, the 25 kilo newton per meter cube. This is the 1 meter of width of the staircase this, that you can say 1 meter width of the stair case times 25 will be give me the width and divide by G this 1 means kilo newton bar meter bar meter width or kilo newton per square metre.

We are talking the staircase is moving like this. The staircase is going like this. So, I am taking 1 meter width and we are having the each step. So, each step we can take it so; that means, we can say if you project it it will go off. So, you will get something that inter dimensional get the unit 1. So, I shall get per metre width I can get it, this is the width I can find it out that is the dead load we can get it.

So, you have whole design, upto only different so far the staircase concern. So, if I calculate the dead load. So, now, you can concentrate that it as a slab or a beam. So, what is the difference between the slab and the beam? Slab means only you shall provide the reinforcement due to bending moment and shear force at where it is that 1, that we shall decide it such a way that the depth, so we shall increase such a way so that, we need not specify provide any steer up, any shear reinforcement. So, then we shall talk it as a slap. But if you provide these one as a shear up; that means, we have to designing at a beam.

So, in our case shear we shall design it as a slab because, we are not going to provide any shear reinforcement. So, let us take one example atleast let us start today.

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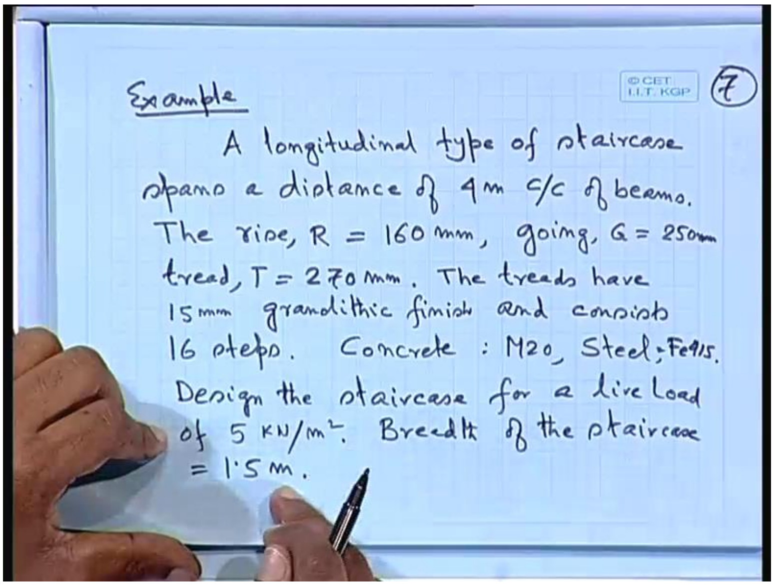

And this type of staircase is called longitudinal type. So, our longitudinal type up staircase spans a distance of 4 meter. That means, it is supported by 2 beams and the distance between 2 beams is 4 meter. The rise R equal to 160 millimeter, going G equal to 250 millimetre, tread T equal to 270 millimetre and we can consider this one, the threads have 15 millimetre that granolithic finish. So, there is one say finish over that, that we are providing the plates and consists of 16 steps.

We are specifying all those things, but for actual case in the actual problem for a building design, we have to specify this 160 millimetre rise, going, thread or number of step that have to calculate depending on the floor area, floor length and also the height. So, that also you have to suitably you have to adjust and you have to flow height, but here we are specifying. So, what about the concrete with M20 steel Fe 415. Design the staircase for a live load of 5 kilo newton per square meter and breadth of the staircase equal to 1.5 millimeter.

So, we have all the details. The beams that 1 that will has to span between 4 meters, the rise 160 millimeter, going 250 millimeter, thread 270 millimeter that it has a finish because, these sort of floor finish we can say this is the floor finish, but we have to specifically mention. We shall take the unit weight of these 1 granolithic finish 23.5 kilonewton per meter cube; that we shall take. The another 1 25 kilo newton for concrete and we can calculate the 16 steps from the going also. Concrete M20, steel Fe 45 and live load 5 kilo newton per square meter, breadth of the staircase that is equal to 1.5 meter. So, 1.5 meter breadth that is given.

