Design of Structure – II

Lecture – 33

In the previous lecture we have seen the two way restrained slab which is having the condition of one long edge discontinuous. In this lecture we are going to see the design of restrained slab with three edges discontinuous and one long edge continuous. Using this condition how to design the two way restrained slab using the moment coefficient which is given in the IS 456:2000 in table 26. So in the case of restrained slab the four corners of the slab is prevented from lifting that is called as the restrained slab.

Design of Two way Slab

Design a reinforced concrete slab for a room of size 4m x 5m clear subjected to a live load of 2.5kN/m^2. Three edges discontinuous (one long edge continuous). The load due to floor finish 1kN/m^2 and partition is 2kN/m^2. Use M20 and Fe415 as materials.

Solution:

Now this is the table 26, it is the table which has to be used for finding the bending moment for the two way restrained slab which all the condition that is interior panel one short edge continuous and one long edge continuous like that they have given the moment coefficient for varies conditions of the slab. Here in our case the condition of the slab is one long edge continuous. Such that the clear dimension of the room is 4m x 5m which is supported on wall. And the effective dimension of room is 4.32m x 5.23m. So thickness of support is 230mm.

So here ly/lx is 5.23/4.23 which is equal to 1.24 < 2 so that it confirms it is two way slab. So we need to calculate the load.

Load calculation:

In the previous case we have seen one long edge discontinuous that is we have used this as the moment coefficient for design of the two way restrained slab in the previous lecture. But in this present lecture we are going to design the two way slab using the different edge condition that is three edges discontinuous and one long edge continuous.

Dead load:

First we are going to assume the thickness of the slab from the deflection criteria that is l/d ratio is equal to 20. That is here in the case of rectangular two way slab we are going to use the shorter direction for calculating the depth of the slab from the deflection criteria.

$$\frac{l}{d} = 20 = d = \frac{l}{20}$$

$$\frac{4230}{20} = 211.5mm$$

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

But I am going to keep as in the previous case I am going to keep overall depth as D is equal to 150mm and d is equal to 130mm. I am going to find out the self weight of the slab. That is 0.156 x 25 which is equal to 3.75kN/m^2. In addition to this they have asked as to consider load due to the floor finish and the partition wall. Load due to floor finish is equal to 1.0kN/m^2 and due to partition that is

2.0kN/m^2. So total dead load on slab is $w_d = 5.75 kN/m^2$. And the live load on the slab is equal to $w_l = 2.50 kN/m^2$. Then the total load acting on the slab is $w = w_d + w_l = 9.25 kN/m^2$.

Bending moment calculations:

We are going to use table 26 of IS 456. So the condition is three edges discontinuous and one long edge continuous. Here the ratio of ly/lx is 1.24. Now the moment coefficient in x direction first one is negative moment coefficient here this 1.24 is the value in between 1.2 and 1.3. The α_x for negative moment value is 0.071 and positive moment coefficient that is equal to 0.053 and for 1.3 it is 0.076 and 0.057. And then for α_y there is no negative moment coefficient and there is a positive moment coefficient of 0.043. So we need to select the α_x value of 0.24 by interpolating the value. So negative moment α_x here it is 0.073 and for positive moment coefficient is 0.0548 and α_y that is 0.043. Among this two we have to select the maximum moment coefficient that is 0.073. So the maximum moment coefficients are $\alpha_x = 0.073 \,\&\, \alpha_y = 0.043$.

$$M_{ux} = 1.5 \times \alpha_x w l_x^2;$$

$$= 1.5 \times 0.073 \times 9.25 \times 4.23^2$$

$$= 17.28 kNm$$

$$M_{uy} = 1.5 \times \alpha_x w l_x^2;$$

$$=1.5\times 0.043\times 9.25\times 4.23^2$$

$$=10.17kNm$$

So among this two bending moment there is a maximum bending moment that is used to calculate the effective depth of the slab.

Effective depth of the slab:

Consider one meter width of the slab and also consider a balanced section. In the case of the balanced section to find out the effective depth of the slab we are going to equate the maximum bending moment to the limit state of the moment.

$$M_{u\max}=17.28\times 10^6=0.138 f_{ck} bd^2$$

$$d=\sqrt{\frac{17.28\times 10^6}{0.138\times 20\times 1000}}=79.13mm<130mm$$

Hence it is safe against flexure. Now we need to check the depth of the section against the deflection. I am going to keep the assumed depth as the overall depth 150mm and d as 130mm.

