Design of Structures – II

Lecture – 24

In the previous lecture we have seen in detail about the behavior of one way and two way slabs and the classification of behavior of one way and two way slabs. And also we have seen how the reinforcement has been provided and how the slab has to be spanned in the case of both one way and two way slabs. And also we have seen the difference between the one way and two way slab. In this lecture we are going to cover the behavior of one way and two way slabs that is under designed guidelines as per IS 456:2000. These are all the design guidelines we need to understand before start designing the slabs. There are effective span of the slabs, loads on slabs, nominal cover, minimum reinforcement, maximum spacing of bars, maximum diameter of bars and types of two way slab. As for IS 456:2000 we see how to find the effective span of the slab.

General Design Guidelines:

As per IS 456:2000

Effective span of slab:

Effective span of slab shall be lesser of the following

- l = clear span + d (effective depth)
- l = centre of centre distance between the support

For example this is the slab which is supported on the walls. The thickness of wall is 230mm and the clear span is 3m. The thickness of slab is 125mm. Here how to find out effective span of slab. First one is the centre to centre support of the

slab. It is $l_{eff} = 3 + 0.23$ that is equal to 3.23m. And another one is clear span that is 3m plus the effective depth of the span which is 0.125m this will be equal to 3.125m. From this two l effective will be adapted as 3.125m.

Loads on slab

Dead loads

a. Self weight of slab itself
b. Weight of partitions
c. Weight of floor finishes etc.
d. Weight of floor finishes etc.

Live loads as per IS 875

Next the shuttering of the slab that the reinforcement should not be directly resting over the shuttering of the slab or the centering work of slabs that is it has to be placed on the clear cover below the reinforcement. That is the clear cover which is normally providing by means of the cover blocks below the reinforcement. The thickness of the cover floor we normally called as nominal slab for IS 456.

<u>Nominal cover:</u>

- For mild exposure – 20mm
- For moderate exposure – 30mm
- However, if the diameter of bar do not exceed 12mm or cover may be reduced by 5mm. Thus for main reinforcement up to 12mm diameter bar and for mild exposure the nominal cover is 15mm.

Minimum reinforcement:

The reinforcement in either direction in slab shall not be less than

- 0.15% of the total cross sectional area for Fe-250 steel
- 0.12% of the total-cross sectional area for Fe-415 & Fe-500 steel.

In the case of mild steel if you use that is otherwise called as Fe-250. If you choose the mild steel in the case of reinforcement the AST required must not be less than 0.15% of the total cross sectional area. If you take Fe-500 than the reinforcement will not exceed 0.12% of the total cross section. Here using load we are going to find the bending moment and using the bending moment we are going to find the depth of the slab. Then we are going to find the reinforcement and that should be again checked with a minimum reinforcement as per IS 456:2000. Then after finding the AST reinforcement we are going to find the spacing between the reinforcement in the case of slab or the spacing between the bars.

The maximum spacing of bars:

Main steel:

The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300mm whichever is smaller. That is the first one is three times the effective depth of the span.

Distribution steel:

The horizontal distance between parallel reinforcement bars provided against shrinkage and temperature shall not be more than five times the effective depth of a solid slab or 450mm whichever is smaller.

Maximum diameter of bar:

The maximum diameter of bar in slab shall not exceed D/8, where D is the total thickness of slab.

There is one way slab which the slab is spanning in only one direction and in the two way slab the span is in two directions. And the two way slab is continuous about more than two supports. In the two way slab there are simply supported slab and restrained slab. That type of slab is normally rest slab and in the case of two way slab we are going to see the simply supported slab which is supported on four walls. And another slab is two way simply supported slabs.

In case of restrained slab it means that the slab is built into the wall. So at the supports there is a partial restrains which is developed. In order to resist this partial restrain when the restrain is developed at the support here it means that it has certain provision to resist the corners that is the lifting up of corners at the four corners of the slab. When you construct a wall over the slab the four corners are preventing from lifting and also preventing from the torsion. So here it is called as restrain slab which is used to avoid or prevent the lifting up of the four corners of the slab.

Two way simply supported slabs:

Then how to design this two slabs that is in the simply supported slabs there is a separate codal provision to design and the restrained slab.

The bending moments $M_x \& M_y$ for a rectangular slabs simply supported on all four edges with corners free to lift or the slabs do not having adequate provisions to prevent lifting of corners are obtained using,

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

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

Where $\alpha_x \& \alpha_y$ are coefficients given table 27, IS:456-2000 and W- total load/unit area; $l_x \& l_y$ -lengths of shorter and longer span.

