Design of Structure – II

Lecture – 30

In the previous we have seen the design of one way continuous as one way continuous floor slab and one way continuous roof slab. And also we have seen the reinforcement detailing. In this lecture we are going to see the design of two way slab that is simply supported slab. If you design a two way slab that is simply supported slab does not provide any abdicate provision to resist the torsion at corner. In the case of two way simply supported slab it is freely supported over the walls if it is freely supported on the beams. So it is the four corners are lifted up. In order to resist the lifting up of the slab at the corners or in order to resist the torsion at the corners we need to separately design corner reinforcement that is called torsion reinforcement at the four corners. So in the case of two way simply supported slabs there is a separate table which is given in the code book that is table 27 which is used to design or which is used to find out the moment coefficient for the two way simply support for finding the bending moment for two way simply supported slab. So in the case of simply supported slab there are steps to calculate. First we need to calculate the load before that we need to calculate whether it is two way simply supported slab or one way slab. If it is two way simply supported slab first we need to calculate the total load acting on the slab. Then we need to refer the table 27 for finding the bending moment at the various places that is support as well as at the mid-span.

Using the bending moment we need to first find out the effective depth of the slab and using the bending moment here we are finding whether it is a two way slab and the slab is suspended along two directions. We need to find the bending moment at both the direction and we need to select the maximum bending moment and effective depth of the slab. It is not like in the one way simply supported slab it is the two way slab we need to find the reinforcement along the directions on the respective bending moments and also we need to check the depth of the footing against the deflection. Finally we need to draw the reinforcement detailing of the simply supported slab. Now we are going to find the reinforcement of the simply supported slab. We need to work out some examples.

Example Problem

Analyse and design the reinforcement required for a two way slab simply supported on all the four sides with corners free to lift or the slabs do not having adequate provisions to prevent lifting of corners. The effective dimension of the room is 3.5m x 3.5m. 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:

Now here the effective size of the room is $l_y \times l_x$ which is equal to 3.5m x 3.5m. The ratio ly/lx is equal to 3.5/3.5 which is equal to 1. It is less than 2 hence it has to be designed as two way slab. So it is two way simply supported slab and it does not have any addicate provision to resist the torsion at the corners. So we need to find out the bending moment coefficients by referring a separate table that is table 27 of IS 456:2000.

Before designing the thickness of the slab first we need to calculate the load which is acting over the slab.

Load calculation:

Dead load:

Dead load which consist of self weight of the structure itself and weight of the floor finish. In the case of this building that is it has the effective dimension of 3.5m by 3.5m within this we are not constructing any partition wall. So we need to consider only the self weight of the wall as well as the floor finish as the dead load. We are not going to consider any partition wall which is constructed inside the building. So to find out the self weight of the slab first we need to assume the thickness of the slab. This assumption is based on the deflection criteria. But here we have normally in the case of simply supported slab we have followed the deflection rule that is,

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

It is for a simply supported slab but a separate codal provision which has been given in IS 456:2000 for the two way slab with the condition that is the span of slab should not exceed 3.5m and the type of loading should not exceed 3.0kN/m^2. If the span of slab that is the shortest span that should not exceed 3.5m and the type of load should not exceed 3.0kN/m^2. We can use the deflection control as that is l/d ratio that is overall ratio has 35. If you use main steel bar the overall depth ratio is 35. If you use deform bar this value again reduced by multiplying the 0.8 which is the separate codal provision which is given in IS 456:2000 for a two way simply supported slab that the condition of the shortest span that should not exceed 3.5m and the loading type should not exceed 3.0kN/m^2.

$$D = \frac{l}{35 \times 0.8} = \frac{3500}{35 \times 0.8} = 125mm$$

I am going to keep D is equal to 125mm as the overall depth of the slab.

$$d = 125 - 15 - 10/2 = 105mm$$

Here the first one is self weight of the slab in the case of dead load of the slab thee self weight is the overall thickness of the slab that is $0.125 \times 25 = 3.125 kN/m^2$.

And the weight of floor finish is equal to $0.024 \times 24 = 0.60 kN/m^2$. Now total dead load over the slab is $w_d = 3.725 kN/m^2$.

Live load on the slab:

The live load on the given slab which is equal to $w_l = 3.0 kN/m^2$. Now total weight on the slab W is equal to 6.725kN/m^2.

Bending moment calculation:

As I have already told you that there is a separate table that is table 27 of IS 456:2000 which is used to find out the moment coefficient for the two way simply supported slab for the ratio of ly/lx. Here the ratio is equal to 1 and α_x is the moment coefficient along x direction and α_y is the moment coefficient along y direction. So for x direction it is 0.062 and for y direction again it is 0.062. This is the moment coefficient. In similar way we need to find the moment coefficient for both the direction of simply supported slab which do not have any addicate provision to resist torsion at corners.

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

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

Here in both the expression we have used lx that is the shortest span that is most important.

$$M_x = 0.062 \times 6.725 \times 3.5^2 = 5.11 kN/m$$

$$M_y = 0.062 \times 6.725 \times 3.5^2 = 5.11 kN/m$$

So the bending moment along both the direction is 5.11kN/m.

$$M_{ux} = M_{uy} = 1.5 \times 5.11 = 7.665 kNm$$

<u>Effective depth of the slab:</u>

The effective depth of the slab is calculated by considering a balanced section. And also 1m width of the slab and when you consider this as the balanced section. We need to equate maximum bending moment value and the limiting state of the bending moment.