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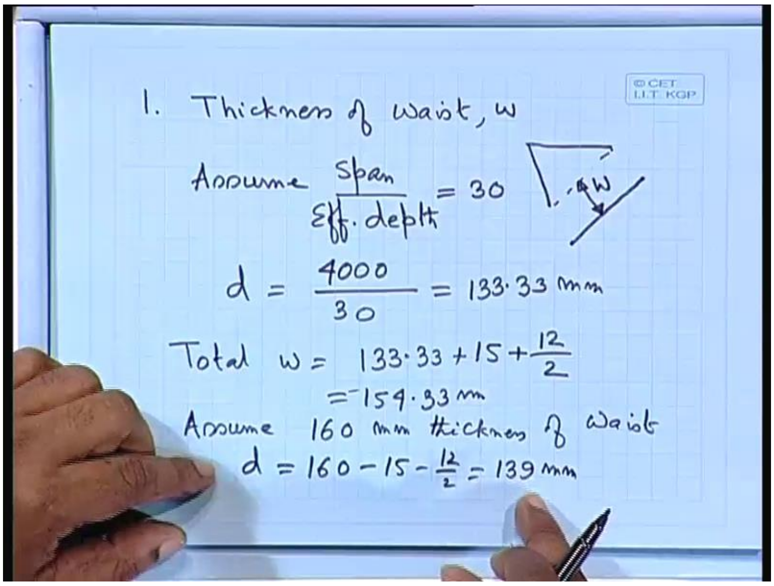

Number 1 what about the thickness of waist. So, we are talking, let us just draw a figure. So, this is your thickness of your waist. Let us assume span by affective depth equal to 30. We can assume span by effective depth equal to 30 that we can assume because, reinforcement and other things involved so, we can assume that 30. So, there are so many factors are involved so we can assume that 30. So, d will be equal to span how much span equal to 400 millimeter; that what specified divided by 30 which comes as 133.33 millimeter.

So, we can write down total W; this 1 should be equal to 133.33 plus 15 millimeter cover plus 12 millimeter bar. If we assume that we shall provide that 12 by 2 which comes as 154.33 millimeter. So, let us provide or we can assume that, we shall finally, we shall provide 160 millimeter we need not know whether we have to change it. So, let us assume that 160 millimeter thickness of west. After checking only we can provide. So, d will be equal to 160 minus 15 minus 12 by 2 which comes as 139 millimetre. So, this d this is your we have got it from here computate. And finally, we have providing 139 millimeter. So, we are providing 139 millimeter. So, now let us calculate the dead.

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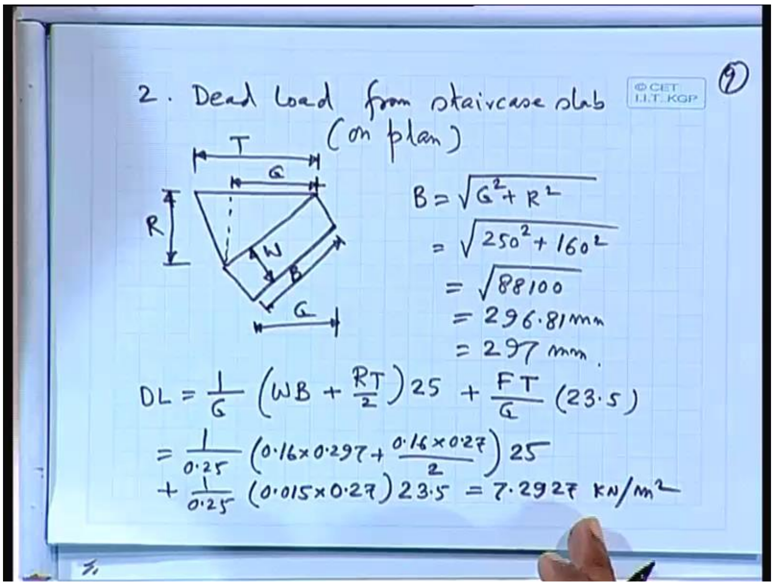

So, dead from staircase slab and we shall get it on plan. So, this is G, this is T thread, this is R rise, W, B and this is G. B equal to root of G square plus R square equal to, G equal to we have taken 250, R equal to 160 equal to 296.81 millimetre let us say 297 millimetre. Dead load it will be per meter length of the horizontal 1; 1 by G we have already got it WB plus RT by 2 times 25 plus F is the floor finish the thickness, F times T, T is the thread we have the whole thread divided by G times the unit weight 23.5. So, we can get it as G 0.25, W is point 1.6 that we have got it 160 millimetre so, 0.16 times, B you have got it 297.297, R equal to that R we have got it that rise 160 so, 0.16 times, T 270 millimetre 0.27 by 2 times 25. So, we are putting all the values, here can I manage, let us manage it here. So, plus 1 by 0.25 times, F is floor finish 0.15 15 millimetre times, T 270 millimetre 0.27 times, 23.5 unit weight and which comes as 7.2927 kilo newton per square meter.

