Dr. Jamal Zalatimo

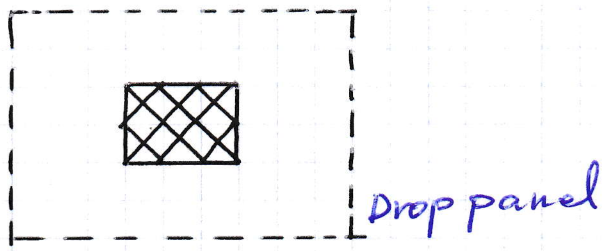
Types

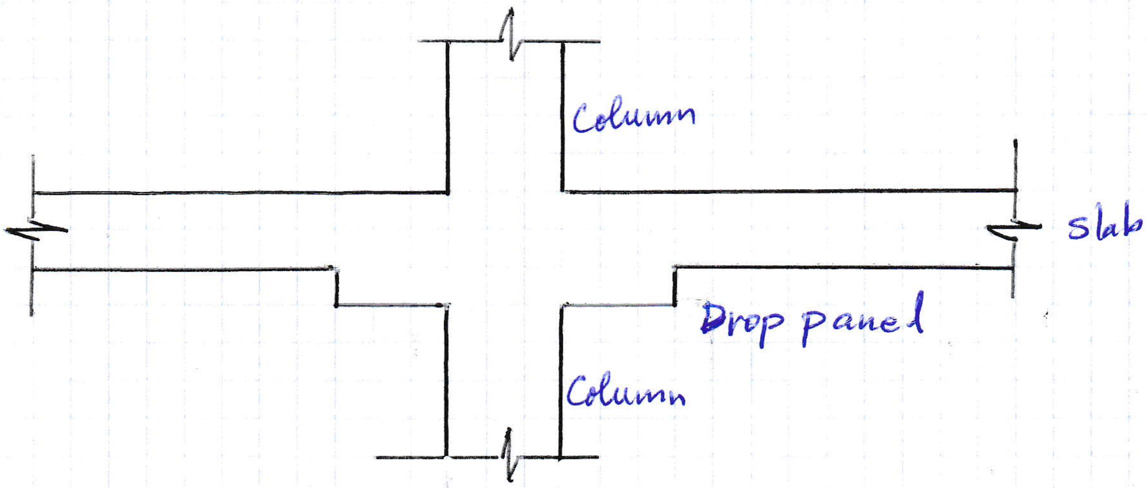
A) Two-way Slab on Beams

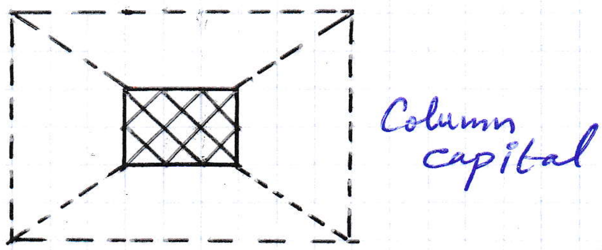
Solid, Ribbed, Waffle

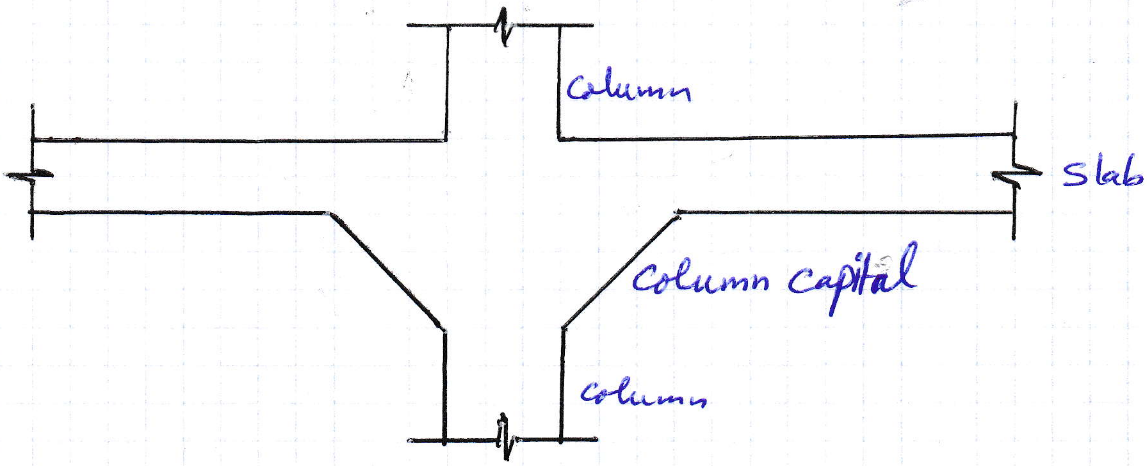
