Design of Structure – II

Lecture – 23

In the previous lecture we have seen the design of beams and the flexure by using working stress method and limit state method. We have seen both rectangular and flanged section and the working stress and the limit state method in detail and in addition to that we have also seen the designer continuous beam. Now in this lecture we are going to study the Limit state design of slabs. And we are going to see the behavior of one-way and two-way slabs under the gates of classification of slabs, behavior of one-way slab, behavior of two-way slab and differences between one way and two way slabs.

Classification of slabs:

Before seeing the designing slab we need to see what are the classification of slabs available in the field.

The slabs are classified based on many aspects,

Based on shape: Square, rectangular, circular and polygonal in shape.

That is it is the square slab which is supported on four walls. So here the ly and lx are same. That is if you take $\frac{lx}{ly} = 1$ it will be equal to 1. Then if it is rectangular slab and it is supported on four walls. The width of slab is different from the length of the slab i.e., here it is taken as lx and that is taken as ly therefore $\frac{lx}{ly} > 1$.

And it is also designed as circular in shape and the radius of the slab which is normally denoted by a. Or else it may be in any polygonal shape.

Based on type of support: Slab supported on walls, slab supported on beams, slab supported on columns (Flat slabs). Normally the slab supported on the wall is called as simply supported slabs and it is freely supported slab. And the slab which is supported on the beam is may be restrain slab which is having abdicate provision to resist torsion at corners. Next the slab directly supported on column is called as flat supported slabs. the flat slab is most suitable for sudden circumstances that the span of column is at both the direction or more and the height of the roof is less. In the case of flat slab which is designed or which is directly supported on column without any beam in any directions. It means that it doesn't have any beams at both the direction. So in order to resist the moment as well as the shear forces to the support. The support has to be enlarged to resist moment as well as the shear-force at the support. Normally the maximum bending moments which is developed at the supported that is the negative bending moment. And the moment which is developed in between the support is called the positive bending moment. It is somewhat less than the maximum bending moment. In order to resist the maximum negative bending moment here the amount of column should be increased. The increased or enlarged portion is called as capital. This much of amount of concrete is used to resist this negative bending moment as well as the shear-force and near the middle of the span we got the slab portion. And near the end of the support again the thickness of the slab is gradually increased. The increased portion of the slab here it is called drop. This is the drop which is the bending moment near the phase of the support. In this manner we have the drop as well as the column head or capital. This type of slab is called as flat slab which is directly resting on column without any beam.

Here in such cases the beam has to be completely avoided and the slab has to be directly resting over the column.

Based on support or boundary condition: Simply supported, cantilever slab, Overhanging slab, Fixed or continuous slab. Here the simply supported slab is the slab which is supported at its ends only that is called as simply supported slab. Next one is cantilever slab where the one end of the slab is fixed and the other end is free. This is called as cantilever slab. And then the slab which is fixed at both the end is called as the fixed slab. The continuous slab is the slab which is continuous over the support or it has been supported more than two supports is called as the continuous slab. And then overhanging slab that is the slab is extended beyond the face of the support and the portion of the slab here it is called as overhanging portion. The portion between the support is called as simply supported portion. So this type of slab is called as overhanging slabs which is extended beyond the supports.

Based on use: Roof slab, Floor slab, Foundation slab, Water tank slab. Normally in the case of building which having more than two floors. So here these slabs are called as floor slabs and the intermediate slabs are called as floor slabs. And final the floor that is provided at the top is called as floor slab. And the foundation slab, the foundation slab which is normally happen in the case of design of the mat foundation.

Based on the cross section or sectional configuration: Ribbed slab or grid slab, solid slab, filler slab, Folded plate.

Based on the spanning directions: One way – Spanning in one direction which is the slab spanning in one direction and the slabs spanning in two directions is called two way slab – spanning in two direction.

In general, the rectangular one way and two way slabs are very common and are discussed in detail.

Here under what circumstances we need to design the one way slab. This is the building here the slab has to be designed for the building as ly and lx. Where lx is the length of x direction and ly is along y direction. If you take ly as 9m and lx as 3m then the ratio $\frac{ly}{lx} = 9/3 = 3$. It is greater than 2 the slab has to be designed as one way slab. It means that in the type of slab the slab is going to be spanned along the shaded direction. It can also be supported on this side also and the reinforcement also along the one direction.

In the case of one way slab take the cross section of the slab. This is the cross section of the slab now it is these are all the support and I have already told you that the simply supported beam which is supported at edge that is subjected to some forces this is the deflection of the slab. When it deflects like this then this slab is also going to resting on the walls. Here the deflection along this direction is longer than the deflection along shorter direction. Hence the deflection along longer direction is completely spanned along only one direction that is along shorter direction. But in the case of two way slab how the two way slab will be supported as say this is the room and here it is the taken as ly and this is taken as lx. The ratio ly/lx is less than or equal to two the slab has two way deflection.

