Design of structures – II

Lecture – 28

In the previous lecture we have the design of one way simply supported floor slab and one way simply supported roof slab. In this lecture we are going to design one way continuous slab. Normally we all know the continuous slab is the slab which is supported over more than two supports. It is spanning along only one direction so it is called as one way continuous slab. We are going to design this continuous slab by doing one worked example. First as usual we are going to start with the load calculation and using load calculation the load will be normally calculated separately that is dead load and live load. Since the IS code has given certain codal provision to find out the binding moment at various location for the continuous slab along with certain conditions.

In the case of continuous slab when you use the moment coefficient as per IS 456:2000 the minimum span should be minimum of 3 span and also more. And if the span of the slab is varying then the variation should not be more than 15% of the longest. And also when the load is not uniform throughout the entire section of the slab the variation should also the moment at support should be the average sum of the moment which from either side of the supports. Along with the conditions the moment coefficients has to be used for finding out the bending moment at various locations of the continuous slab. And using the moment coefficient we can calculate the bending moment and using the bending moment we have got four bending moment in the case of continuous slab we have to select the maximum bending moment for finding out the effective depth of the slab. The effective depth of the slab normally found by equating the maximum bending moment to the limiting value of the moment by considering our section is the based one. Then after calculating effective depth of the slab the area of reinforcement has to be calculated for the maximum bending moment. In the reinforcement calculation we are going to find out main steel as well as the distribution steel. Main steel which is normally calculated for the maximum bending moment and the distribution will be normally minimum reinforcement as per IS 456:2000 the minimum reinforcement will be 0.15% of the cross section of the concrete.

Here we are also going to find out the spacing between the reinforcement for both as well as the distribution reinforcement that spacing should also be again checked with the maximum spacing as per IS 456. And finally we are going to also check the depth of the slab that is deflection and we are going to draw the longitudinal section of the continuous slab which shows the reinforcement details.

One Way Continuous Floor Slab

Design a five span one way continuous floor slab over an effective span of 3.0m required for an institutional building. It carries a live load of $3kN/m^2$ and consider other dead load also. Adopt M20 concrete and Fe415 steel. Draw the section of slab showing reinforcement details also.

Solution:

So this are all the moment coefficients which we are going to find out the bending moment at various places that is there are two places one is span moment and another one is support moment. In the case of span moment we are going to find out the bending moment at the middle of end span and in the middle of interior spans. And in the case of support moment we are going to find the support by moment next to the support and other interior support. They have given a moment coefficient separately for dead load and live loads. So we are going to add these moment coefficients for calculating the total bending moment at four places.

So for obtaining bending moment using this moment coefficient the moment coefficient has to be multiplied by the total design of the effective span.

One way continuous floor slab:

Here the effective span is given in the problem. They have given five span continuous slab that is effective span $l_{eff} = 3m$. The effective span of each span is 3.0m, so first we shall start with the load calculation.

Load Calculation:

Dead load:

The dead load consist of self weight of the structure itself or self weight of the slab itself and the weight of partitions and the weight of floor finish. So for finding the self weight of the slab we need to assume the size of slab from the deflection criteria. So l/d ratio for continuous slab is 26.

$$\frac{l}{d} = 26; d = \frac{l}{26} = \frac{3000}{26} = 115.4$$

$$D = 115.40 + 15 + 8/2 = 134.38$$

But I am going to assume based on my experience since it is a trial and error method I am going to assume D is equal to 125mm. And finally I am going to check this depth against limit state of the flexure.

The first dead load is the self weight of the slab that is 0.125 x 25 which is equal to 3.125kN/m^2. Next the weight of partitions and the weights of partition as per IS 456 is 1.96kN/m^2. Next one is weight of floor finish since the slab is designed for an institutional building we are normally providing a concrete for a thickness of 25mm and it is multiplied by its unit 24 and we get 0.60kN/m^2 as the weight of floor finish. So the total dead load since it is the continuous slab the load should be calculated separately i.e., live load and dead load should be calculated separately that is 5.685kN/m^2.

Live load on floor slab:

This is given in the problem if it is not given we need to refer IS 875 for the live load. Here that is given in the problem that is 3kN/m^2.

Bending moment calculation:

Span moment:

The span moment is moment near the middle of end span that is

$$= +\frac{1}{12} w_d l^2 + \frac{1}{10} w_l l^2 = 6.96 kNm$$

This is the bending moment near the middle of support. Next the moment at the middle of interior span that is equal to

$$=+\frac{1}{16}w_d l^2+\frac{1}{12}w_l l^2$$

This is positive that indicates it is a sagging moment. So the moment here it is 5.45kNm.

Support moments:

Moment at support next to end supports that is minus since it is hogging moment,

$$=-\frac{1}{10}w_d l^2-\frac{1}{9}w_l l^2$$

$$=-8.12kNm$$

Next the moment at other interior supports that is

$$=-\frac{1}{12}w_d l^2-\frac{1}{9}w_l l^2$$

$$=-7.26kNm$$

So here we are having four bending moments at four places. Among this bending moment we are only going to select the maximum bending moment to find out the effective depth of the slab. This is not like in the case of continuous beam, in the case of continuous beam normally we are finding the effective depth from the maximum bending moment but area of reinforcement must be calculated for four bending moments and that reinforcement has been provided at the locations. But in the case of continuous slab we are finding the maximum depth as well as the area of reinforcement for the maximum bending moment. When you find the area of reinforcement for four bending moment there will be the conjunction of reinforcement and the overlapping of reinforcement will be developed or will be created in the case of continuous slabs. That's why in the case of continuous slab the area of reinforcement should be calculated for the maximum bending moment only.