So, this is all what I getting here the dead load 7.2927 kilo newton per square meter. What about the design load?

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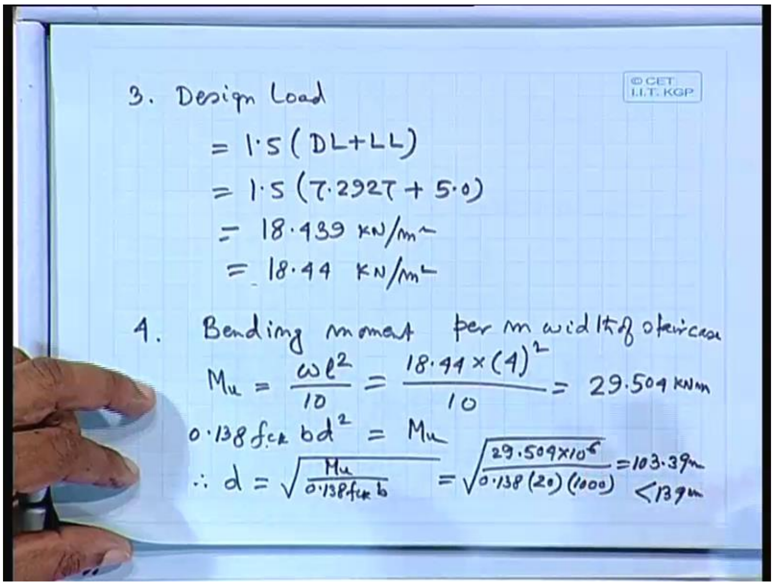

Design load equal to 1.5 times dead load plus live load equal to 1.5, so 7.2927 we have already have computed plus 5.0 that which have to provide, 18.439 kilo newton per square meter equals 8.44 kilo newton per square meter let us assume. What about the bending moment which is your Mu, Mu will be equal to that w l square by 10, we shall take it not 8 w l square by 10 equal to 18.44 times the effective span 4 4 square by 10 which comes as 29.504 kilo newton metre. So, we are getting this one.

What about the now you have now you have to check, whether the depth we have got it correct or not. So, that we can find out as from 0.138 f c k b d square equal to Mu. So, d equal to root of Mu by 0.138 f c k b equals 29.504 into 10 to the power 6 divide by 0.138 M20 grade times, what about B? There are these B how much will be B here because, we have taken these moment per meter width bending moment per meter width let us make it finish specific per meter width of stair case because, I have not taken that 1.5 meter. I have taken that per meter width of staircase, this we have got it kilo newton per square meter.

If you the 1 alternative could be that, same design that we have take it if 18.44 times 1.5 into multiply what the width of the staircase, then we can directly we can get it here, we can write down d as 1500, but since we have taken here till now it is 1 meter width. So, I have to specify here 1000; that you please note and which comes as 103.39 millimetre. So, less than 139 millimetre. The other alternative could be that we can calculate Mu that was I know B, I know f c k, I know d so, I can calculate Mu. So, this Mu if it is get up then this this value, then also you can say it is safe and then you can check it with d you can calculate and you can find out less than the d provided. Other alternative that, if we provide that d here and calculate that moment of resistance of the section and it should be more than the value you have computed. That one also you can calculate. So, now, you have to provide steel So, our depth is… So, you have to provide steel. So, what shall we can provide.