B) Flat Slab

Solid, Ribbed, Waffle









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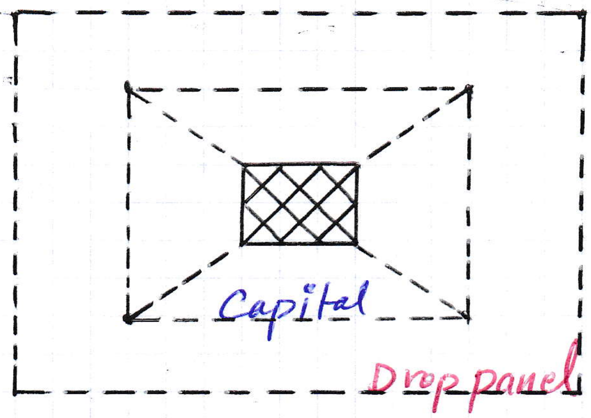
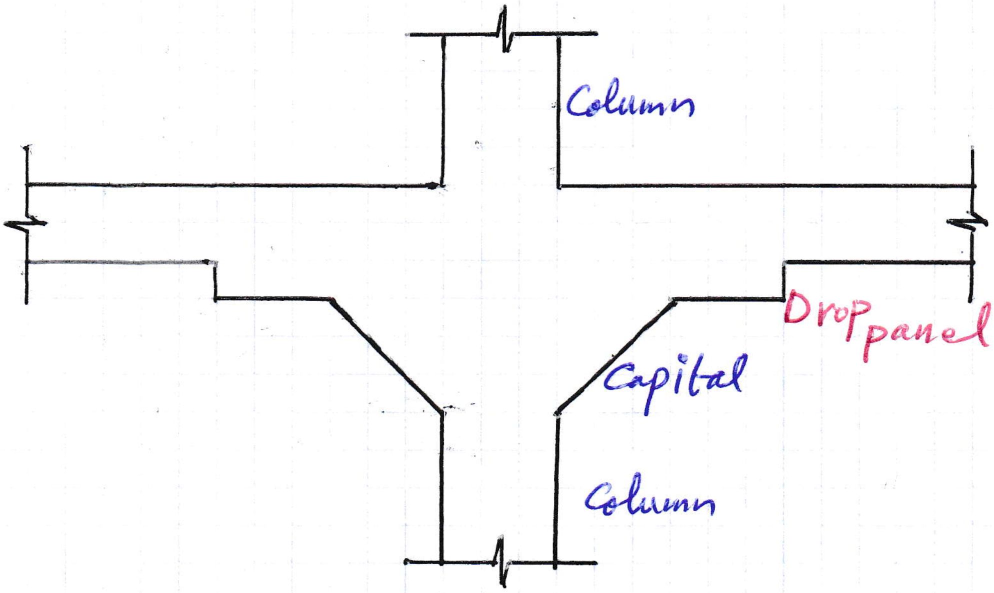
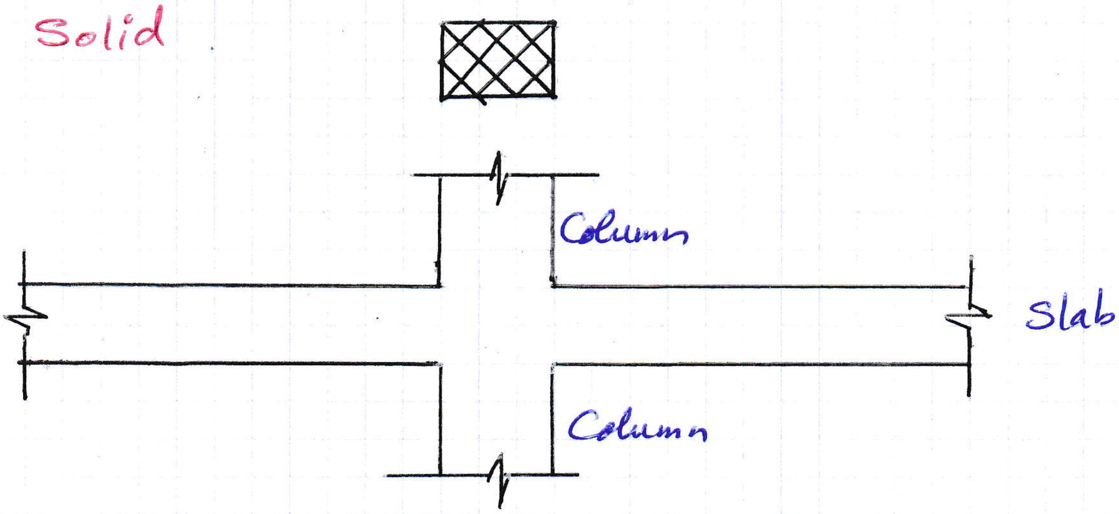




