Design of Structures – II

Lecture – 26

In the previous lecture we have seen in detail about the behavior of one way slab, behavior of two way slab and in the case of two way slab there are two way simply supported slab and two way restrained slabs. And also we have seen the behavior of these slabs. We have also seen the design guidelines required to design the one way, two-way and two way continuous slab. And also we have seen in detail about the reinforcement required for those slabs.

Now in this lecture we are going to start designing one way slab using certain examples. In this we are going to start with the total load on slab, bending moment, effective depth of slab, reinforcement that is main steel and distribution steel, finally we are going to check the depth of the slab against the deflection and also we are going to see the reinforcement detailing of the slab. The first problem we are going to solve is,

Design a simply supported floor slab for a room 8m x 3.5m clear in size supported on 230mm thick wall, if the superimposed load is $3kN/m^2$. Consider other dead loads also. Use M20 and Fee415 as materials. Draw the section of slab showing reinforcement details also.

Solution:

Consider this as the room it is supported over the wall on all four sides. So the clear size of the room is 8m BY 3.5m. It is supported on all four sides and the thickness of wall is 230mm. First we need to identify whether this slab is one way slab or two way slabs.

$$\frac{ly}{lx} = \frac{8}{3.5} = 2.21 > 2$$

Hence it is designed as one way slab before that from the dimension of the room we need to identify whether the slab has to be designed one way slab or two way slab. Here first we need to calculate the load acting on the slab.

Load acting on the slab:

In the case of load there are two loads one is dead load and another one is live load. The load includes the structure itself and the weight of partition and the weight of floor finishes. Next load is the live load which is given in the problem or else we can select it from IS 875 for the respective room of the respective building.

Here it is supported on 230mm wall and the super imposed load is 3kN/m^2. Consider other dead loads also use m20 and Fe415 as materials and draw the section of the slabs. So we have identified this as the one way slab and it is supported on these two walls along 3.5m direction and this is the cross section of the slab. And this is the slab that is spanned along shorter direction that is 3.5m side. And the thickness of support is 230mm or 0.23m.

First one is dead load that is self weight of the slabs in order to find out the self weight of the slab we need to know the thickness of the slab the thickness of the slab can be identified or assumed from the deflection limits. Here the slab is supported along the shorter direction the depth can be calculated using l/d ratio. Here the l can be used as 3.5m that is lx/d is equal to 20. So 20 is for simply supported slab that is d is equal to lx/20 that is equal to 3730/20 that is equal to

186.5mm. We need to use the thickness of the slab for calculating the support more than 186.5mm. But based on my experience I am using the value here d is equal to 186.5mm plus clear cover for the slab is 15 and plus I am going to use 10mm diameter bar then the value of d is equal to 205.5mm. So we can use this as 210mm. I am going to assume the overall depth of the slab as 150mm. If it is very less again we are going to redesign the thickness of the slab by assuming more than this 150mm. Normally we call this as trial and error method of structure.

Now first one is the self weight of the slab is the overall thickness of the slab that is 0.15m into the unit weight of the concrete is 25 that is equal to 3.75kN/m^2. In this problem they are asked us to consider other dead load also. For the self weight of the dead load is weight of floor finish. Normally in the case of the building they are providing 1 inch here we are assuming the weight of concrete floor is 0.025m that has to be again multiplied by 24 that is 0.60kN/m^2. So in the case of slab the load must be calculated per meter square. So we are assuming that we are designing the slab for 1m^2. Next the weight of the partition as per IS 875 the weight of the partition is 1.96kN/m^2. If you use this weight the thickness of the partition wall should not exceed more than 150mm that is normally we are using 115mm thick of wall. So I have taken this as weight of partition wall. I am including the weight of partition in the design so I can construct the partition wall anywhere on the slab. Now we need to find out what is the dead load that is indicated by W_d which is equal to 6.31kN/m^2.

Live load on slab:

Live load on slab is $3kN/m^2$. Now the total load on the slab that is W_d+W_l which is equal to $9.31kN/m^2$.

Effective span of the slab:

Here we need to find out the effective span that is denoted by (l_{eff}). Normally the effective span is equal to clear span plus the depth of the slab. Hence the effective span is equal to 3.65m or the center to center distance will be equal to 3.23m.

$$l_{eff} = l + d = 3.5 + 0.15 = 3.65m$$

$$= l + 0.23 = 3.5 + 0.23 = 3.73m$$

Bending moment calculation:

Using W and l we are going to find out the bending moment. So the ultimate bending moment M_u is the design moment should be multiplied by the partial weight that is equal to,

$$M_u = \frac{1.5 \times 9.31 \times 3.65^2}{8} = 23.90kNm$$

Now I am considering while finding the bending moment I need to consider one meter width of the slab. By considering one meter width of the slab I am going to find out effective depth of the slab from bending moment.

