Date 01.5.2020

Department of Civil Engineering do

Diploma -4th SEM

03-Lecture Notes on

Two way R.C.C. slab

by limit state method

A.K.Agrawal
A.M.I.E. civil
Lecturer
Civil Engg. Deptt
M.P.Polytechnic ,GKP

Two-way Slabs

Two-way slabs subjected mostly to uniformly distributed loads resist them primarily by bending about both the axis. However, as in the one-way slab, the depth of the two-way slabs should also be checked for the shear stresses to avoid any reinforcement for shear. Moreover, these slabs should have sufficient depth for the control deflection. Thus, strength and deflection are the requirements of design of two-way slabs.

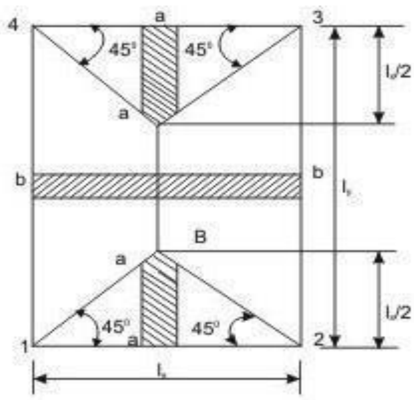

Figure 2.2 strips for shear

Computation of shear force

Shear forces are computed following the procedure stated below with reference to Fig.2.2.

The two-way slab of Fig. 2.2 is divided into two trapezoidal and two triangular zones by drawing lines from each corner at an angle of 45^{o}. The loads of triangular segment A will be transferred to beam 1-2 and the same of trapezoidal segment B will be beam 2-3. The shear forces per unit width of the strips aa and bb are highest at the ends of strips. Moreover, the length of half the strip bb is equal to the length of the strip aa. Thus, the shear forces in both strips are equal and we can write,

$$V_u = W(l_x/2)$$

where W = intensity of the uniformly distributed loads.

The nominal shear stress acting on the slab is then determined from

$$\tau_v = \frac{V_u}{bd}$$

Computation of bending moments

Two-way slabs spanning in two directions at right angles and carrying uniformly distributed loads may be analysed using any acceptable theory. Pigeoud‘s or Wester-guard‘s theories are the suggested elastic methods and Johansen‘s yield line theory is the most commonly used in the limit state of collapse method and suggested by IS 456 in the note of cl. 24.4. Alternatively, Annex D of IS 456 can be employed to determine the bending moments in the two directions for two types of slabs: (i) restrained slabs, and (ii) simply supported slabs. The two methods are explained below:

(i) Restrained slabs

Restrained slabs are those whose corners are prevented from lifting due to effects of torsional moments. These torsional moments, however, are not computed as the amounts of reinforcement are determined from the computed areas of steel due to positive bending moments depending upon the intensity of torsional moments of different corners. Thus, it is essential to determine the positive and negative bending moments in the two directions of restrained slabs depending on the various types of panels and the aspect ratio l_y/l_x.

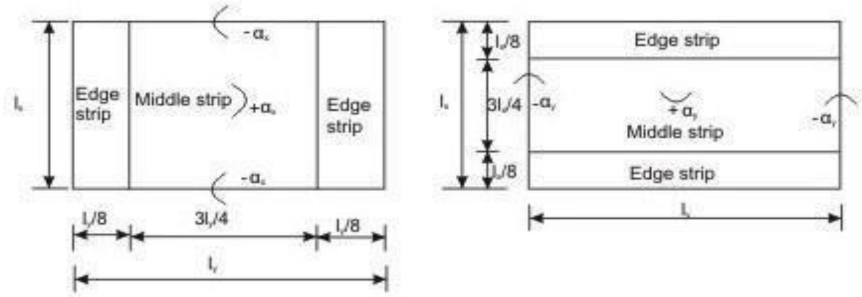

Figure 2.3 (a): For Span l_x Figure 2.3 (b): For Span l_y

Restrained slabs are considered as divided into two types of strips in each direction: (i) one middle strip of width equal to three-quarters of the respective length of span in either directions, and (ii) two edge strips, each of width equal to one-eighth of the respective length of span in either directions. Figures 2.3 (a) and b present the two types of strips for spans l_x and l_y separately.