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

$$d = \sqrt{\frac{M_{ux}}{0.138 f_{ck}}} = \sqrt{\frac{7.665 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$d = 52.70 < 105 mm$$

Hence it is safe against the flexure. Now I am going to keep the depth of slab as 125mm and d as 105mm in order to check the depth of the section against the deflection.

Area of reinforcement:

Along both the direction,

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

This is the expression which is used to find out the area of reinforcement which is required for singly reinforced or under reinforced section.

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

$$= 0.05 A_{st}$$

$$A_{st}{}^2 - 5047.97 A_{st} + 1.02 \times 10^6 = 0$$

$$7.665 \times 10^6 = 0.87 \times 415 \times A_{st} (105 - 0.416 \times 0.05 A_{st})$$

$$A_{st(req)} = 210.87 mm^2$$

Check with minimum A_{st}:

The minimum A_{st} for deformed bars it is 0.12% of the cross sectional area of concrete.

$$= \frac{0.12}{100} \times 1000 \times 105 = 126 mm^2 < 210.87 mm^2$$

Hence A_{st} required for our design is $210.87mm^2$.

Check for maximum spacing:

By using 8mm diameter bar and the spacing of reinforcement is,

$$= \frac{\pi/4 \times 8^2 \times 1000}{210.87} = 238.37mm$$

So for maximum spacing there is a maximum parallel main reinforcement that should not exceed the least of the following that is 3 x d and the second one is 300mm. That 3d is 3 x 10^5 which is equal to 315mm. Here the lesser value is 300mm. So I can adopt 8mm diameter bar at 200mm c/c on both the directions.

Check the depth of the sections against deflection:

It is similar to as we have done in the previous problem that is equal to,

$$\frac{l}{D} = 35 \times 0.8; D = 125mm$$

For 125mm thickness of the slab the main reinforcement has been provided as 8mm diameter bar at 200mm c/c.

Now we need to see the reinforcement detailing. Here before seeing the reinforcement detailing first we need to design the torsion reinforcement at four corners. Since it is the two way simply supported slab this slab which do not have any addicate provision to resist torsion at corners. So to avoid or to prevent the lifting up of the corners we must provide the reinforcement at the corners in the form of mesh reinforcement both top as well as at the bottom. That is at the top two layers and at the bottom two layers. As per IS 456:2000 the torsion reinforcement is equal to the Ast required for the main reinforcement.

$$A_{st} = 3/4 A_{st(req)} = \tfrac{3}{4} \times 210.87 = 128.13 mm^2$$

Using 8mm diameter bar for corner reinforcement and spacing of 8mm diameter bar of the corners,

$$= \frac{\tfrac{\pi}{4} \times 8^2 \times 1000}{128.13} = 390 mm$$

That is I am taking this as 300mm approximately. So this reinforcement has to be provided at the corners. So here this is the slab which is the square slab, now how to resist the torsion at the corners. This is the portion need to provide the 8mm diameter bar at 300mm c/c in the form of line along both the directions. That is both at both top as well as at the bottom. Here the reinforcement is 3/4th of the main reinforcement. Along with the reinforcement this is the main reinforcement we are providing in the case of two way slab. That is the reinforcement has to be provided along both the direction. Alternate bar has to be cranked over the supports. So here when you take the cross section, it is simply supported on walls. So this is the cross section of the reinforcement. The wall has to be cranked at 0.1l from the face of the support to avoid the tension at top. If 50% of the reinforcement has be provided at the top to resist the torsion to avoid the partial resistance which is developed at the support and this is also the main reinforcement. But in the case of one way simply supported slab this reinforcement has been normally distribution reinforcement. Here since it is a slab the reinforcement along both the direction are the main reinforcement. This is the main reinforcement that is 8mm diameter bar at 200mm c/c. Andd this effective span of the slab is 3.0m(l) and this is the cross section of the reinforcement and this is the plan view of the reinforcement.

So in the case of the two way simply supported slab which do not have any adequate provision to resist the torsion at the corners. We need to provide the torsion reinforcement in addition to the main reinforcement at four corners in four layers. The length of the reinforcement at the face of the support from the end of the slab and this is the design of the two way simply supported slab for a building. We have found the bending moment along both the direction since it is a two way simply supported slab. There is a bending moment along both the direction and the reinforcement is provided along both the direction.

Summary:

So far we have seen the design of two way simply supported slab by using the moment coefficient given in table 27 of IS 456:2000. We have designed one slab that is using the worked example. And the thickness of the slab as well as the reinforcement has been found and also the reinforcement detailing has been discussed.

Question:

To design the section:

1. Design a two way reinforcement concrete floor slab for a room of size 4m x 5m 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 slab simply supported on all the four sides with corners free to lift or the slabs do not having adequate provisions to prevent lifting of corners. The clear dimension of the room is 5m x 5m. It is supported on 230mm thick wall. Live load on slab is $1.5 kN/m^2$. 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.
- Ashok Kk. Jain, "Reinforced concrete: Limit State Design" Nem Chand & Bros., Roorkee (Vol 6th Ed) year: 2006.