Effective depth of the slab:

The effective depth of the slab will be find by equating M_u to M_{ulim}. It means that I am assuming this section as a balanced section.

$$M_u = M_{u\lim} = 0.138\, fck.bd$$

$$d = \sqrt{\frac{M_u}{0.138\, fck.b}}$$

$$d = \sqrt{\frac{23.90 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$= 93.06mm$$

Where D is 150mm and d is 150 – 15-8/2 which is equal to 131mm, it is very less than the value 93.06mm. Hence it is safe against flexure. Next I am going to keep D as 150mm since I am going to check this with another limit state.

<u>Area of reinforcement:</u>

In the case of one way simply supported slab there are two reinforcements one is main steel and another one is distribution steel. So the main steel which is found from the bending moment and since we have increased the depth of the slab this slab is automatically under reinforcement. So it is designed as singly reinforced rectangular section. So I am going to use the formula to find the Ast for the singly reinforced section.

Main steel:

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

$$x_u = \frac{0.87\, f_y A_{st}}{0.36\, fckb} = 0.05 A_{st}$$

$$23.90 \times 10^6 = 0.87 \times 415 \times A_{st} (131 - 0.416 \times 0.05 A_{st})$$

$$A_{st}^{\;2} - 6297.4A_{st} + 3.18\times10^6 = 0$$

$$A_{st}(req) = 553.59mm^2$$

Check for minimum steel:

The minimum A_{st} required for the steel is 0.12% of cross sectional area of the concrete.

$$= \frac{0.12}{100}\times1000\times131 = 151.2mm^2 < 553.59mm^2$$

$$A_{st}(req) = 553.59mm^2$$

Here I am going to use the 10mm diameter bar and finding the spacing of bar as,

$$= \frac{1000\times{\pi}/{4}\times10^2}{553.59} = 141.87mm$$

Check with maximum spacing:

Check this spacing with the maximum spacing given in the problem.

The maximum spacing should not exceed the 3d and the 300mm. That is 3 x 131 which is equal to 393mm whichever is less. Here the lesser value is 300mm which is more than 141mm. So I am providing 10mm diameter bar at 125mm c/c. Here I am not keeping 141mm to avoid the practical defect.

$$A_{st}(pro) = \frac{1000\times{\pi}/{4}\times8^2}{125} = 623.62mm^2$$

Distribution steel:

Here I am using 6mm diameter ms bar. The minimum reinforcement for ms bar it is 0.15% of cross sectional area of the concrete.

$$=\frac{0.15}{100}\times 1000\times 131=175mm^2$$

So using 6mm diameter ms bar the spacing of reinforcement is,

$$=\frac{1000\times {\pi}/{4}\times 6^2}{175}=176mm$$

Check with maximum spacing:

The maximum spacing here should not exceed two cases that is 5 x 131 that is equal to 655mm and another case one is it should not be less that 450mm. So here the minimum value is 450mm but I have designed is 176mm. Here I am providing 6mm diameter ms bar at 150mm c/c.

Check for deflection:

Here the l/d ratio is equal to 20 and it has to be again modified by multiplying with the modification factor depending upon the type and area of reinforcement which is developed in the reinforcement.

$$\frac{l}{d}=20\times M.F$$

$$p_t=\frac{100A_{st}(pro)}{bd}=\frac{100\times 623.32}{1000\times 131}=0.46\%$$

$$f_s = 0.58 f_y \frac{A_{st}(req)}{A_{st}(pro)} = 213.77 N/mm^2$$

From figure 4 of IS 456 modification factor here it is 1.5. So I can find the depth as,

$$d = \frac{l}{20 \times M.F} = \frac{3723}{20 \times 1.5} = 123.33 < 131mm$$

So it is more safe and economical. So here D is 150mm and the main steel is 10mm bar at 125mm c/c and the distribution steel is 6mm diameter at 150mm c/c. Now we need to draw the cross section of the slab. The effective span of the slab is 3.723m and the main reinforcement should to be cracked from the face of the support at 0.1l.

<u>Summary:</u>

In this lecture we have seen the design of one way simply supported slab for the span of 3.5m and we have designed the thickness of the slab as well as the reinforcement required for it. Also we have seen the reinforcement detailing of the slab.

<u>Question:</u>

To design the section:

1. Design a one way simply supported floor slab for a residential building of effective span 3.5m. It carries a live load of 1.5kN/m^2, floor finish of 1.0kkN/m^2 and also partition wall of 1.96kN/m^2. Adopt M20 concrete and Fe415 steel. Draw the reinforcement details also.

2. Design a one way simply supported 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.

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 6^{th} Ed) year: 2006.