Design of Structure – II

Lecture – 25

In the previous lecture we have seen in detail about how to find out moment coefficients for two-way simply supported slab and two way restrain slab. And also how to find out the bending moment for one way simply supported slab. We have also seen in detail about the design guidelines about the design of slab as per IS 456:2000. That is starting effective span of the slab, total load which is acting on the slab, moment and then arrangement of the reinforcement that is what is the maximum spacing of reinforcement and what is the maximum diameter of the bar.

In this lecture we are going to see the arrangement of reinforcement for one way slab and two-way slab and also for one way continuous slab. And also we are going to provide the reinforcement that is the reinforcement normally based on it behavior only when it is subjected to the kind of forces.

Simply Supported Slab

In the case of a simply supported slab if it is resting on the wall at the ends. When it is subjected to any kind of forces W kN/m^2 then it will be deflected like this. Normally the provision of reinforcement depends on the deflection of the elements. First we must know how the structure of the elements must be deflected and based on that we can identify the location where the tension is developed. Normally in the case of RCC concrete is very strong in compression and in the case of tensile portion we are going to provide the tensile reinforcement. For that we need to identify where the tensile strength is take place. Here in the case of simply supported slab the deflection took place like this and from the deflection the tension is developed in the bottom. In order to resist the tensile stress of the bottom the reinforcement has to be provided at the bottom. So here this is the support and this is the slab portion. The reinforcement should be normally adapted like this and this is the arrangement of reinforcement in the case of pure simply supported slab. So after finding out the reinforcement we are going to find out the maximum spacing between the reinforcement and this is called as the main reinforcement.

This reinforcement has to be properly placed with proper spacing. In order to keep the proper spacing of the reinforcement it has to be provided in the perpendicular direction. That reinforcement is used to distribute the main reinforcement with the proper spacing. That perpendicular reinforcement is called as the distribution reinforcement. This distribution reinforcement is not only to distribute the main reinforcement with proper spacing it is also to avoid the crack which is developed due to the shrinkage and the temperature. This is the arrangement of reinforcement in the case of a pure simply supported slab.

Now the next case this is the simply supported slab there is a slab which is provided over the tank that is constructed in the residential area. That is fully resting on the wall. This is an example of pure simply supported slab. Normally we are constructing a wall over the slab, what will happen in the case of simply supported slab if we construct a wall over it. Say here we are having the wall over it. If it is the one way simply supported slab and here ly/lx is greater than 2. In the case of this slab this is the bending nature of the slab. When it is build into the wall the portion over the support deflected upwards and the portion between the supports will be deflected downwards. This is the positive moment and that will be the negative moment. Now how to provide the reinforcement in this case, take this as the support and this is the plan route and this is the portion of the slab.

Here as per IS code when you provide the reinforcement at the bottom the 50% of the reinforcement has been provided to the bottom has to be cracked near the supported and bring it to the top to resist this tension. This one which has to be 0.1l face of the support and the 50% of the reinforcement has to be cracked at a distance 0.1l face of the support. This is called as the main reinforcement which has to be again provided at the top as well as at the bottom. The top reinforcement is drawn using dotted line and the bottom reinforcement is drawn using continuous line. This means that alternate path has to be cranked over the supported to resist the tension which is developed at the top. It has to be cranked at 0.1l from the face of the support and in order to keep this main reinforcement one direction there is the reinforcement which is provided in the perpendicular direction and that reinforcement is called as distribution reinforcement. Here in order to resist the partial restrain over the support IS code says that only 50% is enough to resist the partial restrain which is developed over the support. It is by means of cracking the main reinforcement over the support at 0.1l from the phase of the support. This is more than enough for resisting this torsion. This is the arrangement of reinforcement in the case of one way simply supported slab.

Now in the case of two way slab the ratio of ly/lx will be less than or equal to 2. In this case also here it is the pure simply supported slab where the wall is not going to be constructed over the slab. The main reinforcement has to be provided along both the direction which is called as mesh form of reinforcement. Here the reinforcement normally we are providing at the bottom along both the direction as the main reinforcement. That is called as the mess form of reinforcement. Both the reinforcements are called as the main reinforcement and there is a bending along both the direction and we need to find the bending moment at both the direction.

Now if this two way slab is build into the wall, for example if the wall is going to be constructed about the slab. Here this slab is also bends like this and in order to resist this deflection over the support the 50% of the reinforcement has to be cranked in the support at a distance 0.1l from the phase of the support and to bring it to the top. So here if it is l_x and another direction will be l_y and then the alternate bar should be connected over the straight bars. And these bars are also called as the main reinforcement in another direction. So here in the plan view this is the arrangement of the reinforcement. In this direction also we need to provide the main reinforcement and it has to be cranked over the support at the distance of 0.1l from the phase of the support. So alternate bar has to be cranked over the support along both the direction and bring it to the top to resist the tension over the support along both the direction. This is in the case of two way slabs. Here the wall is built into the restrained slab we need to have the tension at the top over the support and we need to point the reinforcement at the top. So here in order to resist that moment over the support the 50% of the main reinforcement has to be cranked over the support at the distance of 0.1l from the phase of the support and bring it to the top along both the direction. If it is in one direction it is one way slab.

