Design of Structure – II

Lecture – 29

In the previous lecture we have seen the design of one way continuous floor slab and also we have seen the reinforcement detailing of the slab. By referring IS 456 we have used the moment coefficient to find out the bending moment at various places of the slab. And also we have considered what are the dead load which is acting over the plate slab and live load separately and we have calculated the bending moment at various places. Using the maximum bending moment we have designed the depth of the slab as well as the reinforcement required for it.

In the same way in this lecture we are going to design one way continuous roof slab. What are the loads acting on the roof slab that is the load acting on the roof top is entirely different from the load acting on the floor slab as for as the dead load is concerned. Here they have asked as to design,

Design One way Continuous Proof Slab

Design a three span one way continuous roof slab for a residential building of effective span 3m. It carries a live load of 1.5kN/m^2 and weathering course and tile of 1.0kN/m^2. Adopt M20 concrete and Fe415 steel. Draw the reinforcement details also.

Solution:

In the previous problem we have designed a floor slab for institutional building but here we are going to design the roof top for the residential building which is subjected to the point load of 1.0kN/m^2. The axis is provided in the roof slab which is 1.5kN/m^2. These are all the moment coefficients which is given in IS 456:2000 for finding the bending moment at various places. These are the bending moment given separately for live load and the dead load. The span of the slab is 3m. First we need to calculate load on the slab.

Load calculation:

Dead load:

To find out the self weight of the slab we need the thickness of the slab. The thickness of the slab is normally assumed from the deflection criteria that is l/d ratio for the continuous slab is 26.

$$\frac{l}{d} = 26$$

$$d = \frac{l}{26} = \frac{3000}{26} = 115.40mm$$

$$D = 115.40 + 15 + 8/2 = 134.40mm$$

So we need to assume 135mm as the overall depth of the slab for finding out the self weight of the slab. Based on mu experience for the span of 3m I can assume the depth of the slab is 125mm. Finally we need to check whether this is safe and also it should be economical. So the basic aim of structural designing is that the structure should be same and also should be economic that is most important. That why I am taking the thickness of the slab as 125mm to find out the self weight of the slab. So self weight of the slab here it is

$$= 0.125 \times 25 = 3.125kN/m^2$$

Since it is the roof slab the load due to weathering course and tile that is takenas 1.0kN/m^2. So the total dead load is equal to

$$w_d = 4.125 kN/m^2$$

Live load on slab:

Since it is the roof slab and it is the residential building axis provided will be considered that is 1.5kN/m^2. Now we need to find out the bending moment at various places.

Moment calculation:

Span moments:

Moment near the middle of end span that is equal to,

$$= \frac{1}{12} w_d l^2 + \frac{1}{10} w_l l^2$$

$$= \frac{1}{12} \times 4.125 \times 3 + \frac{1}{10} \times 1.5 \times 3^2$$

$$= 5.79 kNm$$

Moment at the middle of interior span,

$$= \frac{1}{16} w_d l^2 + \frac{1}{12} w_l l^2$$

$$= 4.57 kNm$$

Support moments:

Moment at the support next to end support and these are all the negative bending moment that is the support called hogging bending moment,

$$= -\frac{1}{10} w_d l^2 - \frac{1}{9} w_l l^2$$

$$= -6.71 kNm$$

Moment at other interior supports,

$$= -\frac{1}{12} w_d l^2 - \frac{1}{9} w_l l^2$$

$$= -6.09 kNm$$

So here among four bending moments the maximum bending moment is moment at the support next to the end support. That has to be considered for finding the effective depth of the slab as well as the area of reinforcement required for it.

Effective depth of the slab:

For finding effective depth of the slab we considering our section as balanced section and also one meter width of slab. Normally we are designing the thickness of the slab as well as area of reinforcement for 1m width of the slab. Since it is considered as the balanced section by equating the maximum bending moment to the limiting state of bending moment will be,

$$M_u = M_{u\max} = 0.138 f_{ck} b d^2$$

$$d = \sqrt{\frac{M_{u\max}}{0.138 f_{ck} b}} = \sqrt{\frac{10.065 \times 10^6}{0.138 \times 20 \times 1000}}$$

$= 60.39mm$

This is less than 106mm. Hence it is safe against flexure.

Area of Reinforcement

Now we need to find out the area of reinforcement.

Main steel:

The main steel has to be designed against the maximum reinforcement.

$$M_u = M_{u\max} = 0.87 f_y A_{st} (d - 0.416 x_u)$$

This is the equation which is used to find out the area of reinforcement for a singly reinforced. Here,

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times A_{st}}{0.36 \times 20 \times 1000} = 0.05 A_{st}$$

So the maximum bending moment is

$$10.065 \times 10^6 = 0.87 \times 415 \times A_{st} (106 - 0.416 \times 0.05 A_{st})$$

After solving this expression we will get the quadratic equation,

$$A_{st}^2 - 5096.05 A_{st} + 1.34 \times 10^6 = 0$$

$$A_{st(req)} = 278.13 mm^2$$

So I am going to check this Ast with the minimum Ast.