Area of Reinforcement

First along the shorter direction that is for the bending moment along x direction,

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

$$17.28\times 10^6=0.87\times 415\times Ast(130-0.416\times 0.05A_{st})$$

$$x_u=\frac{0.87 f_y A_{st}}{0.36 f_{ck} b}=0.05A_{st}$$

$$A_{st}^2 - 6249.87A_{st} + 2.30\times10^6 = 0$$

$$A_{st}(req) = 393.25mm^2$$

Here I am going to use 8mm diameter bar and the spacing of reinforcement will be,

$$= \frac{\pi/4 \times 8^2 \times 1000}{393.25} = 127.82mm$$

Check with maximum spacing:

The maximum spacing should not exceed the least of the following that is 3 x d and another one is 300mm. So 3 x d is 3 x 130 which is equal to 390mm. The least value here it is 300 which is somewhat more than 127.82mm.

So A_{st} provided is 8mm bar at 110mm c/c. This is the reinforcement along shorter direction.

$$A_{st}(pro) = \frac{\pi/4 \times 8^2 \times 1000}{110} = 456.96mm^2$$

Now along longer direction, here the $M_{uy} = 10.17kNm$,

$$M_{uy} = 0.87 f_y A_{st}(d - 0.416x_u); x_u = 0.05A_{st}$$

$$10.17\times10^6 = 0.87\times415\times A_{st}(130 - 0.416\times0.05A_{st})$$

$$A_{st}^2 - 6249.87A_{st} + 1.354\times10^6 = 0$$

$$A_{st}(req) = 224.72mm^2$$

Spacing of Reinforcement

By using 8mm diameter bar, I am going to find out the spacing of reinforcement. The spacing of reinforcement is again,

$$= \frac{\pi/4 \times 8^2 \times 1000}{224.72} = 223.68mm$$

Here I am providing 8mm diameter bar at 200mm c/c along y direction.

Check the depth of the slab against deflection:

Here the l/d ratio is 20 that has to be modified by multiplying the modification factor. And this has to be found from figure 4 of IS 456. So this are all the curves which represent the stress in reinforcement. This graph shows the modification factor verse percentage calculation.

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

$$= \frac{100 \times 450.96}{1000 \times 130}$$

$$= 0.35\%$$

$$f_s = 0.58 f_y \frac{A_{st}(req)}{A_{st}(pro)}$$

$$0.58 \times 415 \times \frac{393.25}{456.96}$$

$$207.14N/mm^2$$

$$d = \frac{l}{20 \times M.F} = \frac{4230}{20 \times 1.6} = 129.06 < 130mm$$

This depth of section is safe against deflection and also this depth is most economical. So D is equal to 130mm and now I am going to draw the cross section of the slab. Along x direction the reinforcement is 8mm diameter bar at 110mm c/c. And along y direction it is 8mm diameter bar at 200mm c/c.

This is the cross section of the slab, so here I am taking the cross section along x direction that is 4.23m and along y direction it is 5.23m. Here along the x direction it is the straight bar and this will be the crank reinforcement. Alternate bar has to be cranked near the face of the support that is 0.1l from the face of the support. So both the reinforcements are main reinforcement since it is the two way slab. In the case of the plan view this is the reinforcement along x direction. If you take the wall here this is the reinforcement along y direction. This is the arrangement of reinforcement or the detailing of reinforcement as per SP 34. Here we have seen a slab of three edges discontinuous and one long edge continuous. With this condition we have found the bending moment from the table 26 and using the moment coefficient we have found the bending moment at the respective places. And we have provided the reinforcement for the respective bending moments.

<u>Summary:</u>

In this lecture we have seen the design of two way restrained slab. In this slab the three edges are discontinuous and one long edge is continuous. So with this condition we have found the bending moment coefficients from the table 26 of IS

456. And we have found the respective bending moment for the respective bending coefficients. We have found the effective depth of the slab for maximum bending moment and also we have designed the reinforcement required for the maximum bending moment along x direction as well as y direction.

Questions:

To design the section:

1. Design a two way reinforced concrete floor slab for a room of size 3m x 5m when the corners of the slabs are prevented from lifting and subjected to a live load of $3kN/m^2$. The load due to partition wall is $2.5kN/m^2$ and floor finish is $0.6kN/m^2$. Use M20 and Fe415 as materials.
2. Design the reinforcement required for a two way simply supported slab for room of size 6m x 6m clear. It is supported on 230mm thick wall. Live load on slab is $1.5kN/m^2$. Three edges discontinuous (one short edge continuous) consider other dead load 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.
- Ashok Kk. Jain, "Reinforced concrete: Limit State Design" Nem Chand & Bros., Roorkee (Vol 6th Ed) year: 2006.