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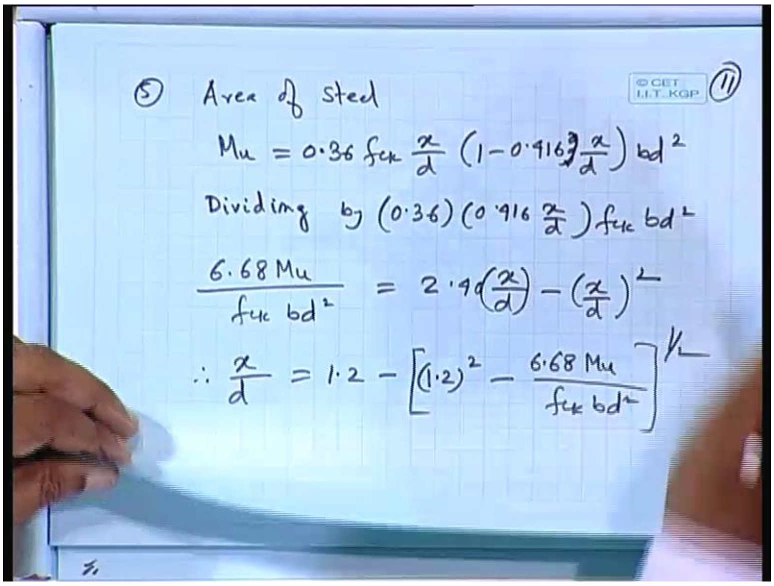

So, what shall we can provide. So, you aimed at this 1 0.36 f c k x by d 1 0.416 x by so x by d times bd square. This is the basic formula from where we have got it that, just let me write down once more dividing by 0.36 times 0.416 x by d f c k bd squar if we divide then, we get it 6.68 Mu by f c k bd square equals 2.40 x by d minus x by d whole square. We get this equation. And finally, we get x by d equals to 1.2 minus 1.2 the whole square minus 6.68 Mu by f c k bd square times square root of that. So, this is your that formula from where you can get x by d if, I know Mu f c k b, and d. So, when that is the case which we have got it here. So, we know Mu ,we know f c k, we know b we know d so, we can find out x by d. So, let us calculate x by d.

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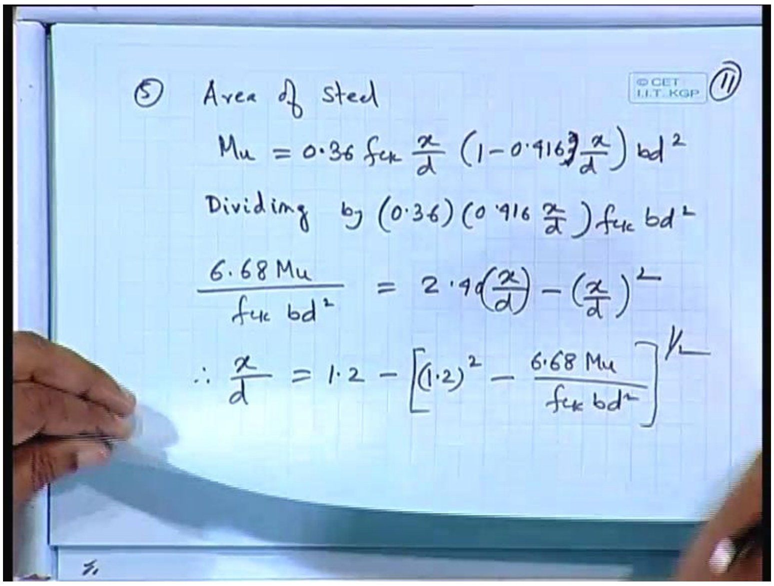

So, 6.68 Mu by f c k b d square equal to 6.68 times 29.504 that is the moment multiplied by 10 to the power 6 divided by 20 times thousand that is the width meter width times the effective depth of this layer which comes as 0.51. So, we can take it that as x by d equals to 1.2 minus root power 1.44 four minus 1.51 equals 0.23564. Therefore z equals to d times 1 minus 0.416 x by d equals 139 minus 0.416 times 0.23564 equals 139 times 0.9019. Please note because, why I have written this 1, I can directly put the value, but please note that 0.9019. Generally, it comes 0.85 times d 0.9 0.95 times d.

If you do not sometimes what we do if we do not know there is a we would like to calculate the area of steel. So, for experience you can find out that z the lever arm we can take say 85 percent of the effective depth or 95 percent of that; that means, that is the range that is why I have written here that, work range that also you should know. Directly we do not want to calculate all those things, we have no calculator, but we would like to calculate say at site itself we would like to estimate. So, that way also we can find out. So, which comes as 125.36 millimetre. So, z we have got it. So, what about the area of steel then?

