Design of Structure – II

Lecture – 34

In the previous lecture we have seen the design of slabs that is one way slab, two way simply supported slabs, two way restrained slabs and one way continuous slabs. So these are all the slabs designed based on the moment coefficients given in IS 456:2000. And we have found the bending moment and we have designed the thickness of the slab and the area of reinforcement required for the respective bending moment. Also we have seen in detail about the detailing of reinforcement based as SP 34:1987.

In this lecture we are going to discuss about the design of circular slabs. We are going to cover the design concept of simply supported circular slab normally we all know that the circular simply supported slab means the slab which is supported densely where it simply support on walls or supports. Next it is fixed that is both ends are fixed circular slab then partially fixed circular slab and its behavior, bending moment calculations and reinforcement detailing. Before that we need to know where the circular slabs has been used,

Uses of Circular Slabs

In a roof of a room or hall circular in plan, the slab has to be designed in circular slab that is simply supported or fixed circular slab.

It is normally used in the circular water tanks or towers and the roof of pump houses constructed above the tube wells so here the circular slabs which is plays a vital role. And we are also seen the traffic control post at the intersection of roads. So these are all the various places where we are using the circular slabs.

<u>Behavior – Circular slabs:</u>

In the circular slabs the bending which is takes place in two perpendicular directions. So the reinforcement should be provided along both the direction that should be in the form of mesh reinforcement since it bends along both the directions. In the case of simply supported slab there is a radial bending moment as well as the circumferential bending moment which is developed. Among these two bending moment we need to select the maximum bending moment and for the maximum bending moment, we need to provide the reinforcement along both the directions. In case of circular slab there is a circumferential moment which is normally developed at the ends of the slab. The reinforcement moment which is required for the circumferential moment which is normally placed in center or at the bottom i.e., over the mesh arrangement of reinforcement around the edge of the slab. That reinforcement which helps to avoid the sliding of reinforcement at the edge and it is also provided the anchorage to the mesh form of reinforcement at the edges. This has to be provided over the development length of the reinforcement.

But in the case of fixed slab there is the bending moment which is occurs at the edges. That is the radial bending moment is the negative bending moment. To resist that negative bending moment we need to provide the reinforcement at the top in the radial direction. So in order to keep that radial direction reinforcement that has to be uniformly spaced. And in order to distribute that radial reinforcement at top up to a distance of point of contra flexure the reinforcement has to be tied up with the circumferential reinforcement. That reinforcement is mainly used to distribute that reinforcement at the top with the proper spacing. And also it is used to avoid the sliding of reinforcement from its respective spaces. Here in the case of bottom reinforcement at the edges we need to provide a circumferential reinforcement over a length of development length of the reinforcement. That much amount of circumferential reinforcement which is also used to avoid the sliding of reinforcement at the edges and also used to keep the reinforcement with the proper position. This is the behavior of circular slab.

Design of Circular Slab

In this Circular Slab, we need to consider what are the loads distributed over the entire area of the slab. So the load which are normally dead loads and live loads. We are going to find what are the dead load, it is normally includes self weight of the structure itself and the weight of floor finish. In addition to this dead load we need to also consider the live load.

So we are going to find out total load which is acting on the slab. And also we know the radius of the slab. Let us consider a circular slab having,

w - UDL

a - Radius of slab

M_r - Radial bending moment at any point 'r' distance from the center of slab

$(M_r)_c \,\&\, (M_r)_e$ -Radial moment at center and edge respectively

M_θ -Circumferential moment at any point 'r' distance from the centre of slab

$(M_\theta)_c$ & $(M_\theta)_e$-Circumferential moment at center and edge respectively.

Here I am going to draw the circular slab, so here it is simply supported at the edges. So here when you take the radius of the slab it is written as 'a' which is subjected to some kind of uniformly distributed load. Then how to provide the reinforcement in this case, so here this is the circumferential bending moment diagram it is denoted by M_θ diagram. That is circumferential moment diagram. There is a circumferential moment diagram at the center that is 3/16 wa^2. And there is a circumferential moment at the edge which is 2/16 wa^2. This is the circumferential moment diagram for the simply supported slab. So to resist this circumferential moment at the edge we need to provide the reinforcement at the edges over a distance of the development length of reinforcement in the circumferential direction.

Since it is the simply supported circular slab the radial moment at the edge is zero and the maximum moment which is normally developed at the center and this moment is 3/16 wa^2 which is equal to the circumferential moment at the center. Then how to design the simply supported slab, thickness of the slab as well as the area of the reinforcement required for it. Here we are having two moments one is circumferential moment and another one is radial moment. So here the circumferential moment and the radial moment at the center are almost equal that is 3/16 wa^2. From the moment we are going to provide the reinforcement both are positive. So we need to provide the reinforcement at the bottom i.e., here this is the circular slab in order to resist this moment the reinforcement should be placed along both the direction. This is to resist $(M_\theta)_c$ & $(M_r)_c$. This is the form of arrangement of reinforcement to resist the bending moment.

Now in order to resist the bending moment that is at the support the reinforcement has to be placed in the circumferential dimension. This is the moment has to be provided at the distance of L_d from the face of the support. The development length of reinforcement is

$$= \frac{\phi \sigma_{xt}}{4\tau_{bd}}$$

So to resist this bending moment in the case of simply supported circular slab the reinforcement has been provided at the bottom for resisting the radial as well as the circumferential moment at the center and also at the edges. So this circumferential moment at the edge of the slab that is at the circular form which is used to resist the sliding of this mesh form of reinforcement at the edge. It is also provide necessary encourage to this radial moment reinforcement at the edges. Normally there is a chance of slipping up of reinforcement at the edge in order to keep this reinforcement in proper position the reinforcement has been provided. It is not only to resist the circumferential moment at the edge it is also to keep the main reinforcement at this respective place in order to avoid the sliding of reinforcement. This is in connection with the simply supported circular slab. The circumferential moment at any point at 'r' distance from the centre of slab is $M_\theta = w/16(3a^2 - r^2)$. And the radial moment at the distance 'r' from the center is $M_r = +3/16(3a^2 - r^2)$. the radial shear force at any radius 'r' $F_r = \frac{1}{2} w.r / unit.width$.