c) Flat Plate

Solid



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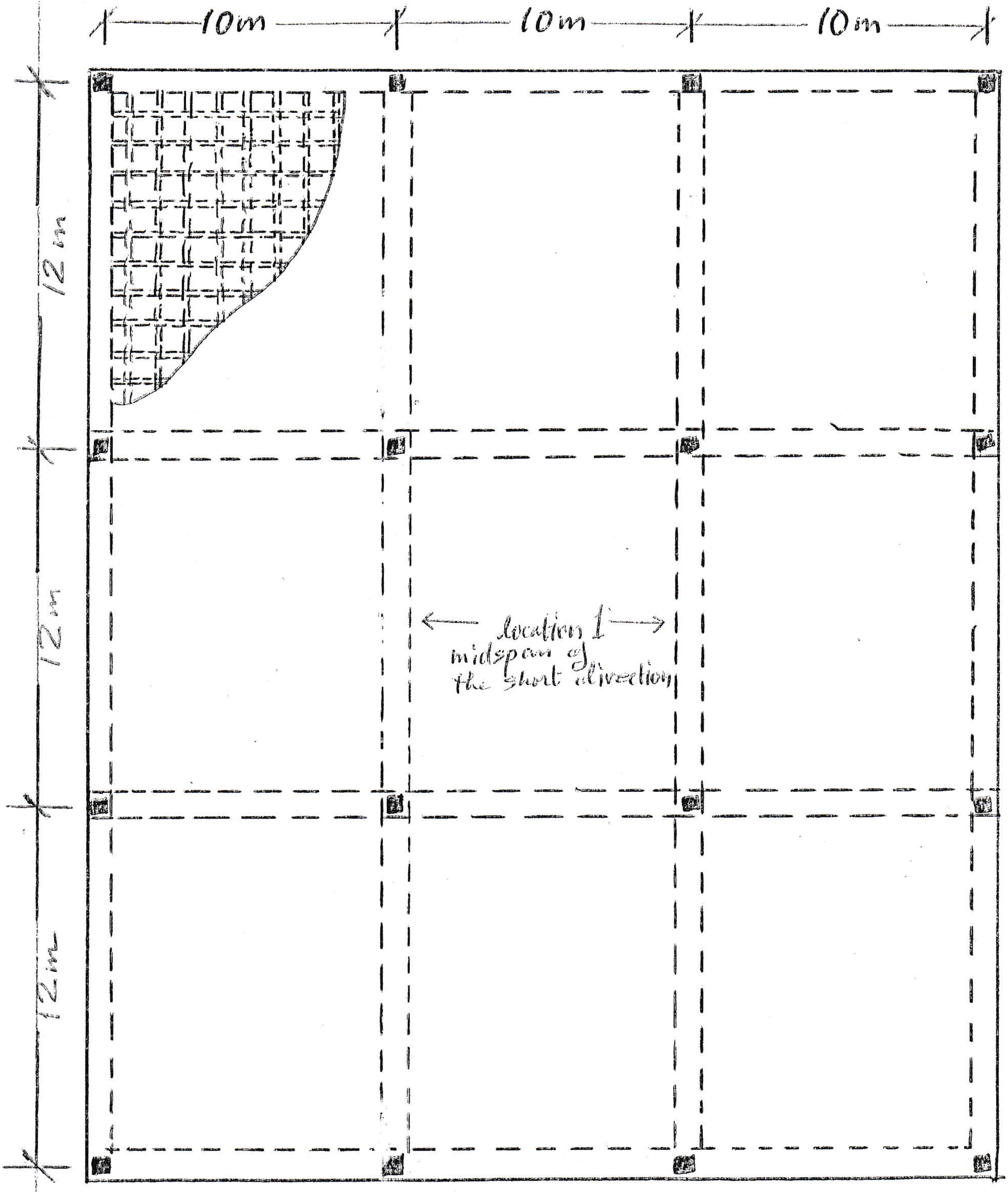
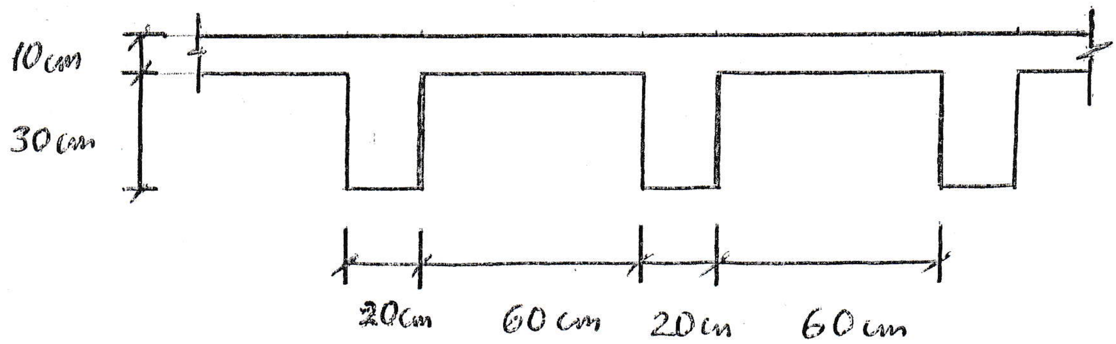
Dr. Jamal Zalatimo (4)





Methods of Analysis

Dr. Jamal Zalatimo

1) Tabulated Coefficients

Two-way slab on beams

Beams must be relatively stiff
(or walls)
on all column lines

2) Direct Design Method

structural slab is divided
into "frames" in both directions
" Equivalent Frames"