Effective depth of the slab:

By assuming a balanced section, normally the depth of the slab will be found by equating the maximum bending moment to the limiting state of the bending moment.

$$M_{u\max} = 1.5 \times 8.12 = 12.18 kNm$$

$$M_{u\max} = M_{u\lim} = 0.138 f_{ck} bd$$

$$d = \sqrt{\frac{M_{u\max}}{0.138 f_{ck} b} = \frac{12.18 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$= 66.43 mm$$

So we have kept D is equal to 125 and d is equal to,

$$d = 125.15 - 10/2 \ = 105 mm$$

Therefore 66.43mm is less than 105mm hence it is safe against flexure. Next this depth of footing has to be again checked for the deflection.

Area of reinforcement:

Main steel:

So here since it is singly reinforced section the reinforcement required for this slab has been found from the equation,

$$M_u = 0.87 f_y A_{st} (d - 0.416 x_u)$$

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times A_{st}}{0.36 \times 20 \times 1000}$$

$$= 0.05 A_{st}$$

$$12.18 \times 10^6 = 0.87 \times 415 \times A_{st} (105 - 0.416 \times 0.05 A_{st})$$

$$A_{st}^{\ 2} - 5096.05 A_{st} + 1.62 \times 10^6 = 0$$

$$A_{st(req)} = 340.67 mm^2.$$

<u>Check with minimum A_{st}:</u>

The minimum A_{st} must be equal to 0.12% of cross sectional area of concrete. That is equal to,

$$= \frac{0.12}{100} \times 1000 \times 106 = 192 mm^2$$

This is very less than 340.67mm^2. Hence Ast required for the continuous slab is 340.67mm^2. And I am using 8mm diameter bar. The spacing of reinforcement that is spacing which is normally calculate as one meter width of the slab divided by 340.67,

$$= \frac{\pi/4 \times 8^2 \times 1000}{340.67} = 147.55 mm$$

<u>Check with maximum spacing:</u>

Maximum spacing for main steel is 3d that is 3 x 105 which is equal to 315mm and the second one is 300mm. This 300mm is greater than the 147.55mm. Hence adopt 8mm diameter bar at 125mm c/c. Next one is distribution steel the distribution steel is normally we use 6mm ϕ ms bar,

$$= \frac{\pi/4 \times 8^2 \times 1000}{125} = 402.12mm^2$$

$$A_{st(req)} = \frac{0.15}{100} \times 1000 \times 105 = 159mm^2$$

So using 6mm ϕ the spacing of distribution steel is,

$$= \frac{\pi/4 \times 6^2 \times 1000}{150} = 177.83mm^2$$

Hence we can adopt 6mm ϕ at 150mm c/c.

Check depth of the section against deflection:

Here the l/d ratio is equal to 26 for the continuous slab and it has to be again modified by multiplying with the modification factor. This modification factor is found from the figure 4 of IS 456.

$$\frac{l}{d} = 26 \times M.F$$

$$p_t = \frac{100 A_{st(pro)}}{bd}$$

$$= \frac{100 \times 402.12}{1000 \times 105} = 0.4\%$$

The stress in the steel is given as,

$$f_s = 0.58 f_y \frac{A_{st(req)}}{A_{st(pro)}} = \frac{0.58 \times 415 \times 340.67}{402.12} = 203.92 N/mm^2$$

$$d = \frac{l}{26 \times M.F} = \frac{3000}{26 \times 1.6} = 72.12mm < 105mm$$

Hence it is safe and economical section. Now we have to draw the reinforcement detailing. So this is the span of the slab it has given five span continuous slab. The span of slab is 3m. So here first we need to provide a straight bar for the entire length. And the alternate bars have to be cranked over the support. This is the bar which is used to resist the negative bending moment which is developed at the support. It has to be cranked at 0.25l on either side of the centre of the support on continuous edge and 0.15l from the center of the support on the discontinuous edge. So here it has to be cranked at 0.15l from the center of the support. And in order to resist the 100% bending moment we need to provide another 50% reinforcement over the interior supports at the top for a distance of 0.3l on either side of the face of the support. This has to be provided only over the interior support. This is the main steel and these are all the distribution steel we have found. So here this is 8mm ϕ at 125mm c/c and these are all the distribution reinforcement 6mm ϕ at 150mm c/c. This is the longitudinal section of the slab.

Summary:

In this lecture we have seen the design of one way continuous floor slab. In the case of floor slab we have considered the dead loads and live load in the case of load. And we have considered self weight of the slab and as well as the floor finished and the partition. And also we have seen a worked example it has been carried to design the slab and also detailing of reinforcement have been drawn.

Questions:

To design the section:

1. Design a three span one way continuous floor slab for a residential building of effective span 3.5m. It carries a live load of 1.5kN/m^2, floor finish of 1.0kN/m^2 and also partition wall of 1.96kN/m^2. Adopt M20 concrete and Fe415 steel. Draw the reinforcement details also.
2. Design a five span one way continuous roof slab over an effective span of 4.0m required for an institutional building. It carries a live load of 3kN/m^2 and floor finish of 1.0kN/m^2. Adopt M20 concrete and Fe415 steel. Draw the section of slab showing reinforcement details also.

References:

- IS 456:2000 Plain and reinforcement concrete – Code of practice.
- IS 875 (1-5):1987 Code of practice for design loads (other than earthquake) for buildings and structures.
- SP34:1987 Handbook of concrete reinforcement and detailing.
- S.N. Sinha, “Reinforced concrete Design”, Tata McGraw hill publishing Co. Ltd, New Delhii, 1998.

- Ashok Kk. Jain, “Reinforced concrete: Limit State Design” Nem Chand & Bros., Roorkee (Vol 6^{th} Ed) year: 2006.