Design of Structure – II

Lecture – 32

In the previous lecture we have seen the design of simply supported slab which is rectangular simply supported slab that supported on four sides. It do not have any adequate provision to resist the corners from lifting. In this lecture we are going to design the two way slab that is restrained slab which is having proper adequate provision to resist corners from lifting. So here in this also we are going to calculate the total load on the slab and before that we need to find out whether the slab is two way slab or one way slab from the ratio ly/lx. If the ratio is less than two then it has to be designed as two way slab. Then using load as well as the span of the slab we are going to find out the bending moment as per IS codal service which is given in table 26. For simply supported slab table 27 has to be used for finding out the bending moment and for restrained slab which has adequate provision to resist the torsion we need to use the table 26 for finding out the bending moment coefficients.

Using the maximum bending moment here in the case of restrained slab we are going to find out both negative as well as positive moment along both the direction. We are going to get two moments at each direction. From four moments we are going to select the maximum bending moment for finding out the effective depth of the slab. In the case of reinforcement along x direction we are going to have two moments and from the two moments we are going to select the maximum bending moment for the reinforcement which is used to find out the reinforcement in the case of x direction. And along y direction we are also having two moments that is positive as well as the negative moment. Among this two we are going to select the maximum bending moment for finding out the reinforcement along y direction. Finally we are going to check the depth of the footing against deflection and also we are going to draw the reinforcement detailing in the case of restrain slab.

Design of Two Way Slab

Analyze and design the reinforcement required for a two way slab simply supported on all the four sides when the corners of the slabs are prevented from lifting. The clear dimension of the room is 4m x 4m with one long edge discontinuous. It is supported on 230mm thick wall. Live load on slab is $3kN/m^2$. Consider other dead loads also. Use M20 and Fe415 as materials.

Solution:

This is the table 26 which is given in IS 456 for the restrain slab which is having adequate provision to resist the torsion. So here the condition given in the problem is one long edge discontinuous. Using this one we are going to find out the respective moment coefficient for x-direction as well as y direction for negative and positive bending moment. And using this bending moment we are going to find out the effective depth of the slab as well as the reinforcement for it. Here the clear dimension of the room is 4m x 4m. And the effective dimension it is supported on 230mm wall on all four sides and the effective dimension of room is 4.23m x 4.23m. The condition for the two way restrain slab is one long edge discontinuous. Here as usual we are going to find out the ratio ly/lx that is equal to 4.23/4.23 which is equal to 1. It is lesser than two hence it is confirmed that it is two way slab.

Load calculation:

Dead load:

For the dead load first we need to assume the thickness of the slab from the deflection criteria. So here the dimension of the room is more than 4m that is we need to follow the usual effective dead ratio l/d is equal to 20.

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

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

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

But I am going to keep the overall depth of the slab as 150mm. So normally we need to assume somewhat more than the depth which we get from deflection criteria. But anyway based on my experience I am keeping depth equal to 150mm. And I am going to check the depth against the bending as well as against the serviceability criteria. If it is not same we need to again redesign by assuming somewhat more than the thickness which we have been assumed in the first one.

The self weight of the slab is 0.15 x 25 which is equal to 3.75kN/m^2. In addition to that they have asked as to consider other dead loads also. There is self weight of the slab and then self weight of floor finish. So I am going to provide the floor finish of 0.025 x 24 which is equal to 0.60kN/m^2. In addition to this I am also considering the weight of partitions. The weight of partition here it is 1.96kN/m^2.

Now the total dead load is equal to $w_d = 6.31kN/m^2$. And here dead load we have calculated.

Live load on the slab:

Live load on the slab is given in the problem that is $w_l = 3.0kN/m^2$. Now we are finding total load on the slab. The total load on the slab is given as,

$$w = w_d + w_l = 9.31kkN/m^2$$

Bending moment calculation:

In the case of bending moment now we are going to use the table 26 to find the moment coefficients for the ratio ly/lx =1. From the table 26 with the condition of one long edge discontinuous the first one is α_x which is negative moment coefficient that is for 1 it is equal to 0.037 and next for positive moment coefficient at mid-span is 0.035. These are the two moment coefficient along x direction. Then α_y that is long span coefficient in the y direction is equal to 1. So here for any ratio that is for any value of α_x the negative moment coefficient in y direction is 0.037 and positive moment coefficient is 0.028. So here the moment coefficient along x as well as y direction are same. To find out moment that is

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

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

Here we are having two values for both the x and y direction so we are going to choose the maximum value for the bending moment.

$$M_x = 0.037 w l_x^2 = 5.88 kNm$$

$$M_y = 0.037 w l_x^2 = 5.88 kNm$$

$$M_x = M_y = 5.88 kNm$$

$$M_{ux} = M_{uy} = 1.5 \times 5.88 = 8.82 kNm$$

So this is the way of calculating the bending moment coefficient for a two way restrained slab which is having adequate provision to resist torsion at the corners. Here the condition of slab is one long edge discontinuous and other three edges are continuous.