The maximum positive and negative moments per unit width in a slab are determined from

$$M_x = \alpha_x w l_x^2 \qquad (1)$$

$$M_y = \alpha_y w l_x^2 \qquad (2)$$

where α_x and α_y are coefficients given in Table 26 of IS 456, Annex D, cl. D-1.1. Total design load per unit area is w and lengths of shorter and longer spans are represented by l_x and l_y, respectively. The values of α_x and α_y, given in Table 26 of IS 456, are for nine types of panels having eight aspect ratios of l_y/l_x from one to two at an interval of 0.1. The above maximum bending moments are applicable only to the middle strips and no redistribution shall be made.

Tension reinforcing bars for the positive and negative maximum moments are to be provided in the respective middle strips in each direction. Figure 2.3 shows the positive and negative coefficients α_x and α_y.

The edge strips will have reinforcing bars parallel to that edge following the minimum amount as stipulated in IS 456.

(ii) Simply supported slabs

The maximum moments per unit width of simply supported slabs, not having adequate provision to resist torsion at corners and to prevent the corners from lifting, are determined from Eqs.(1) and (2), where α_x and α_y are the respective coefficients of moments as given in Table 27 of IS 456, cl. D-2. The notations M_x, M_y, w, l_x and l_y are the same as mentioned below Eqs.(1) and (2) in (i) above.

Detailing of Reinforcement

The detailings of reinforcing bars for (i) **restrained slabs and (ii) simply supported slabs** are discussed separately for the bars either for the maximum positive or negative bending moments or to satisfy the requirement of minimum amount of steel.

(i) Restrained slabs

The maximum positive and negative moments per unit width of the slab calculated by employing Eqs. (1) and (2) are applicable only to the respective middle strips (Fig.2.3). There shall be no redistribution of these moments. The reinforcing bars so calculated from the maximum moments are to be placed satisfying the following stipulations of IS 456.

