<u>Design of structure – II</u>

<u>Lecture – 35</u>

In the previous lecture we have seen in detail about the behavior of circular slab which is subjected to UDL and also we have seen the reinforcement detailing of varies surplus slabs such as simply supported slab, fixed supported circular slab. Now let us start designing the slab one by one. So in this lecture we are going to design a simply supported surplus slab by doing certain worked example. In this first we must know the effective span of the slab. By knowing the effective span of the slab we will find the bending moment of the slab then using the loads we want to find out the bending moment at varies places that is the circumferential bending moment and the radial bending moment. And we are going to find out the effective depth of the slab for the maximum bending moment and we are going to find out the respective bending moments. And we need to calculate the spacing of reinforcement and we are also going to see in detail about how to provide the reinforcement in the case of simply supported slab.

Design of Simply Supported Circular Slab - 1

Design a circular slab for a room 6m in diameter (clear) and supported on 350mm thick masonry walls. Live load on slab is 2.0 kN/m^2. Also consider waterproofing load 1.75 kN/m^2 and floor finish 1kN/m^2. Use M20 mix and Fe415 grade steel.

<u>Solution:</u>

Here there is a circular slab which is simply supported at the edges. So here this is the slab which is simply supported and here the effective span of the slab is

6.35m and the effective radius of the slab is 6.35/2. So the diameter of the slab is 6m and effective diameter is 6.35m.

Load calculations:

Dead loads:

The dead load includes the self weight of the slab. So to find out the self weight of the slab the thickness of the slab which is normally assumed from its deflection control i.e., l/d ratio for simply supported slab is 20.

$$d = \frac{l}{20} = \frac{6350}{20} = 317.5mm$$

$$D = 317.5 + 20 + 10/2 = 342.5mm$$

Here I am going to consider from my experience D is equal to 250mm and d is equal to 230mm. Then the self weight of the slab is

$$0.25 \times 25 = 6.25kN/m^2$$

$$f_s = 1.00kN/m^2$$

$$Water.proffing.load = 1.75kN/m^2$$

Now the total dead load is equal to,

$$w_d = 9.0kN/m^2$$

Live load on the slab:

The live load on the problem is given in problem which is equal to,

$w_l = 2.0kN/m^2$

Now total load acting on the slab is,

$w = w_d + w_l = 11.0kN/m^2$

Here in the simply supported slab we are having a circumferential moment of 3/16wa^2 at the center and 2/16wa^2 at the edge and the radial moment of 3/16wa^2 at the center. We need to satisfy the moment at the center and also we need to satisfy the moment at the edge that is circumferential moment.

<u>The effective span of the slab:</u>

The effective span of the slab is,

$= 6 + 0.35 = 6.35m$

$= 6 + 0.25 = 6.23m$

Here we are going to select whichever is less hence the effective span of the slab is 6.23m.

<u>Bending moment calculation:</u>

There are two bending moments one is circumferential moment and another one is radial moment. So we all know that M_r at the edge is zero. So M_θ at the center which is equal to M_r at the center which is equal to 3/16wa^2 which is equal to 20.01kNm.

$M_{\theta u} = M_{ru} = 1.5 \times 20.01 = 30.02kNm$

This is the radial moment at the center as well as the circumferential moment at the center. Next the circumferential moment M_θ at the edge that is 2/16wa^2 which is equal to 13.34kNm.

$$M_{\theta eu} = 1.5 \times 13.39 = 20.01 kNm$$

So we have calculated the bending moment.

Effective depth of the slab:

Normally the effective depth of the slab will be found from the maximum bending moment. So among this two bending moment maximum bending moment is

$$M_{ax} BM = M_{ru} = M_{cu} 30.02 kNm$$

So by considering one meter width of the slab and by equating maximum bending moment to limiting state of bending moment we get,

$$30.02 \times 10^6 = 0.138 f_{ck} b d^2$$

$$d = \sqrt{\frac{30.02 \times 10^6}{0.138 \times 20 \times 1000}} = 104.29 mm < 230 mm$$

Hence this is safe against flexure or bending moment.

Area of reinforcement:

First we need to find out what is the area of reinforcement required for the circumferential bending moment at the center and the radial moment at the center.

$$M_{\theta uc} = M_{ruc} = 30.02 kNm$$

Here I am keeping the value of D as 250mm and d is equal to 230mm.

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

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

$$30.02 \times 10^6 = 0.87 \times 415 \times A_{st} (230 - 0.416 \times 0.05 A_{st})$$

$$A_{st}^2 - 11057.46 A_{st} + 4 \times 10^6 = 0$$

$$A_{st}(req) = 374.43 mm^2$$

We need to check this with the maximum value and I am going to use 8mm diameter bar to find the spacing of reinforcement.

$$= \frac{\pi/4 \times 8^2 \times 1000}{374.43} = 134.25 mm$$

Design of Simply Supported Circular Slab - 2

Check with the Maximum Spacing

The maximum spacing is normally should not be more than the least of the following that is 3d and 300mm. So 3d is 3 x 230 which is equal to 690mm. So here the least value is 300mm which is greater than the calculated value. So we can provide 8mm diameter bar at 110mm c/c.