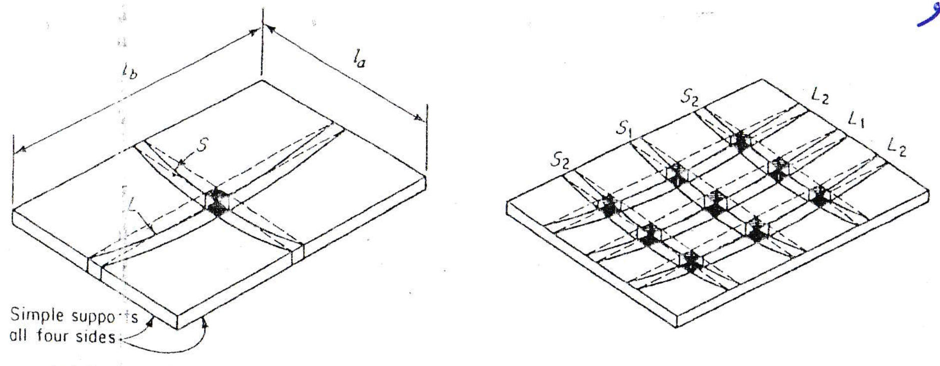
3) Equivalent Frame Method

The structure, from the top floor
to the bottom floor,
or, in special cases, the slab
are divided into "equivalent
frames" in both directions.

3') ⇒ "Equivalent beams"

4) Computer software –

Three-dimensional analysis



(a) Bending of center strips of slab

(b) Grid model of slab

Figure 5.5 Two-way slab on simple edge supports.

Figure 5.5*a* shows the two center strips of a rectangular plate with short span l_a and long span l_b. If the uniform load is w per square foot of slab, each of the two strips acts approximately like a simple beam uniformly loaded by its share of w. Because these imaginary strips actually are part of the same monolithic slab, their deflections at the intersection point must be the same. Equating the center deflections of the short and long strips gives

$$\frac{5w_a l_a^4}{384EI} = \frac{5w_b l_b^4}{384EI} \qquad (a)$$

where w_a is the share of the load w carried in the short direction and w_b is the share of the load w carried in the long direction. Consequently,

$$\frac{w_a}{w_b} = \frac{l_b^4}{l_a^4} \qquad (b)$$

One sees that the larger share of the load is carried in the short direction, the ratio of the two portions of the total load being inversely proportional to the fourth power of the ratio of the spans.

This result is approximate because the actual behavior of a slab is more complex than that of the two intersecting strips. An understanding of the behavior of the slab itself can be gained from Fig. 5.5*b*, which shows a slab model consisting of two sets of three strips each. It is seen that the two central strips S_1 and L_1 bend in a manner similar to that of Fig. 5.5*a*. The outer strips S_2 and L_2, however, are not only bent but also twisted. Consider, for instance, one of the intersections of S_2 with L_2. It is seen that at the intersection the exterior edge of strip L_2 is at a higher elevation than the interior edge, while at the nearby end of strip L_2 both edges are at the same elevation; the strip is twisted. This twisting results in torsional stresses and torsional moments which are seen to be most pronounced near the corners. Consequently, the total load on the slab is carried not only by the bending

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moments in two directions but also by the twisting moments. For this reason bending moments in elastic slabs are smaller than would be computed for sets of unconnected strips loaded by w_a and w_b. For instance, for a simply supported square slab, $w_a = w_b = w/2$. If only bending were present, the maximum moment in each strip would be

$$\frac{(w/2)l^2}{8} = 0.0625wl^2 \qquad (c)$$

The exact theory of bending of elastic plates shows that, actually, the maximum moment in such a square slab is only $0.048wl^2$, so that in this case the twisting moments relieve the bending moments by about 25 percent.

The largest moment occurs where the curvature is sharpest. Figure 5.5*b* shows this to be the case at midspan of the short strip S_1. Suppose the load is increased until this location is overstressed, so that the steel at the middle of strip S_1 is yielding. If the strip were an isolated beam, it would now fail. Considering the slab as a whole, however, one sees that no immediate failure will occur. The neighboring strips (those parallel as well as those perpendicular to S_1), being actually monolithic with it, will take over that share of any additional load which strip S_1 can no longer carry until they in turn start yielding. This inelastic redistribution will continue until in a rather large area in the central portion of the slab all the steel in both directions is yielding. Only then will the entire slab fail. From this reasoning, which is confirmed by tests, it follows that slabs need not be designed for the absolute maximum moment in each of the two directions (such as $0.048wl^2$ in the example of the previous paragraph) but only for a smaller average moment in each of the two directions in the central portion of the slab. For instance, one of the several analytical methods in general use permits the above square slab to be designed for a moment of $0.036wl^2$. By comparison with the actual elastic maximum moment $0.048wl^2$, it is seen that, owing to inelastic redistribution, a moment reduction of 25 percent is provided. 5

