<u>Design of Structure – II</u>

<u>Lecture – 36</u>

In the previous lecture we have seen the design of simply supported circular slab and the reinforcement required for it. In this lecture we are going to discuss about the design of fixed circular slab and also the reinforcement detail required for it. In this we are going to cover or we are going to find out the effective span of the slab and load acting on the slab. Using total load acting on the slab we are going to find out the bending moment at varies places. In this fixed circular slab there are two bending moment which is developed that is circumferential bending moment at the center and the radial moment at the edge as well as in the center since it is fixed the radial bending moment is also developed at the edge. In order to satisfy these three moments we need to find out the reinforcement detailing for it. And also we are going to find out the spacing of reinforcement and finally we want to check the spacing with the maximum spacing as per IS 456:2000. Finally we are going to draw the reinforcement detailing required for the fixed circular slab. So here we are having the problem.

Example Problem

Design a RCC circular cover slab of 7.5m clear diameter supported on 230mm thick beams which can provide complete fixity of the slab. The slab is used to support a parking load of 7.5kN/m^2. Consider floor finish of 1.0kN/m^2. Use M20 mix and Fe415 grade steel.

<u>Solution:</u>

Here they have given fixed circular slab of diameter supported on 230mm thickness beam. The edges are fixed beam. The clear diameter of the slab is 7.5m which is supported over 230mm supports. Now there is a bending moment which is developed and this is the circumferential bending moment M_θ and maximum bending moment here it is $wa^2/16$. And another bending moment that is the radial bending moment and the maximum radial bending moment at the center is $wa^2/16$ and the maximum bending moment at the edge is $2wa^2/16$. So the maximum bending moment or the zero bending moment that occurs at a distance $\frac{a}{\sqrt{3}}$ on either side of the center of the support. Now we need to satisfy this moment and we need to find by finding out the effective depth of the slab as well as the reinforcement required for it.

Here the clear span of slab is 7.5m and it is supported on 230mm thick wall that is an effective span of slab that is 7.73m. Now we need to first find out what was the load on the slab.

Load on slab:

Dead load:

The dead load consist of the self weight of the slab itself in addition to the self weight we need to consider the floor finish of $1.0 kN/m^2$ and the live load over the span is $7.5 kN/m^2$. So thickness of slab which is assumed from l/d ratio which is equal to 20 for simply supported continuous cantilever slab.

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

$$d = \frac{l}{20} = \frac{7730}{20}$$

$$= 386.5mm$$

$$D = 386.5 + 15 + 20 + 10/2 = 406.5mm$$

And based on my experience I am going to keep the diameter of the slab as 300mm and finally we need to check whether our assumption is correct or not against the limit state of collapse as well as the limit state of serviceability. If it is not satisfy we need to redesign by assuming somewhat more than the 300mm. Now the self weight of the slab the self weight of the slab is equal to,

$$= 0.3 \times 25 = 7.5kN/m^2$$

In addition to the self weight they are asking as to consider the weight of floor finish as 1.0kN/m^2. So total dead load on the slab is

$$w_d = 8.5kN/m^2$$

That is in addition to this dead load they are asking us to consider the parking load.

Live load of the slab:

The live load of the slab is $w_l = 7.5kN/m^2$. So total load on the given slab is equal to

$$w = w_d + w_l = 16kN/m^2$$

Effective span:

This is the slab which is supported over the 230mm beam. So effective span of the slab is equal to the clear span plus the depth of the slab we have assumed that is

$$l_{eff} = l + d = l + 0.28 = 7.5 + 0.28 = 7.78m$$

Or c/c distance between the supports i.e., 7.5 + 0.23 that is equal to 7.73m. From these two values we need to select the minimum value that is 7.73m.

Bending moment:

Here we need to find out the bending moment that is circumferential bending moment as well as the radial bending moment. Since it is fixed the circumferential bending moment at $M_{\theta c}$ must be equal to the radial moment at center M_{rc}.

$$M_{\theta c} = M_{rc} = \frac{wa^2}{16}$$

$$\frac{16 \times 3.865^2}{16} = 14.94kNm$$

$$M_{\theta cu} = M_{rcu} = 14.94 \times 1.5 = 22.41kkNm$$

This is the radial as well as circumferential moment at the center. Now there is also the radial moment at the edge.

$$M_{re} = -\frac{2}{16}wa^2 = -\frac{2}{16} \times 16 \times 3.865^2 = 29.38kNm$$

$$M_{reu} = 44.82kNm$$

Effective depth of the slab:

The effective depth of the slab is found against the maximum bending moment. So consider one meter width of the slab and by equating maximum bending moment to the limit state of the bending moment that is by considering the section as the balanced section.

$$M_{u\max} = M_{reu} = 44.82 \times 10^6 = 0.138 f_{ck} bd^2$$

$$d = \sqrt{\frac{44.82 \times 10^6}{0.138 \times 20 \times 1000}} 127.44mm < 280mm$$

So it is safe against flexure. Now we need to find out the reinforcement before checking the depth of the section against deflection or limit state of serviceability.