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

This is the area of reinforcement required for resisting the radial bending moment as well as the circumferential bending moment at the center. So here we need to find the reinforcement required for circumferential moment at the edge that is equal to $M_{\theta eu} = 20.01 kNm$.

$$20.01 \times 10^6 = 0.87 f_y A_{st} (d - 0.416 x_u)$$

$$x_u = 0.05 A_{st}$$

$$A_{st}^2 - 10095.94 A_{st} + 2.544 \times 10^6 = 0$$

$$A_{st}(req) = 258.19 mm^2$$

So using 8mm diameter bar the spacing of reinforcement will be,

$$= \frac{\pi/4 \times 8^2 \times 1000}{258.19} = 194.68 mm$$

Now provide 8mm diameter bar at 175mm c/c as the circumferential reinforcement at the edges for a distance of L_d.

$$L_d = \frac{\phi \sigma_{st}}{4 \tau_{bd}}$$

This is the reinforcement provided in the circumferential direction at the bottom and at the edge for a distance from the face of the support.

$$= \frac{8 \times 0.87 \times 415}{4 \times 1.2 \times 1.6} = 376 mm$$

This reinforcement has to be provided over a distance of 0.376mm from the face of the support at the bottom. This reinforcement is not only provide for the an-courage purposes it is also provide to resist the sliding of bottom reinforcement at the edges.

Check the depth of the section against deflection:

Here l/d ratio for the simply supported slab is 20 and that has to be again modified by multiplying with the modification factor. This modification factor which has to be found from figure 4 of IS 456 which shows the modification factor verses the percentage tensile reinforcement and also depends on the tension developed in the reinforcement. So first we need to find out the percentage of reinforcement to find the modification factor.

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

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

$$= \frac{100 \times 456.96}{1000 \times 230} = 0.2\%$$

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

$$= 0.58 \times 415 \times \frac{374.43}{456.96}$$

$$= 197.28 N/mm^2$$

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

$$= \frac{6230}{20 \times 2}$$

$$= 158.75mm < 230mm$$

Hence it is safe against serviceability as well as the flexure.

Design of Simply Supported Circular Slab - 3

Reinforcement Detailing

Now we need to draw the reinforcement detailing.

This is the slab and in order to resist the radial bending moment as well as the circumferential moment at the center. The reinforcement has to be provided along both the direction. This is the mesh form of reinforcement to resist the maximum bending moment at the center both the radial as well as the circumferential moment. In the case of simply supported slab there is no radial moment at the edge. So here this is 8mm diameter bar at 110mm c/c. This is the reinforcement which is used to resist the circumferential moment as well as this is the simply supported slab you take this as the support. So here this is 6.23m and the reinforcement at the bottom here it is the mesh form of reinforcement. In order to resist the circumferential moment at the edge we have to design the reinforcement that is 8mm diameter bar at 175mm c/c. This has to be provided over a distance of 0.376 from the face of the support. So this is the circumferential reinforcement which has to be provided at the bottom. This is the arrangement of reinforcement for the simply supported slab. So here we have seen what will be the diameter of the slab at 6m, and we have found the effective span of the slab that is 6.23m. And we have calculated the load acting the slab that is dead load and the live load. And we have calculated total load and then using the total load we have found the bending moment that is both circumferential as well as the radial bending moment. In the case of simply supported circular slab the maximum radial moment and the circumferential moment at the center here it is $3/16wa^2$ and there is no radial bending moment at the edge. And there is a circumferential moment at the edge that is $2/16wa^2$. In order to resist this maximum circumferential as well as the radial moment at the center the reinforcement has been provided along both the direction that is the mesh form of reinforcement at the bottom. In order to avoid the sliding of reinforcement and also to satisfy the circumferential moment at the edge we need to find the reinforcement and the reinforcement has been provided in the circumference of the circular slab at the edge. This has to be provided over a distance of development area of the reinforcement that is equal to 0.376 from the face of the support on either side. So this is the arrangement of reinforcement which is required for the design of the circular simply supported slab.

Summary:

Here we have seen in detail about the design of simply supported circular slab then we have carried out a simple problem and from that we have know how to design the simply supported slab, how to find the effective depth of the slab and how to find out the bending moment and how to draw the reinforcement detailing of this circular slab i.e., the simply supported circular slab.

Questions:

Design of simply supported circular slab,

1. Design a simply supported circular slab for a water tank having 6m in diameter (effective) with simply supported edge. Total superimposed load on the slab is 1.5kN/m^2. Use M20 mix and Fe415 grade steel.

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.