Two Way Slab

Next one is in addition to this reinforcement in the case of two way slab. If it is a pure simply supported slab normally in the case of two-way simply supported slab which do not have any abdicate provision to resist the torsion at the corners. It will be lifted up in order to prevent the lifting up of the slab portion at the corners we must provide a separate reinforcement over the corners both top as well at the bottom in the form of mesh. Top there are two layers and in the bottom there are two layers then how to calculate the reinforcement required for it. Once you find out the A_{st} required for the reinforcement. The corner reinforcement that is the torsion reinforcement which has to be provided for a length of l/5 and if it is x-direction then it is $l_x/5$ and if it is y-direction it will be $l_y/5$. Then what is the total area of reinforcement required to resist the torsion at the corners that is ¾ of A_{st} required. Total A_{st} required for the bending moment that is ¾ of the total reinforcement wide separately to resist the torsion at four corners in case of the simply supported slab which do not have any adequate provision to lift the slabs at the corners. This must be provided for a length of l/5 in the form of mesh both at the top and the bottom.

This is the torsion reinforcement provided at the corners that is provided as $l_x/5$ or $l_y/5$. And another one is the continuous slab, in the case of continuous slab that is one way continuous slab it has four spans. Then how to provide the reinforcement in this case is I have already told you that the reinforcement is depends upon the deflection nature of the structure. Now when it is subjected some kind of deflection like this and you must provide the reinforcement at the top that is in the end support. So here in between the two supports the portion will be deflected downwards and the tension is developed at the bottom. So we must provide the reinforcement at the bottom. And over the support it is deflected upward and we need to provide the reinforcement to avoid the tension in the respective places. Then how to provide the reinforcement in the case of one way continuous slab to resist the deflection this is as per IS 456:2000. So here this is the 50% of the reinforcement that has to be provided and another 50% of the reinforcement has to be cranked due to the support and bring it to the top to resist the tension which is developed at the support that is at the top. So here in the case of this continuous slab found four bending moments and four places. That is there are two moments in the span and two moments over the supports. One is moment at the end span that is at the middle of end span and another one is the moment at the other end span. In the case of support moment we are finding the moment at the support next to the end support.

Among four bending moments in the case of slab we are selecting the maximum bending moment for designing the thickness of the slab plus the reinforcement of the slab. It is not like in the case of continuous beam. Since when you design the reinforcement separately for all the four bending moments there will be a chance for conjunction of reinforcement. In order to avoid that conjunction of reinforcement or overlapping of reinforcement one with another we can’t provide the concrete over another reinforcement so to avoid this we normally design the reinforcement against the maximum reinforcement. About which moment will be the maximum moment among the four moments is there is a moment which is present next to the support is always maximum. This seems that the moment coefficients are like that.

Here we have provided 100% of reinforcement and here the alternate bars are cranked over the support but in the mid-span we have provided 100%. But over the support we have provided only 50% of the reinforcement. In order to satisfy another 50% of reinforcement a separate reinforcement has to be provided at all interior supports. This length of reinforcement has to be 0.3l on either side of the phase of the support. It has to be provided to the top exactly opposite to the bottom strain bars. Total length of reinforcement is 0.3l on either side of the phase of the support plus the thickness of the support. But we are not normally providing the extra reinforcement at the end supports. This means there is a partial end supports and here to resist that partial support we can provide only 50% of the reinforcement and that is more than enough for resisting the moments at the end support. So the moment which is normally developed will be $Wl^2/24$ and it is very less when compared to the moment at all other four places. That why there is only 50% can be provided that is more than enough for resisting this bending moment. No need to provide the extra reinforcement in the supports at the end supports. In order to provide or keep the reinforcement with the proper spacing there is the reinforcement in the other direction that is in the perpendicular direction. That reinforcement is called as the distribution reinforcement. This is the reinforcement which is not only to distribute the main reinforcement in proper spacing but it is also to resist the cracks developed due to the shrinkage and the temperature. This is the arrangement of one way continuous slab. These are all the arrangement of reinforcement as per IS 456:2000.

Detailing of reinforcement as per IS 456:2000:

Slabs are considered as divided in each direction into middle and end strips. The maximum moments obtained using equations are apply only to the middle strip. 50% of the tension reinforcement provided at mid-span in the middle strip shall extend in the lower part of the slab to within 0.25l of a continuous edge or 0.15l of a discontinuous edge and the remaining 50% shall extend into support. Then 50% of tension reinforcement at top of a continuous edge shall be extended for a distance of 0.15l on each side from the support and at least 50% shall be provided for a distance of 0.3l on each face from the support.

At discontinuous edge negative moment may arise in general 50% of mid span steel shall be extended into the span for a distance of 0.1l at top. Minimum steel can be provided in the edge strip. Tension steel shall be provided at corner in the form of grid that is in two directions at top and bottom of slab where the slab is discontinuous at both the edges. This area of steel in each layer in each direction shall be equal to ¾ the area required (A_{st}) for maximum mid span moment. This steel shall extend from the edges for a distance of $l_x/5$. The area of steel shall be reduced to half (3/8 A_{st} X) at corners containing edges over only one edges is continuous and other is discontinuous.

Summary:

In this lecture we have seen the behavior of one way and two-way slab. And in this case we have seen the arrangement of detailing of reinforcement as per IS 456:2000 for one way and two-way as well as one way continuous slab.

<u>Questions:</u>

1. Give the IS codal provisions for the detailing reinforcement in slab.
2. Draw the longitudinal section of one way and two way slab showing reinforcement details.

<u>References:</u>

- 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.