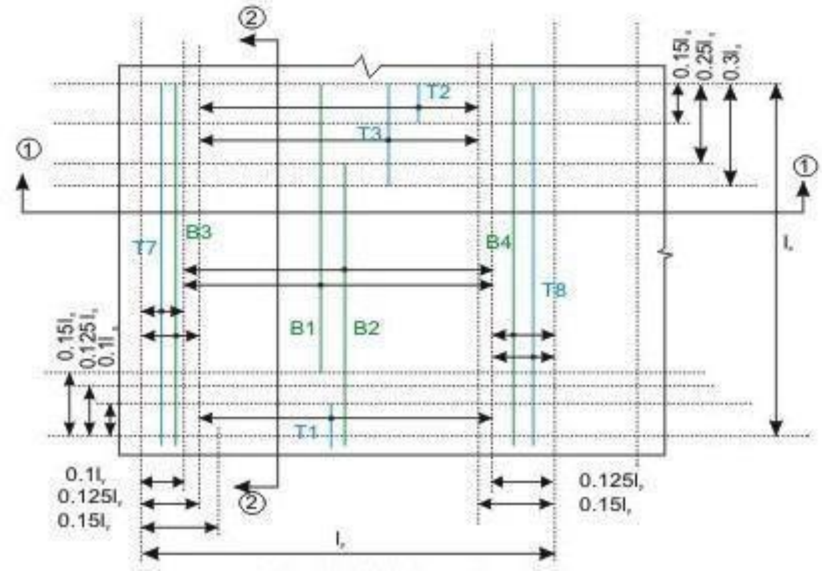

Figure 2.4 (a) Bars along l_x only

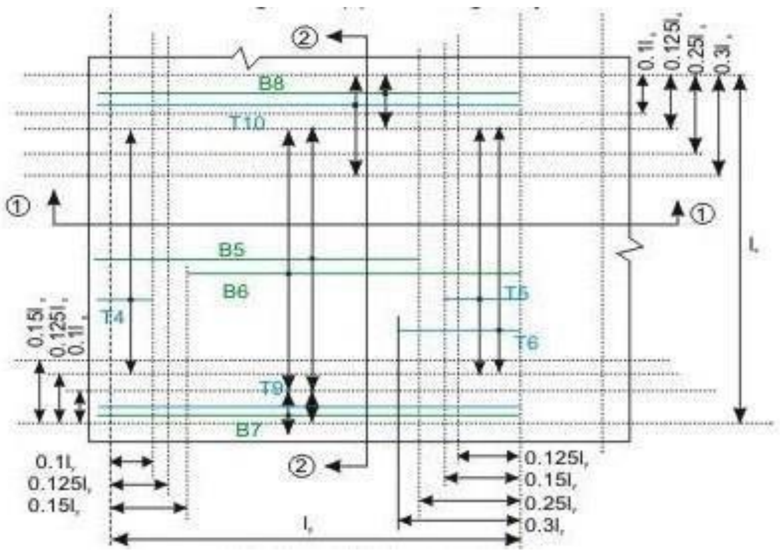

Figure 2.4 (b) Bars along l_y only

Figure 2.4 Reinforcement of two-way slab (except torsion reinforcement)

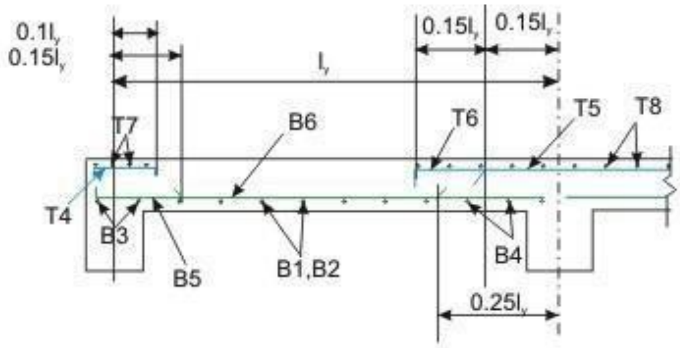

Figure 2.4 (c)

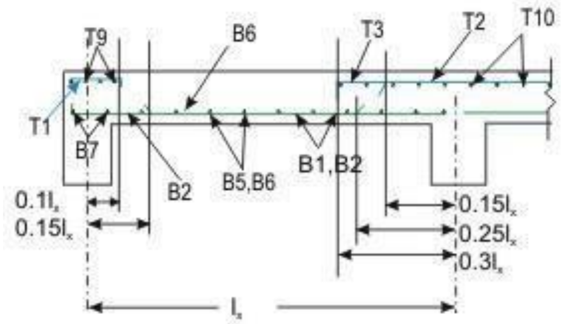

Figure 2.4 (d)

Figure 2.4 Reinforcement of two-way slab (except torsion reinforcement)

- Bottom tension reinforcement bars of mid-span in the middle strip shall extent in the lower part of the slab to within $0.25l$ of a continuous edge, or $0.15l$ of a discontinuous edge (cl. D-1.4 of IS 456). Bars marked as B1, B2, B5 and B6 in Figs.2.4 a and b are these bars.

- Top tension reinforcement bars over the continuous edges of middle strip shall extend in the upper part of the slab for a distance of $0.15l$ from the support, and at least fifty per cent of these bars shall extend a distance of $0.3l$ (cl. D-1.5 of IS 456). Bars marked as T2, T3, T5 and T6 in Figs.8.19.5 a and b are these bars.

