Design of structure – II

Lecture – 31

In the previous lecture we have seen the design of two way simply supported slab which is simply resting on four walls which is having the room of size of same directions. And also which is having the dimension of 3.5m x 3.5m. In the case of 3.5m x 3.5m an effective room of size for finding out or assuming the thickness of the slab to find the self weight by following the codal provision in the case of deflection criteria. When the dimension of room is 3.5m and the loading class is $3kN/m^2$. We have followed the deflection criteria of the simply supported slab that is l/d overall ratio of the deflection. This is again further multiplied by 0.8 deform bar.

In this lecture we are going to see a two way simply supported slab which is resting on wall that have the dimension of 4m x 5m. So in this it is span of the slab is more than 3.5m. So we are going to follow the normal deflection criteria to assume the thickness of the slab to find out the self weight. Here we are going to see the two way simply supported slab and calculate the total load acting on it as well as the bending moment acting on it as given in IS code. Using the maximum bending moment we are going to find out the effective depth of the slab. Since it is the two way simply supported slab we are going to find the reinforcement for both the bending moment and it has to be provided along both the direction. And finally the depth has to be again checked with the limit state of serviceability under deflection. Finally we are going to see the reinforcement detailing of those slab.

Design a Reinforced Concrete Slab

Design a reinforced concrete slab for a room of size for a room of size 4m x 5m supported on 230mm thick walls and subjected to a live load of 2.5kN/m^2. The load due to floor finish is 1kN/m^2 and partition is 2kN/m^2. Use M20 and Fe415 as materials.

Solution:

Here the size of the room given in the problem is 4m. In the case of the self weight of the slab we started assuming the thickness of the slab from the deflection. We can assume the size of room from the separate class, overall depth is notify and further multiplied by 0.8. But in this case the size of the room is more than 3.5m so we cannot follow that deflection criteria. Then the normal deflection criteria, we have that is simply supported slab that is 20. This is the table 27 which is used to find out the bending moment for the two way slab. Here effective size of room is 4.23m x 5.23m. There are four walls and here the effective size is lx x ly. Here first we need to check whether this is one way slab or two way slab.

$$\frac{l_y}{l_x} = \frac{5.23}{4.23} = 1.24 < 2$$

Hence it is designed as two way slab. So here we confirm this is the two way slab. Here we need to find out the load acting on the slab.

Load calculations:

Dead load:

Here the dead load actually means the self weight of the slab and weight of partition and weight of the floor finish. So here they have given the live load on the slab is given as 2.5kN/m^2 and the floor finish is 1kN/m^2. First self weight of the slab, here we need to assume the thickness of the slab for the deflection criteria that is l/d ratio is equal to 20. It is for simply supported slab.

$$\frac{l}{d} = 20; d = \frac{l}{20} = \frac{4230}{20} = 211.5mm$$

This is the effective depth of the slab and overall depth of the slab is,

$$D = 211.5 + 15 + 10/2 = 231.5mm$$

Finally we are going to take D as 200mm and we will check this depth against depth of footing against flexure. So self weight of the slab is

$$0.2 \times 25 = 5kN/m^2$$

The weight of floor finish given in the problem is 1.0kN/m^2. And the weight of partition wall is 2.0kN/m^2. Now we need to calculate the total dead load acting on the slab is equal to $w_l = 8.0kN/m^2$.

Live load on the slab:

The live load of the problem is given in the problem as 2.5kN/m^2. Now the total load on slab is

$$w = w_d + w_l = 10.5kN/m^2$$

Bending moment calculation:

The moment coefficient for the respective place is,

$$\frac{l_y}{l_x} = \frac{5.23}{4.23} = 1.24$$

Based on this one we are going to find out the moment coefficient in x direction and the moment coefficient in y direction. We need to find the bending moment along both the direction. We need to write the α_x for 1.2 is 0.084 and for 1.3 is 0.093 and also α_y for 1.2 is 0.059 and for 1.3 it is 0.055. So we need to find α_x & α_y for the value of 1.24 by interpolation. So linearly interpolate the value of α_x & α_y for 1.24. So here α_x is 0.088 & α_y is 0.0585. The bending moment along x direction is

$$M_x = \alpha_x w l_x^2$$

$$= 0.088 \times 10.5 \times 4.23^2 = 16.53 kNm$$

In similar manner,

$$M_y = \alpha_y w l_x^2$$

$$= 0.0585 \times 10.5 \times 4.23^2 = 10.99 kNm$$

Effective Depth of the Slab:

By assuming our section is a balanced section and considering 1m width of slab. The effective depth of the slab has been calculated by equating maximum bending moment value to the limiting state of bending moment.

$$M_{u\max} = M_{ux} = 1.5 \times 16.53 = 24.80 kNm.$$

$$M_u = M_{u\max} = M_{u\lim} = 0.138 f_{ck} b d^2$$

$$d = \sqrt{\frac{M_{u\max}}{0.138 f_{ck} b}} = \sqrt{\frac{24.80 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$= 94.74mm$$

$$D = 94.74 + 15 + 10/2 = 114.74mm < 180mm$$

Hence it is safe against the flexure. So I am going to keep the effective depth as 200mm and d is equal to 180mm.