The largest moment in the slab occurs at midspan of the short strip S_1 of Fig. 5.5*b*. It is evident that the curvature, hence the moment, in the short strip S_2 is less than at the corresponding location of strip S_1. Consequently, a variation of short-span moment occurs in the long direction of the span. This variation is shown qualitatively in Fig. 5.6. The short-span-moment diagram in Fig. 5.6*a* is valid only along the center strip at 1-1. Elsewhere the maximum-moment value is less, as shown in Fig. 5.6*b*; all other moment ordinates are reduced proportionately. Similarly, the long-span-moment diagram in Fig. 5.6*c* applies only at the longitudinal centerline of the slab; elsewhere ordinates are reduced according to the variation shown in Fig. 5.6*d*. These variations in maximum moment across the width and length of a rectangular slab are accounted for in an approximate way in most practical design methods by designing for a reduced moment in the outer quarters of the slab span in each direction.

It should be noted that only slabs with side ratios less than about 2 need

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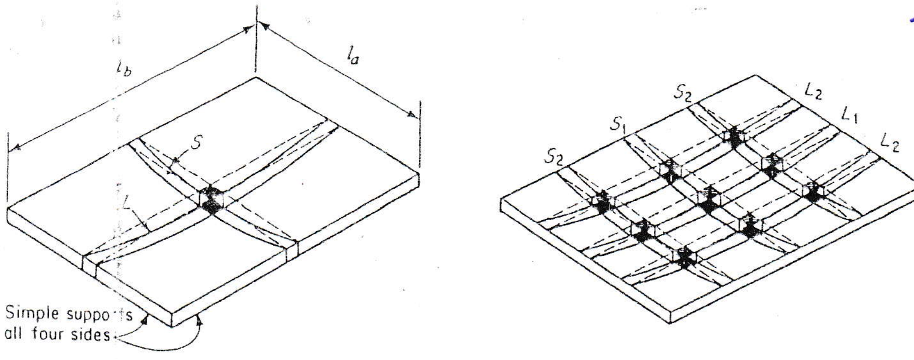

(*a*) Bending of center strips of slab

(*b*) Grid model of slab

Figure 5.5 Two-way slab on simple edge supports.

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$$\frac{5w_a l_a^4}{384EI} = \frac{5w_b l_b^4}{384EI} \qquad (a)$$

where w_a is the share of the load w carried in the short direction and w_b is the share of the load w carried in the long direction. Consequently,

$$\frac{w_a}{w_b} = \frac{l_b^4}{l_a^4} \qquad (b)$$

One sees that the larger share of the load is carried in the short direction, the ratio of the two portions of the total load being inversely proportional to the fourth power of the ratio of the spans.

This result is approximate because the actual behavior of a slab is more complex than that of the two intersecting strips. An understanding of the behavior of the slab itself can be gained from Fig. 5.5*b*, which shows a slab model consisting of two sets of three strips each. It is seen that the two central strips S_1 and L_1 bend in a manner similar to that of Fig. 5.5*a*. The outer strips S_2 and L_2, however, are not only bent but also twisted. Consider, for instance, one of the intersections of S_2 with L_2. It is seen that at the intersection the exterior edge of strip L_2 is at a higher elevation than the interior edge, while at the nearby end of strip L_2 both edges are at the same elevation; the strip is twisted. This twisting results in torsional stresses and torsional moments which are seen to be most pronounced near the corners. Consequently, the total load on the slab is carried not only by the bending

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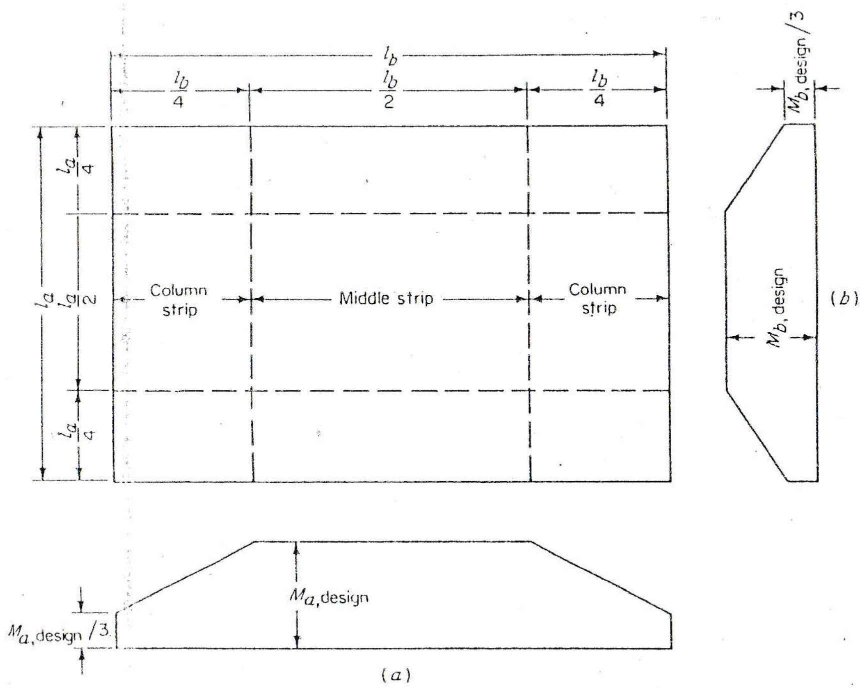

Figure 5.7 Variation of design moments across width of critical sections for simply supported two-way slab.