This means that the slab has to be supported along both the direction on all four walls. So it means that there is a deflection along the longer direction and deflection along the shorter direction. The bending along both the direction has to be considered and the bending moment has to be found along both the direction. For this bending moment we need to find the area of reinforcement. Here the reinforcement has to be provided along only one direction.

Behavior of one way and two way slab:

In this case of one way how the slab has been behaved.

One-way slabs supported by parallel walls or beams, bend in only one direction and transfer their loads to the two opposite support walls or beams. So here this is the slab considered as the one way slab and it is supported on these two opposite beams or opposite walls. And the slab load has to be transferred to these two beams or two walls. This will not be transferred to these two opposite walls of the direction.

Even when a rectangular slab is supported on all the four edge the slabs may be considered as a one-way slab if the length-to-breadth (L/B) ratio of the slab is greater than two. If the $\frac{ly}{lx} > 2$ the slab has to be designed as one way slab that is the bending along the longer direction is very small when compared to the bending along the shorter direction. So it has to be neglected.

A one-way slab is designed for the spanning direction alone; the main tension reinforcing bars of such slabs run parallel to the span. For the transverse direction, a minimum amount of shrinkage reinforcement is provided. That is in the case of one way slab the main reinforcement has to be provided along shorter direction since it is spanned along the shorter direction. And in order to keep this main reinforcement with the proper spacing there is a reinforcement which is provided in the perpendicular direction. This reinforcement is called as distribution reinforcement. And this reinforcement is called as main reinforcement. So this distribution is not only to keep the main reinforcement proper spacing to avoid the cracks due to shrinkage and creep of concrete. That reinforcement is called as distribution reinforcement not only to distribute or to keep the main reinforcement in proper spacing. It is also to avoid the cracks developed due to shrinkage and creep of concrete. So in this case the reinforcement need to provided minimum reinforcement.

One way slab action is assumed in a ribbed floor i.e., slab with joist beams made of precast double tee sections, in ribbed floor with integral beams and also in hollow-block or cored slabs. So this is in the course of ribbed and the beams that the slabs which is having integral beams also. This is that's all about the behavior of one way slab.

Behavior of two-way slab:

Two-way slabs are the slabs that have been supported on four sides and the ratio of longest span and the shortest span is less than 2. That is here ${}^{ly}\!/_{lx} < 2$. There is the bending along both the direction and it has to be considered as the two-way slab. It has to be supported along both the direction. And the reinforcement has to be spanned along both the direction. This two reinforcement is called main reinforcement. But it is not like in the case of one way slab it is spanned along only one direction.

In the two-way slabs load will be carried in both the directions. So main reinforcement is provided in both direction for two-way slab. So in the case of one way slab the load has to be transferred along one direction that is on this two opposite direction walls since it is spanned along only one direction. But in the case of two-way slab since the slab is spanned along both the direction and the main reinforcement is supported along both the direction and the load has to be along both the direction of the beam on opposite sides. So the load will be carried along both the direction. The plan view of one way slab is supported on two opposite edges as supported on all edges. Here in this picture as I have already explained you the bending which is along only one direction. So the reinforcement is along only one direction. This is the behavior of two-way slab.

If it is a rectangular direction the transformation of this load is like this. That is first in the case of rectangular slab the crack is developed from the corners. Here also it is developed from the corners and this which is developed like this. This is the transformation of the load in the case of rectangular slab if ly/lx is less than or equal to 2. If ly/lx is less than 2 then it is perfectly a square slab and the load transformation is like this.

The slab is divided into four triangular portions. But here it is divided into two triangular portions and two trapezoidal portion. So here the load from one portion of triangular portion is transferred to this beam and on this beam also. This is the way of transformation of rectangular as well as the square slab.

Now we have seen the behavior of the slab as well as how the reinforcement has been provided and how the load are transferred to the beam in both one way and two way slabs. Now we need to understand the difference between the one way and the two way slab. In the case of one way slab it is supported by beams in only 2 sides. That is it has to be spanned along one direction which transfer to the two opposite walls. The ratio of longer span panel (L) to shorter span panel (B) is greater than 2. Here the main reinforcement is provided in only one direction for one way slabs.

Where as in the case of two-way slab is supported by beams in all four sides. The ratio of longer span panel (L) to shorter span panel (B) is less than or equal to 2. Thus L/B is less than or equal to 2. And the main reinforcement is provided in both the direction for two way slabs.

Summary:

In this lecture we have seen detailed about the behavior of one-way and two-way slabs under the classification of slabs, behavior of one-way slab, behavior of two-way slab and the differences between one way and two way slabs. Here before designing we must understand how it behave and how the reinforcement has been provided that is most important.

Questions:

1. Explain the classification of slabs.
2. Differentiate between one way and two way slabs.
3. Explain the behavior of one way slab with neat sketch.
4. Explain the behavior of two way slab with neat sketch.
5. Explain the differences between one way and two way 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.
- 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.