Area of reinforcement:

$$M_{rcu} \,\&\, M_{\theta cu}$$

The first one is for the radial moment and the circumferential moment which is equal to

$$M_{rcu} \,\&\, M_{\theta cu} = 22.41kNm$$

This is the bending moment at the center of the slab. So again I am going to keep D is 300mm and d is 280mm.

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

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

$$22.41\times10^{6}=0.87\times415\times A_{st}(280-0.416\times0.05A_{st})$$

$$A_{st}{}^{2}-13461.25A_{st}+3.03\times10^{6}=0$$

$$A_{st}(req)=228.97mm^{2}$$

This is the reinforcement required for the bending moment at the center of the slab by using 8mm diameter bar.

Spacing

Now we need to find out the spacing,

$$=\frac{\pi/4\times8^{2}\times1000}{228.97}=219.53mm$$

So I am going to provide an 8mm diameter bar at 200mm c/c on both direction at the bottom.

<u>For radial moment at the edge:</u>

$$M_{reu}=44.82kNm$$

$$M_{reu}=0.87f_{y}A_{st}(d-0.416x_{u})$$

$$44.82\times10^{6}=0.87\times415\times A_{st}(280-0.416\times0.05A_{st})$$

$$A_{st}{}^{2}-13461.23A_{st}+5.97\times10^{6}=0$$

$$A_{st}(req)=459.16mm^{2}$$

Now I am using 10mm diameter bar for spacing of reinforcement that is,

$$=\frac{\pi/4\times 8^2\times 1000}{459.16}=171.05mm$$

So I can provide 10mm diameter bar at 150mm c/c on radial direction at the top.

$$A_{st}(pro)=\frac{\pi/4\times 10^2\times 1000}{150}=523.60mm^2$$

The reinforcement has to be provided over a length of radial reinforcement at the top,

$$=\frac{D}{2}-\frac{a}{\sqrt{3}}=3.865-\frac{3.865}{\sqrt{3}}$$

$$=1.75m$$

In order to resist or distribute this radial reinforcement at the top with the proper spacing we need to also provide the circumferential reinforcement that is minimum circumferential reinforcement at the top is 10mm diameter bar at 150mm c/c. This is the reinforcement provided over a length of the radial reinforcement. This is also to avoid the sliding of reinforcement at the top. Now I need to draw the reinforcement detailing required for it.

Here this is the slab and this is the reinforcement at the bottom along both the direction to satisfy the radial moment at the center and also the circumferential moment at the center that's the moment is $wa^2/16$. The reinforcement we have found here it is 8mm diameter bar at 200mm c/c. This reinforcement has to be provided both at the top as well as at the bottom. At the bottom it has to be provided over a distance of $L_d=\frac{\phi\sigma_x}{4\tau_{bd}}$. It has to be provided a circumferential reinforcement at the bottom that is the minimum reinforcement over a distance of 0.376m from the face of the support. This is to prevent the sliding of the reinforcement at the bottom at the edge. At the top we need to provide the reinforcement along radial direction to satisfy the radial moment at the edge. This is the reinforcement we have designed that is 10mm diameter bar at 150mm c/c. In order to keep this reinforcement at proper spacing at the top also we need to provide a circumferential reinforcement that is 10mm diameter bar at 150mm c/c. In the case of cross section this is the support and this is the bottom reinforcement on both the direction that is in the mesh form of reinforcement. This is along both the direction that is 8mm diameter bar at 200mm c/c. And also we need to provide a circumferential reinforcement over a distance of 0.376m from the face of the support. At the top we have provided reinforcement in the radial direction for a length of 1.75m from the face of the support. So this is the arrangement of radial reinforcement in the case of fixed circular slab.

Summary:

In this lecture we have seen a detailed design of the fixed circular slab which is subject to parking load of 7.5kN/m^2. And also we have calculated the bending moment that is both radial as well as the circumferential bending moment. We have found the reinforcement required for it. And we have seen the reinforcement detailing of the fixed circular slab that is both at the top as well as at the bottom.

Questions:

Design of fixed supported circular slab,

1. Design a fixed supported circular slab for a room having 6m in diameter (effective). Total superimposed load on the slab is $3kN/m^2$. 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.