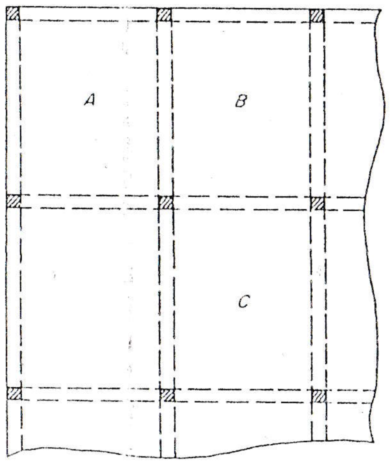

Figure 5.8 Portion of typical two-way slab floor with beams on column lines.

Table 5.2 Coefficients for negative moments in slabs†

$M_{a,neg} = C_{a,neg} w l_a^2$
$M_{b,neg} = C_{b,neg} w l_b^2$ where w = total uniform dead plus live load

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,neg}$		0.045		0.050	0.075	0.071		0.033	0.061
	$C_{b,neg}$		0.045	0.076	0.050			0.071	0.061	0.033
0.95	$C_{a,neg}$		0.050		0.055	0.079	0.075		0.038	0.065
	$C_{b,neg}$		0.041	0.072	0.045			0.067	0.056	0.029
0.90	$C_{a,neg}$		0.055		0.060	0.080	0.079		0.043	0.068
	$C_{b,neg}$		0.037	0.070	0.040			0.062	0.052	0.025
0.85	$C_{a,neg}$		0.060		0.066	0.082	0.083		0.049	0.072
	$C_{b,neg}$		0.031	0.065	0.034			0.057	0.046	0.021
0.80	$C_{a,neg}$		0.065		0.071	0.083	0.086		0.055	0.075
	$C_{b,neg}$		0.027	0.061	0.029			0.051	0.041	0.017
0.75	$C_{a,neg}$		0.069		0.076	0.085	0.088		0.061	0.078
	$C_{b,neg}$		0.022	0.056	0.024			0.044	0.036	0.014
0.70	$C_{a,neg}$		0.074		0.081	0.086	0.091		0.068	0.081
	$C_{b,neg}$		0.017	0.050	0.019			0.038	0.029	0.011
0.65	$C_{a,neg}$		0.077		0.085	0.087	0.093		0.074	0.083
	$C_{b,neg}$		0.014	0.043	0.015			0.031	0.024	0.008
0.60	$C_{a,neg}$		0.081		0.089	0.088	0.095		0.080	0.085
	$C_{b,neg}$		0.010	0.035	0.011			0.024	0.018	0.006
0.55	$C_{a,neg}$		0.084		0.092	0.089	0.096		0.085	0.086
	$C_{b,neg}$		0.007	0.028	0.008			0.019	0.014	0.005
0.50	$C_{a,neg}$		0.086		0.094	0.090	0.097		0.089	0.088
	$C_{b,neg}$		0.006	0.022	0.006			0.014	0.010	0.003

†A crosshatched edge indicates that the slab continues across, or is fixed at, the support; an unmarked edge indicates a support at which torsional resistance is negligible.

computed for this total load. *Negative moments at discontinuous edges* are assumed equal to one-third of the positive moments for the same direction. One must provide for such moments because some degree of restraint is provided discontinuous edges by the torsional rigidity of the edge beam or by the supporting wall.

For *positive moments* there will be little, if any, rotation at the continuous

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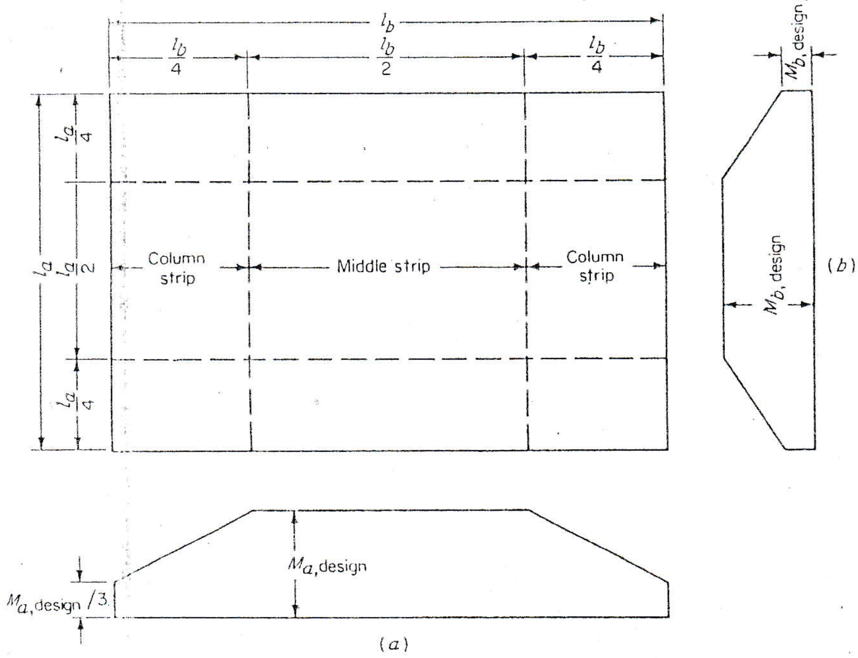