Check with minimum A_{st}:

Minimum A_{st} for the deformed bar is 0.12% of cross sectional area of the concrete.

$$= \frac{0.12}{100} \times 1000 \times 106 = 127.2kN / mm^2$$

This is less than $278.13mm^2$. Hence A_{st} required is $278.13mm^2$. I am going to use 8mm diameter bar spacing of reinforcement for 1m width of the slab is

$$= \frac{\pi/4 \times 8^2 \times 1000}{278.13} = 180.73mm$$

I am also going to check this with the minimum spacing. It is 3 into effective depth of the span that is equal to 318mm and in this case it should not be more than 300mm. So among these two values I am going to select the minimum value. Here the minimum spacing is 300mm but the designed spacing is 180.73mm which is less than 350mm therefore we can adopt the design spacing as 180.73mm. And avoid the practical difficulties we are adopting the spacing as 8mm diameter bar at 150mm c/c.

$$A_{st(pro)} = \frac{\pi/4 \times 8^2 \times 1000}{160} = 314.16mm^2$$

Next in order to keep the main reinforcement with the proper spacing and also to avoid the cracks due to change in temperature as well as the shrinkage of concrete we must provide the reinforcement in the perpendicular direction of the main reinforcement. That reinforcement is called as distribution reinforcement. If you use main steel as distribution reinforcement the Ast for the distribution reinforcement is 0.1% of cross sectional area of the concrete. If you use deform bar it will be 0.12% of cross sectional area of the concrete. Here I am going to use 6mm diameter ms bar. So the Ast required for the distribution reinforcement is

$$A_{st(req)} = \frac{0.15}{100} \times 1000 \times 106 = 159mm^2$$

So spacing of reinforcement by using 6mm diameter for 1m width of the slab is,

$$= \frac{\pi/4 \times 8^2 \times 1000}{159} = 177.83mm$$

I am going to check this spacing with the maximum spacing.

Check with the maximum spacing:

The maximum spacing of the reinforcement should not exceed the following that is 5 x d that is 530mm and the least value here it is 450mm which is somewhat greater than the 177.83mm. So I am adopting 6mm diameter ms bar at 150mm c/c. Now I am going to check the thickness of the slab against deflection.

Check depth of slab against deflection:

So I have found the reinforcement required for the one way continuous slab is the main reinforcement as 8mm diameter bar at 160mm c/c. And the perpendicular reinforcement that is the distribution reinforcement is 6mm diameter ms bar at 150mm c/c. Initially I have assumed the thickness of the slab as 125mm and the effective thickness of the slab as 160mm. And also I have checked that has been confirmed that the slab is most safe against the bending and the flexure.

Now I need to check the thickness of the slab with another limit state that is limit state of serviceability under deflection. From the deflection criteria l/d ratio for one way continuous slab is 26. This factor again has to be multiplied with the modification factor that is M.F. That modification factor must be found from figure 4 of the IS 456. The figure shows that modification factor verse the percentage tension of reinforcement. Here they have given different curves and the different curves mainly depend upon the stress which is developed at the reinforcement. Here also the modification factor has to be again multiplying with the factor 26 which is due to the area of reinforcement as well as the stress which is developed due to the reinforcement.

$$\frac{l}{d} = 26 \times M.F$$

$$p_t = \frac{100A_{st(pro)}}{bd} = \frac{100 \times 314.16}{1000 \times 106} = 0.3\%$$

Next we need to find out the respective graph for the problem, so first we need to find out the stress in the steel reinforcement from the formula,

$$f_s = 0.58 f_y \times \frac{A_{st(req)}}{A_{st(pro)}} = \frac{0.58 \times 415 \times 278.13}{314.16}$$

$$213.09 N/mm^2$$

$$M.F = 1.6$$

Now we need to find out d,

$$d = \frac{l}{26 \times M.F}$$

$$= \frac{3000}{26 \times 1.6} = 72.12mm < 106mm$$

Hence it is safe as well as most economical depth of the slab. Now we are going to see the reinforcement detailing. The reinforcement detailing is same as the previous problem. Here we are having span continuous slab. The span of the slab is 3m. So first we need to provide a straight bar as 50% of the reinforcement provided as the straight reinforcement another 50% should be provided as the crank reinforcement which is used to satisfy the tension which is developed at the top over the supports. So to avoid this the hogging bending moment which the support the reinforcement has been provided at the top so here we have provided only 50% of the reinforcement over the support. But here the maximum bending moment we have adopted from the four bending moment. The maximum bending moment which is normally occurs at next to the end support. We have provided only 50% of the reinforcement and another reinforcement should be provided separately for a distance of 0.3l on either side of the face of the support. This extra reinforcement which has to be provided in-between the two alternate cranked reinforcement so total we have provided the 100% of reinforcement. Over the supports so this has been extended on either side of the supports and the bar should be cranked at a distance of 0.25l on either side of the center of the support at the continuous edges. But at the discontinuous edges it has to be cranked at 0.15l from the center of the support. In the case of end support though we have the wall which has to be considered over the support, this is as per IS 456. This is the detailing of reinforcement in the case of one way continuous slab.

Summary:

In this lecture we have seen the one way continuous roof slab. It is somewhat different from one way continuous floor slab. Only the difference between the continuous and the roof top is the dead load calculation as well as the live load. In case of floor slab the dead load are self weight of the and the weight of floor finish and the partition over the constrains. But in the case of roof slabs the dead load consists of the self weight as well as the structure as well as the weight of the weathering course and the tile. Here also we have seen the design of one way continuous slab by doing certain examples that have been carried to design the slab and also detailing of reinforcement have been drawn.

<u>Questions:</u>

To design the section:

1. Design a three span one way continuous floor slab for a residential building of effective span 3.5m. It carries a live load of 1.5kN/m^2, floor finish of 1.0kN/m^2 and also partition wall of 1.96kN/m^2. Adopt M20 concrete & Fe415 steel. Draw the reinforcement details also.
2. Design a five span one way continuous roof slab over an effective span of 4.0m required for an institutional building. It carries a live load of 3kN/m^2 and floor finish of 1.0kN/m^2. Adopt M20 concrete and Fe415 steel. Draw the section of slab showing reinforcement details also.

<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 6^{th} Ed) year: 2006.