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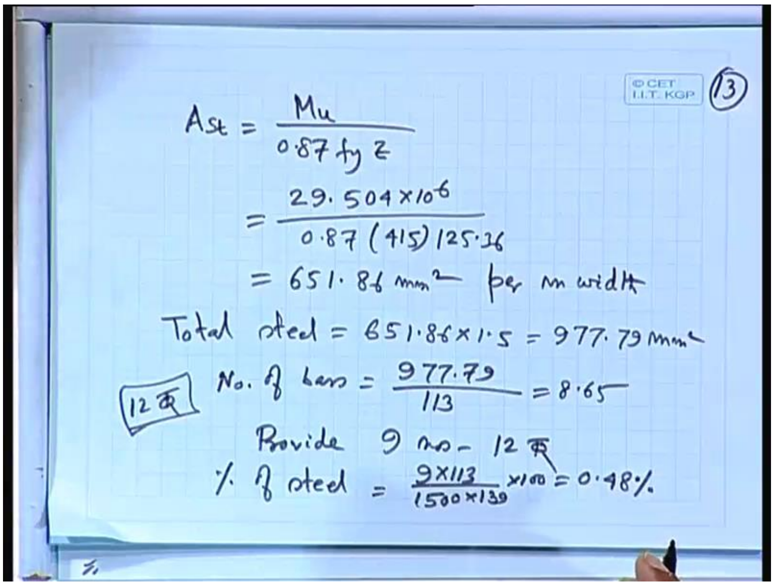

Area of steel will be equal to Mu by 0.87 f y times z, which comes as 29.504 multiplied by 10 to the power 6 divided by 0.87 times 415 times 125.36 equals 651.86 millimetre square. So, what about the total steel? This is per meter width equal to 651.86 times 1.5 equal to 977.79 square milimeter. So, we can provide here that, number of bars 977.79 divided by 113 12 torque equals 8.65. So, provide 9 numbers 12 torque. What about percentage of steel? 9 into 113 divided by 1500 into 139 this is the width I am talking and into equal to 0.48 percentage. So, percentage of steel we have got it 0.48. So, we know the steel and we also know the effective depth. Now, we have to provide the distribution steel.

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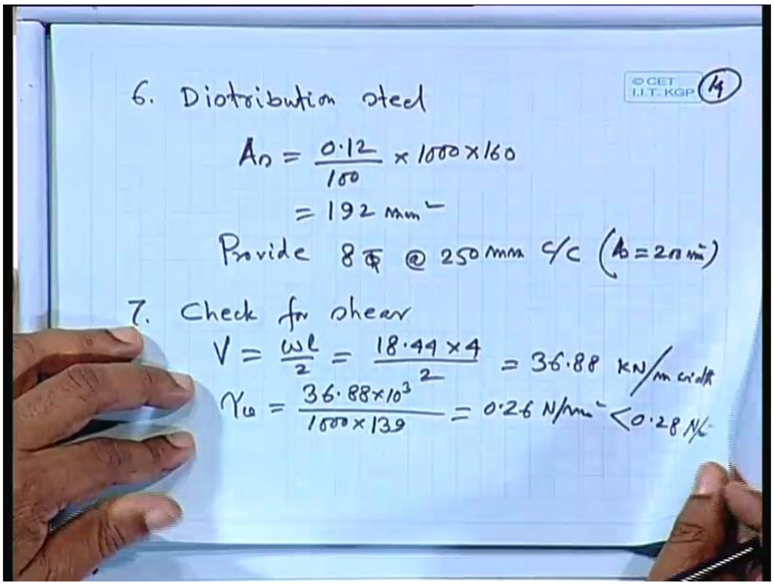

So, distribution steel; that 1 will be equal to 0.12 percent. A s equal to 0.12 by 100 times you can say 1000 that is the per meter width times 160 overall depth comes as 192 millimetre square provide 8 torque at the rate of 250 millimetre from centre to centre for area of steel provided 200 square millimetre. So, we can provide 20 square millimetres. Now, what about the cr we have to check for cr because, up to this we have computed so many things so much, but after this if we find that if cr stays more than the permissible we have to change the section. So, shear force V will be equal to wl by 2 equal to.18.44 times 4 divided by 2 equal to 36.88 kilo newton. So, tov V equal to 36.88 into 10 to the power 3 divided by we were talking this by per meter width so, 1000 times.