- To resist the negative moment at a discontinuous edge depending on the degree of fixity at the edge of the slab, top tension reinforcement bars equal to fifty per cent of that provided at mid-span shall extend $0.1l$ into the span (cl. D-1.6 of IS 456). Bars marked as T1 and T4 in Figs. 2.4 a and b are these bars.
- The edge strip of each panel shall have reinforcing bars parallel to that edge satisfying the requirement of minimum reinforcement. The bottom and top bars of the edge strips are explained below.

- Bottom bars B3 and B4 (Fig. 2.4 a) are parallel to the edge along l_x for the edge strip for span l_y, satisfying the requirement of minimum amount of steel (cl. D-1.7 of IS456).

- Bottom bars B7 and B8 (Fig. 2.4 b) are parallel to the edge along l_y for the edge strip for span l_x, satisfying the requirement of minimum amount of steel (cl. D-1.7 of IS 456).

- Top bars T7 and T8 (Fig. 2.4a) are parallel to the edge along l_x for the edge strip for span l_y, satisfying the requirement of minimum amount of steel (cl. D-1.7 of IS 456).

- Top bars T9 and T10 (Fig. 2.4 b) are parallel to the edge along l_y for the edge strip for span l_x, satisfying the requirement of minimum amount of steel (cl. D-1.7 of IS 456).

(ii) Simply supported slabs

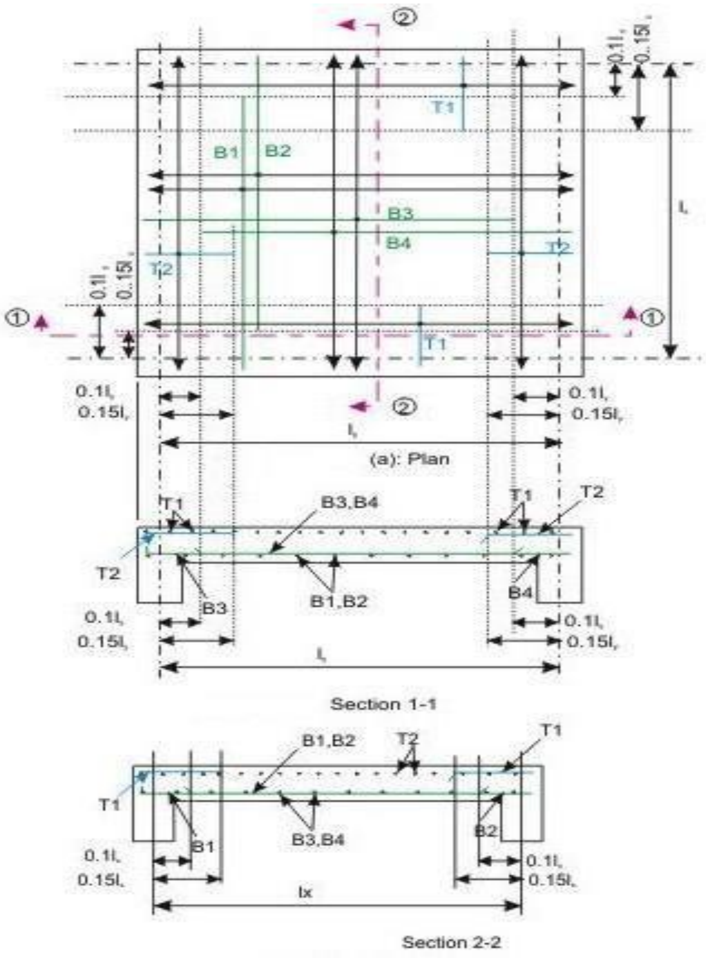

Figure 2.5 Simply supported two-way slab, corners not held down

Figures 2.5 a, b and c present the detailing of reinforcing bars of simply supported slabs not having adequate provision to resist torsion at corners and to prevent corners from lifting. Clause D-2.1 stipulates that fifty per cent of the tension reinforcement provided at mid-span should extend to the supports. The remaining fifty per cent should extend to within $0.1l_x$ or $0.1l_y$ of the support, as appropriate.