Fixed Supported Circular Slab

Next we come to the fixed supported circular slab. Now this is the circular slab which is fixed support at the edges. The radius of the slab is a. Here when you draw the cross section this is fixed support at the edge when it is subjected to any kind of force that is wkN/m^2. Now what is the radial as well as the circumferential moment. So here the circumferential moment at the edge of the slab is zero and the circumferential moment at the center of the slab is $\frac{wa^2}{16}$ and this is known as the M_θ diagram. Since it is the fixed slab there is the moment at the edges and it is $\frac{2}{16}wa^2$. So here the distance of point of zero bending moment from the center of the slab is $\frac{a}{\sqrt{3}}$. Then how to provide the reinforcement in order to resist this moments, here this is the circumferential moment and called as (M_r) diagram that is radial moment diagram. So here first resist this radial as well as the circumferential moment at the center and the reinforcement has to be provided along both the direction in the form of mesh at the bottom. Now here in the case of fixed slab there is the radial negative bending moment at the support. So in order to resist this radial moment of $\frac{2}{16}wa^2$ we need to also provide the reinforcement at the top. This is the figure shows the top reinforcement and this is along the radial direction. At what distance the reinforcement has to be provided that is most important. That is for a distance $a-\frac{a}{\sqrt{2}}$. Because the point of contra flexure which is occur at the center of the slab is $\frac{a}{\sqrt{2}}$.

And for the remaining distance we need to provide the reinforcement. In order to keep this reinforcement at the top at the radial direction we need to provide the reinforcement at the circumferential direction that is called as the circumferential moment. This is called as the minimum reinforcement and that minimum reinforcement which is used to keep the top reinforcement with the proper position or it is also used to avoid the sliding of reinforcement at the top. When we took the cross section of the slab which shows the reinforcement and the bottom reinforcement that is we are providing along both the direction. That is in the form of mesh and this is the radial reinforcement and this is the top reinforcement. Here this is the reinforcement which is to be provided from the face of the support $a-\frac{a}{\sqrt{3}}$. So this is the arrangement of reinforcement in the case of slab which has fixed supports.

Next there is another slab which is called as partially fixed slab. This is the partial fixed slab so here radius of the slab is a. Now we need to draw the cross section. This is the partial fixed slab and the radius of the slab is a. In the case of partial fixed slab there is a circumferential moment edge at the center. This is called the M_θ diagram. Here the circumferential moment ratio at the center is $\frac{2}{16}wa^2$ and at the edge is $\frac{1}{16}wa^2$. Since it is the fixed slab there is a negative radial moment at the edge is $-\frac{1}{16}wa^2$. This is the radial moment diagram and how to resist this radial moment as well as the circumference moment by means of reinforcement. So this is the plan of the reinforcement slab which shows the bottom reinforcement. To resist the circumferential moment at the center and radial moment at the center the reinforcement has to be provided along both the direction. This is the positive moment reinforcement at the center that is the bottom reinforcement. In order to resist this negative moment at the edge there is a radial moment as well as the circumferential moment there is a reinforcement which has to be provided at the top. So this point of contra flexure which occurs at the distance of $a.\frac{\sqrt{2}}{3}$. This point of contra flexure on either side of the center of the slab which occurs at a distance $a.\frac{\sqrt{2}}{3}$ here for the remaining distance the reinforcement has to be provided that is $a-\frac{a\sqrt{2}}{3}$. For that distance at the top the reinforcement has to be provided in the radial direction which is used to resist the negative radial moment at the support at the edge that is 1/16 wa^2. The length of this reinforcement is $a-\frac{a\sqrt{2}}{3}$. As for as the diagram is concern the reinforcement is provided for a distance of $a-\frac{a\sqrt{2}}{3}$. And in order to keep this reinforcement with the proper position and also to satisfy a circumferential length of 1/16wa^2. This is the reinforcement which is not only to resist the circumferential moment but this is also to keep the top radial moment in the proper position and also to avoid the sliding of reinforcement. Here when you take the cross section of the slab which is partially fixed at the end. And this is the radial moment reinforcement at the bottom that is along both the direction of the slab. In order to resist the radial moment at the top since it is fixed there is a negative moment is developed. This is for a distance of $a-\frac{a\sqrt{2}}{3}$ on both the ends of the top. In order to keep this reinforcement to resist the circumferential moment at the edge $1/16wa^2$ the reinforcement has to be provided in both the direction. This is the arrangement of reinforcement. So before designing those slab first we must learn what is the behavior of the slab and how to provide the reinforcement required for it. This is the behavior as well as arrangement for simply supported slab and partially fixed circular slab. So here in the case of partially simply supported slab the circumferential moment at the center of the slab is $2/16\ wa^2$.

Summary:

In this lecture we have seen in detail about the behavior of circular slab that is simply supported circular slab, partially fixed circular slab and also where the slab which is normally circular slab. And also we have seen the behavior of slab and where we have to provide the reinforcement and how the reinforcement has been provided in case of this three slabs that's we have seen in details.

Questions:

1. Give the uses of circular of slabs.
2. Explain the behavior of simply supported circular slab with moment diagram.
3. Explain the behavior of fixed supported circular slab with moment diagram.
4. Explain the behavior of partially fixed supported circular slab with moment diagram.
5. Draw the reinforcement detailing of above said slabs.

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.
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