Area of reinforcement:

Along x direction:

Here the area of reinforcement along shorter direction is,

$$M_{ux} = 24.80kNm$$

To find out the area of the reinforcement we are going to use the expression for finding singly reinforcement section,

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

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

$$= 0.05 A_{st}$$

$$24.80 \times 10^6 = 0.87 \times 415 \times A_{st} (180 - 0.416 \times 0.05 A_{st})$$

$$A_{st}^2 - 8563.64 A_{st} - 3.30 \times 10^6 = 0$$

$$A_{st(req)} = 400mm^2$$

Check with minimum Ast:

$$Min A_{st} = \frac{0.12}{100} \times 100 \times 180 = 216 mm^2 < 400 mm^2$$

$$A_{st(req)} = 400 mm^2$$

Here by assuming 10mm bar and the spacing of the reinforcement. So the spacing of reinforcement is also be found against 1m width of the slab,

$$= \frac{\pi/4 \times 10^2 \times 1000}{400} = 196.35 mm$$

Check with the Maximum Spacing:

The maximum spacing of the parallel reinforcement is that should not exceed three times the effective depth of the slab or 300mm whichever is less. That is 3 x 180 which is equal to 540mm. So hence the 300mm is greater than 196.35mm. Hence adopt 8mm diameter bar at 175mm at c/c. This is along x direction. So Ast provide along x direction is

$$A_{st(pro)} = \frac{\pi/4 \times 10^2 \times 1000}{175} = 448.80 mm^2$$

In similar manner we are going to find out the reinforcement along y direction.

$$M_{uy} = 1.5 \times 10.99 = 16.485 kNm$$

Here also I am going to use the same expression that is

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

$$x_u = 0.05 A_{st}$$

$$16.485 \times 10^6 = 0.87 \times 415 \times A_{st} (180 - 0.416 \times 0.05)$$

$$A_{st(req)} = 262.17 mm^2$$

Here I am using 8mm bar and spacing of bar I get here it is

$$= \frac{\pi/4 \times 8^2 \times 1000}{262.17} = 191.73 mm$$

So provide 8mm diameter so this spacing is within the maximum spacing that is we have seen in the reinforcement for x-direction. Here I am providing 8mm diameter bar at 175mm c/c.

<u>Check the depth of the slab against the deflection:</u>

$$\frac{l}{d} = 20 \times M.F$$

Hence the depth of the slab against the deflection has to be found from the figure 4. This figure 4 shows the modification factor verse the percentage tension reinforcement.

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

$$= \frac{100 \times 448.4}{1000 \times 180} = 0.25\%$$

The modification factor here it is 1.9.

$$f_s = 214.53 N/mm^2$$

$$d = \frac{l}{20 \times M.F} = 111.32 < 180mm$$

This is safe but it leads to uneconomical when comparing 180mm with 111.32mm is very less. So we can again redesign the section by reducing the distance of the section.

Reinforcement detailing:

This is a simply supported slab which is resting on the edges. So here in the case of two way simply supported slab the reinforcement along both the direction is the main reinforcement. If you take this as the lx as 4.23m along this the reinforcement is 10mm at 175mm c/c and this reinforcement that is the reinforcement perpendicular to the direction of 4.25mm that is along 5.23mm. That reinforcement is 8mm diameter at 175mm c/c. In this case we need to also design the torsion reinforcement, which is normally 3/4th of the main reinforcement that is which has been used in the direction 448.80mm^2.that has to be provided along lx/5 and ly/5 at the corners to resist the lifting up of the slab or to resist the torsion. We need to provide the torsion in addition to the main reinforcement that is in four layers along x as well as y direction that is two layers at the top and two layers at the bottom. That reinforcement is normally 3/4th of the main reinforcement.

Summary:

In this lecture we have seen worked example which have been carried out to design the slab and also detailing of reinforcement have been drawn.

Question:

To design the section:

1. Design a two way reinforced concrete roof slab for a room of size 5m x 6m subjected to a live load of 0.75kN/m^2. The load due to floor finish is 1kN/m^2. Use M20 and Fe415 as materials.
2. Design the reinforcement required for a two way slab which do not having adequate provisions to prevent lifting of corners. The clear dimension of the room is 6m x 6m. It is supported on 230mm thick wall. Live load on slab is 1.5kN/m^2. Consider other dead loads also. Use M20 and Fe415 as materials.

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.
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