Numerical Problem

Q3 -Design a R.C. slab for a room measuring 5mx6m size. The slab is simply supported on all the four edges, with corners held down and carries a super-imposed load of 3 KN/m^2 inclusive of floor finish etc. Use M20 grade of concrete and Fe 415 grade of steel.

Solution

Computation of loading and bending moment

From deflection point of view l/d=20 for simply supported slab. Let us assume $p_t = 0.2\%$ for an under-reinforced section. Hence from figure 4 of IS 456:2000, we get modification factor =1.68.

Hence l/d=20x1.68 =33.6

and d =l/33.6 = 5000/33.6 =148.8 mm

Providing 20 mm nomonal cover and 8 mm bar

D=148.8+20+8 =172.8 mm

Hence assume an overall depth of 180 mm for the purpose of computing dead load

(i) Self weight of slab per m^2 = 0.18x1x1x25 =4.5 KN/m^2

(ii) Super-imposed load @ 3 KN/m^2 = 3 KN/m^2

Total load w =7.5 KN/m^2

Hence w_u =1.5x7.5 = 11.25 KN/m^2

Taking an effective depth of 150 mm.

Effective l_y = 6+0.15 = 6.15m

Effective l_x = 5+0.15 = 5.15m

Therefore $\frac{l_y}{l_x} = \frac{6.15}{5.15} = 1.2 < 2$

From table 27 of IS 456:2000 $\alpha_x = 0.072$ and $\alpha_y = 0.056$

$$M_{ux} = \alpha_x w_u l_x^2 = 0.072x11.25x5.15^2 = 21.483 KN - m$$

$$M_{uy} = \alpha_y w_u l_x^2 = 0.056x11.25x5.15^2 = 16.709 KN - m$$

For short span, width of middle strip $= \frac{3}{4} l_y = \frac{3}{4} x6.15 = 4.61m$

Width of edge strip = 0.5x(6.15-4.61) = 0.77m

For long span, width of middle strip $= \frac{3}{4} l_x = \frac{3}{4} x5.15 = 3.87\ m$

Width of edge strip = 0.5x(5.15-3.87) = 0.64m

Computation of effective depth and total depth

$$d = \sqrt{\frac{M_{ux}}{R_u b}} = \sqrt{\frac{21.483x10^6}{2.761x10^3}} = 88.2mm$$

However, from the requirement of deflection keep D= 180 mm.

Therefore , d=180-20-4=156 mm and that for long span d=156-8=148 mm

Computation of steel reinforcement for short span

$$A_{stx} = 0.5\frac{f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6M_{ux}}{f_{ck}bd^2}}\right]bd = 403.2mm^2$$

Spacing of 8 mm bar $S_x = \frac{1000x50.3}{403.2} = 124.7\ mm$

However, use 8 mm bars @120 mm c/c for the middle strip of width 4.61m.

Edge strip of length = 0.77m

The reinforcement in the edge strip = $\frac{0.12x180x1000}{100} = 216\ mm^2$

Provide spacing 8 mm 225 c/c.

Computation of steel reinforcement for long span

$A_{sty} = 327.9\ mm^2$

Spacing of 8 mm bar $S_y = 153.4\ mm$

Provide 8 mm bars @150 mm c/c for the middle strip of width 3.87m.

For edge strip of width = 0.64m , $A_{st} = 216\ mm^2$

Hence provide spacing 8 mm @ 225 c/c.

Torsional reinforcement at corners

Size of torsion mesh = $\frac{l_x}{5} = \frac{5.15}{5} = 1.03m$ from the centre of support or 1.03+0.08 = 1.10 from the edge of the slab.

Area of torsional reinforcement = $\frac{3}{4}A_{stx} = \frac{3}{4}x403.2 = 302.4mm^2$

Required spacing 8 mm @ 166 mm

Provide spacing 8 mm @ 150 c/c.