This is the table which is used to find out the moment coefficients $\alpha_x \& \alpha_y$ based on ly and lx. When you find out the value of lx and ly if the value is equal to 1.1 then $\alpha_x = 0.074 \& \alpha_y = 0.061$. From this we can easily find out the values of Mx and My. By substituting the values we can get the moment along both the direction. Then using the moments we are going to find the reinforcement along both the direction that is in the case of two way simply supported slabs. And in this slabs the four corners are not preventing from lifting up of the slabs. in addition to this reinforcement to avoid the lifting up of the corners in this case of slabs the corners has to be provided with the addition reinforcement that is called as torsion reinforcement.

Here how to provide the reinforcement in the case of the two way simply supported slab. That is 50% of tensional reinforcement provided at the mid span can be curtailed at 0.1lx or 0.1ly from support. Consider this is the slab which is supported and this is the slab reinforcement to be provided in the case of simply supported slab. Since there is no purely simply supported slab there is a partial restrain developed at the support when you construct a wall or any parapet at certain height. So when you construct the parapet wall over the supports the slab will bend upward in the case of supports. So there is a tension which is developed over the support at the top. To resist this 50% of the reinforcement has been provided over the support. It has to be cracked at 0.1l from the face of the support. That is the reinforcement of the simply supported slab.

Two way restrained slabs:

The two way restrained slab is different from the two way simply supported slab. In the case of two way restrained slab the restrained is assumed over the support so the four corners are preventing from lifting up of the slab. Here how to find the moments restrained in the slab. In the case of two simply supported slab we have used table 27 to find out the bending moment from ly/lx ratio. Whereas in the case two way restrained slab there is a separate table which is table 26 which is given in IS 456:2000 to find out the bending moment for the restrained slab. The restrained slab may be restrained or supported over the supports. If you are going to form any another floor this slab will be called as the restrain slab. If you are not going to construct any wall over the restrained slab then the slab is treated as simply supported slab since there is no restrain over the supports. And in this case the four corners of the slabs will be lifted up. But in the case of

restrain slab if you are going to construct any wall over the slab there is a restrain which is developed over the slab to support so the four corners are prevented from lifting up. There are many cases one is interior panel and another one is one short edge continuous and another one is long edge continuous. Next one is two adjacent edges discontinuous, two short edge discontinuous, two long edge discontinuous etc. in similar manner the various categories are given in the bending moment. Here I am showing a diagram of a building which is having the different panels. The different panels are designed as two way slabs that is restrained slabs. And how to identify the panel in this categories so in this building the interior panel i.e., here the four sides are continuous one and here we have the interior panel. And the second one is example for the short edge discontinuous. The third one in one long edge discontinuous and the other three are continuous. Next the four one two adjacent plates are discontinuous and other two adjacent plates are continuous and also two short edges are continuous. The sixth one is two long edges are discontinuous and the two short edges are continuous. Next one is three edges discontinuous so here we are having one long edge is continuous. The next three edges are discontinuous and one short edges is continuous. Here it is called as restrain slab, the slab here is supported over the beam and it is not freely resting on the wall. If the wall is resting on the wall without any beam and if you are going to construct any wall over the slab then it is called as the restrained slab. For this cases we need to use this table for finding the bending moment.

For the simply supported slab with the four corners are not preventing from lifting. If it is freely supported on the wall we need to use the table 27 for finding out the bending moment. For example in the case of bending moment how we need to find the bending moment. First we need to find out the ratio ly/lx. We all know that in the case of two way slab the ratio should be less than 2. For the long span coefficient on this direction there is a negative moment as well as positive moment. Since it is the restrained slab there is a negative moment and positive moment on each side. Using this moment coefficient a slab which is subjected to uniformly distributed load and from this 1/8 is called the moment coefficient. On Y-direction we are having two moment and in X-direction we are having two moments and in the x-direction we are going to select the maximum bending moment and also in the y-direction we are going to select the maximum bending moment. And we are going to design the reinforcement for the maximum bending moment. This is in the case of simply supported as well as restrained slab.

Summary:

In this lecture we have seen in detail about how to calculate the moment coefficients for finding the bending moment in the case of two way simply supported slabs as well as two way restrained slab. Before finding the bending moment we have seen the effective factors such as effective span of slab, load on slab, nominal cover, minimum reinforcement, the maximum spacing of bars, maximum diameter of bar, types of two way slab.

Questions:

1. Give the IS specifications for the following:
    - Effective span of slab
    - Nominal cover
    - Minimum reinforcement
    - The maximum spacing of bars
    - Maximum diameter of bar
2. Explain the types of two way slab.

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.