Please note that each time we are putting the values even, if it is for meter width or the taking the total width. If it is total width then in that case you will provide here 1500. But here it is 18.44 per meter with. So, which comes as 0.26 Newton per square millimetre. So, even then this 1 with the 0.15 percent steel we can get it for 0.48 percentage of steel from the table 19 of IS 456 I can find out the permissible. Even if I take say 0.15percent which is coming less than 0.28. So, 0.28 Newton per square meter for the minimum in the output that provided; that is about 0.15 percentage that is less than that. So, we need not that so we need not change the section. So, it can take care the shear force. Now what about the deflection?

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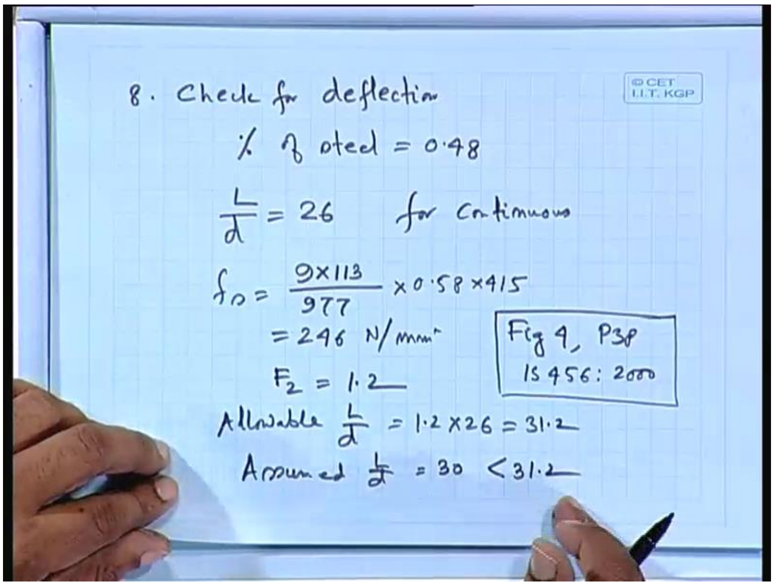

So, this deflection we shall check it from the point of view of l by d ratio, from the point of view of l by d ratio. So, we shall get it as the percentage of steel provided, that is 0.48. So, if we now go back to that your that table or figure just for your reference, that is, in figure in the IS code that is in figure 4 of 38, we shall take this one say as continuous beam continuous beam or continuous slab w s, we hav not taken w s square y ws square y thing we have taken. If we takes a 0.38 in the continuous then, we can take minimum 1 that is the l by d that is a 26, 26 is the l by d ratio.

So, we shall take the l by d ratio that is a 26, but it is for a continuous. That 1 you will get it in flaws 23.2.1, while it is given that basic values of span to a specific depth. Ratios for spans upto 10 meter, cantilever 7 simply supported 20 and continuous 26 we are taking continuous here, we have taken w l square by 8, similarly 26 for continuous. And so what we can do it here. Now, what about the modification factor. There are so many others, but I said taking from figure 4.

So, f s we have used how many bars, 9 bars of 12 dia each of them 113 square millimetre. We have to provide 977; that is the 1 we have to provide. We have to provide 977 isn’t it. Then, we have computed 977. 977 we have computed. So, 9 into 133 times 0.58 f y times 415. So, that is your f s which comes as 246 Newton per square millimetre. So, I shall get it from figure 4. This is from figure 4, if I show you this is figure 4 in page 38. In figure 4 there are so many curves. There are so many curves in figure 4. So, I said take the corresponding 1 and interpolate it. And which will come in as for 246 that f 2 the factor that is comes as 1.2.

So, this is from just for your reference: figure 4 page 38 of IS 456 2000. So, we shall get it multiplication factor 1.2. So, allowable l by d equal to 1.2 into 26 equal to 31.2. And we have assumed l by d, that is, 30 which is less than 31.2. So, you can find out that which it is acceptable. So, 1 more checking is there and that is it will take to your say crack and that house will that is there are two things that is told; these are coming from serviceable limit state. 1 checking is coming from the l by d ratio and other checking will come from the spacing. So, you have to check the spacing whether it is less than 3 d or not. And; obviously, whatever we are provided say 9 bars. If you which is provided in 1500 millimetre, we will find out it is less than 3 d.

Similarly, for the distribution steel whatever we are provided, so that one also we will find out that 250 millimetre which is less than 3 d. So; that means, from the cracking point of view also we can say it is alright. So, now we have to do the reinforcement and that we shall do it in appropriate place end. Okay.

Thank you.