Effective depth of the slab:

Here I am going to consider one meter width of the slab. Normally we are designing the slab for one meter depth and the same has to be adopted for entire area of the slab. And also by considering a balanced section so by equating the maximum bending moment and the limit state of the bending moment that is,

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

$$d = \sqrt{\frac{M_{u\max}}{0.138 f_{ck} b}} = \sqrt{\frac{8.82 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$= 56.53 mm < 180 mm$$

Hence it is safe against flexure that is limit state of collapse.

Area of reinforcement along both the direction:

Since here the M_{ux} and M_{uy} are same the reinforcement alone both the directions are almost same. So here $M_{ux} = M_{uy}$.

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

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times A_{st}}{0.36 \times 20 \times 1000} = 0.05 A_{st}$$

$$8.82 \times 10^6 = 0.87 \times 415 \times A_{st}(d - 0.416 \times 0.05 A_{st})$$

$$A_{st}^{\ 2} - 6249.87 A_{st} + 1.17 \times 10^6 = 0$$

$$A_{st(req)} = 193.77 mm^2$$

Check with minimum Ast:

$$Min.A_{st} = \frac{0.12}{100} \times 1000 \times 130 = 156 mm^2 < 193.77 mm^2$$

$$A_{st(req)} = 193.77 mm^2$$

I am using 8mm diameter bar and then I am finding spacing for reinforcement as,

$$= \frac{\pi/4 \times 8^2 \times 1000}{193.77} = 260.21 mm$$

This spacing is should be again check with the maximum spacing.

Check for Maximum Spacing

The maximum spacing should not exceed 3 times the effective depth of the slab and 300mm whichever is less. That is 3 x 130 that is equal to 390mm. Here this

300mm is somewhat greater than 266.21. hence adopt 8mm diameter bar at 230mm c/c.

$$A_{st(pro)} = \frac{\pi/_4 \times 8^2 \times 1000}{230} = 218.55mm^2$$

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

Here the l/d ratio is 20 and this has be again modified by multiplying with the modification factor.

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

I have already told you that this modification factor has to be found from figure 4 of IS 456:2000. It has several numbers that is 4 or 5 curves depends on the stress which is developed in the reinforcement and this graph shows the modification factor. In order to find the modification factor we need to find out the percentage tensile reinforcement,

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

$$= \frac{100 \times 218.55}{1000 \times 130}$$

$$= 0.17\%$$

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

$$= 0.58 \times 415 \times \frac{193.77}{218.55} = 212.75 N/mm^2$$

So by referring the figure 4 by using the percentage of reinforcement and the stress developed in the reinforcement the modification factor here it is 2.0.

$$d = \frac{l}{20 \times M.F} = \frac{4230}{20 \times 2.0} = 103.25 mm < 130 mm$$

So here it is safe as well as economical section. The basic aim of structural design is the structure should be safe and it should be more economical. Here we are going to adopt the depth of the section as 150mm and the effective depth of the section is 130mm and their reinforcement is 8mm diameter bar at 230mm c/c.

Reinforcement detailing:

Here it is a square slab and it is a restrained slab. This is the straight bar with cranked reinforcement. And this is the main reinforcement in another direction i.e., in y direction. Both the reinforcements are same since the size of slab ly is equal to lx. Here is 4.23mm x 4.23mm dimension of the bar and it has the 8mm diameter bar at 230mm c/c. The alternate bar has to be cranked at the support or from the face of the support as 0.1l. If we take this as the plan view then the reinforcement has to be provided along both the direction. Since it is the restrained slab we are not providing the reinforcement at the corners which is prevented from lifting. So we need not provide the torsion reinforcement at the corners.

Summary:

In this lecture we have seen a problem which is used to design a two way restrained slab for a room of size 4m x 4m which is resting on 230mm wall. So it has the adequate provision to resist the torsion at the corners. And also here we have seen the design of slab that is the design consisting of thickness of slab as well as the reinforcement detailing.

Questions:

To design the section:

1. Design a two way reinforced concrete floor slab for a room of size 5m x 6m when the corners of the slabs are prevented from lifting and subjected to a live load of $3kN/m^2$. The load due to floor finish is $1kN/m^2$ and partition is $2kN/m^2$. Use M20 and Fe415 as materials.
2. Design the reinforcement required for a two way simply supported slab for room of size 5m x 5m 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 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.
- Ashok Kk. Jain, “Reinforced concrete: Limit State Design” Nem Chand & Bros., Roorkee (Vol 6th Ed) year: 2006.