Figure 5.7 Variation of design moments across width of critical sections for simply supported two-way slab.

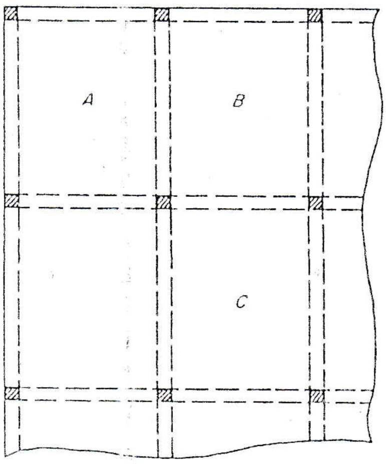

Figure 5.8 Portion of typical two-way slab floor with beams on column lines.

Table 5.2 Coefficients for neg

$M_{a,neg} = C_{a,neg} w l_a^2$
$M_{b,neg} = C_{b,neg} w l_b^2$ where w = tot

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case
1.00	$C_{a,neg}$		0.045	
	$C_{b,neg}$		0.045	0.07
0.95	$C_{a,neg}$		0.050	
	$C_{b,neg}$		0.041	0.07
0.90	$C_{a,neg}$		0.055	
	$C_{b,neg}$		0.037	0.07
0.85	$C_{a,neg}$		0.060	
	$C_{b,neg}$		0.031	0.06
0.80	$C_{a,neg}$		0.065	
	$C_{b,neg}$		0.027	0.06
0.75	$C_{a,neg}$		0.069	
	$C_{b,neg}$		0.022	0.05
0.70	$C_{a,neg}$		0.074	
	$C_{b,neg}$		0.017	0.05
0.65	$C_{a,neg}$		0.077	
	$C_{b,neg}$		0.014	0.04
0.60	$C_{a,neg}$		0.081	
	$C_{b,neg}$		0.010	0.03
0.55	$C_{a,neg}$		0.084	
	$C_{b,neg}$		0.007	0.02
0.50	$C_{a,neg}$		0.086	
	$C_{b,neg}$		0.006	0.02

†A crosshatched edge indicates t
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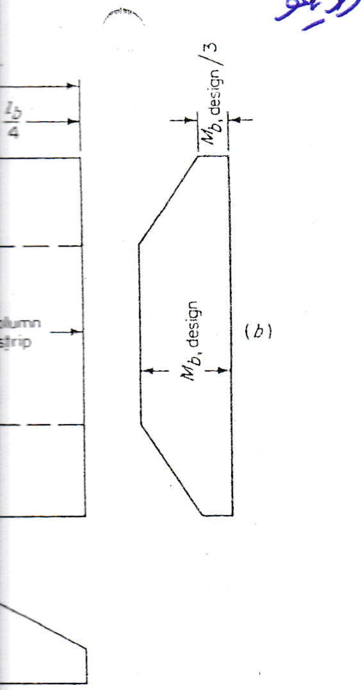

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Table 5.2 Coefficients for negative moments in slabs†

$M_{a,\text{neg}} = C_{a,\text{neg}} w l_a^2$
$M_{b,\text{neg}} = C_{b,\text{neg}} w l_b^2$ where w = total uniform dead plus live load

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,\text{neg}}$		0.045		0.050	0.075	0.071		0.033	0.061
	$C_{b,\text{neg}}$		0.045	0.076	0.050			0.071	0.061	0.033
0.95	$C_{a,\text{neg}}$		0.050		0.055	0.079	0.075		0.038	0.065
	$C_{b,\text{neg}}$		0.041	0.072	0.045			0.067	0.056	0.029
0.90	$C_{a,\text{neg}}$		0.055		0.060	0.080	0.079		0.043	0.068
	$C_{b,\text{neg}}$		0.037	0.070	0.040			0.062	0.052	0.025
0.85	$C_{a,\text{neg}}$		0.060		0.066	0.082	0.083		0.049	0.072
	$C_{b,\text{neg}}$		0.031	0.065	0.034			0.057	0.046	0.021
0.80	$C_{a,\text{neg}}$		0.065		0.071	0.083	0.086		0.055	0.075
	$C_{b,\text{neg}}$		0.027	0.061	0.029			0.051	0.041	0.017
0.75	$C_{a,\text{neg}}$		0.069		0.076	0.085	0.088		0.061	0.078
	$C_{b,\text{neg}}$		0.022	0.056	0.024			0.044	0.036	0.014
0.70	$C_{a,\text{neg}}$		0.074		0.081	0.086	0.091		0.068	0.081
	$C_{b,\text{neg}}$		0.017	0.050	0.019			0.038	0.029	0.011
0.65	$C_{a,\text{neg}}$		0.077		0.085	0.087	0.093		0.074	0.083
	$C_{b,\text{neg}}$		0.014	0.043	0.015			0.031	0.024	0.008
0.60	$C_{a,\text{neg}}$		0.081		0.089	0.088	0.095		0.080	0.085
	$C_{b,\text{neg}}$		0.010	0.035	0.011			0.024	0.018	0.006
0.55	$C_{a,\text{neg}}$		0.084		0.092	0.089	0.096		0.085	0.086
	$C_{b,\text{neg}}$		0.007	0.028	0.008			0.019	0.014	0.005
0.50	$C_{a,\text{neg}}$		0.086		0.094	0.090	0.097		0.089	0.088
	$C_{b,\text{neg}}$		0.006	0.022	0.006			0.014	0.010	0.003

†A crosshatched edge indicates that the slab continues across, or is fixed at, the support; an unmarked edge indicates a support at which torsional resistance is negligible.

(6)

computed for this total load. *Negative moments at discontinuous edges* are assumed equal to one-third of the positive moments for the same direction. One must provide for such moments because some degree of restraint is provided discontinuous edges by the torsional rigidity of the edge beam or by the supporting wall.

For *positive moments* there will be little, if any, rotation at the continuous

Table 5.3 Coefficients for dead-load positive moments in slabs†

$M_{a,pos,dl} = C_{a,dl} w l_a^2$ where w = total uniform dead load
$M_{b,pos,dl} = C_{b,dl} w l_b^2$

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,dl}$	0.036	0.018	0.018	0.027	0.027	0.033	0.027	0.020	0.023
	$C_{b,dl}$	0.036	0.018	0.027	0.027	0.018	0.027	0.033	0.023	0.020
0.95	$C_{a,dl}$	0.040	0.020	0.021	0.030	0.028	0.036	0.031	0.022	0.024
	$C_{b,dl}$	0.033	0.016	0.025	0.024	0.015	0.024	0.031	0.021	0.017
0.90	$C_{a,dl}$	0.045	0.022	0.025	0.033	0.029	0.039	0.035	0.025	0.026
	$C_{b,dl}$	0.029	0.014	0.024	0.022	0.013	0.021	0.028	0.019	0.015
0.85	$C_{a,dl}$	0.050	0.024	0.029	0.036	0.031	0.042	0.040	0.029	0.028
	$C_{b,dl}$	0.026	0.012	0.022	0.019	0.011	0.017	0.025	0.017	0.013
0.80	$C_{a,dl}$	0.056	0.026	0.034	0.039	0.032	0.045	0.045	0.032	0.029
	$C_{b,dl}$	0.023	0.011	0.020	0.016	0.009	0.015	0.022	0.015	0.010
0.75	$C_{a,dl}$	0.061	0.028	0.040	0.043	0.033	0.048	0.051	0.036	0.031
	$C_{b,dl}$	0.019	0.009	0.018	0.013	0.007	0.012	0.020	0.013	0.007
0.70	$C_{a,dl}$	0.068	0.030	0.046	0.046	0.035	0.051	0.058	0.040	0.033
	$C_{b,dl}$	0.016	0.007	0.016	0.011	0.005	0.009	0.017	0.011	0.006
0.65	$C_{a,dl}$	0.074	0.032	0.054	0.050	0.036	0.054	0.065	0.044	0.034
	$C_{b,dl}$	0.013	0.006	0.014	0.009	0.004	0.007	0.014	0.009	0.005
0.60	$C_{a,dl}$	0.081	0.034	0.062	0.053	0.037	0.056	0.073	0.048	0.036
	$C_{b,dl}$	0.010	0.004	0.011	0.007	0.003	0.006	0.012	0.007	0.004
0.55	$C_{a,dl}$	0.088	0.035	0.071	0.056	0.038	0.058	0.081	0.052	0.037
	$C_{b,dl}$	0.008	0.003	0.009	0.005	0.002	0.004	0.009	0.005	0.003
0.50	$C_{a,dl}$	0.095	0.037	0.080	0.059	0.039	0.061	0.089	0.056	0.038
	$C_{b,dl}$	0.006	0.002	0.007	0.004	0.001	0.003	0.007	0.004	0.002

†A crosshatched edge indicates that the slab continues across, or is fixed at, the support; an unmarked edge indicates a support at which torsional resistance is negligible.

edges if *dead load* alone is acting, because the loads on both adjacent panels tend to produce opposite rotations which cancel, or nearly so. For this condition, the continuous edges can be regarded as fixed, and the appropriate coefficients for the dead-load moments are given in Table 5.3. On the other hand, the maximum *live-load moments* are obtained when live load is placed only on the particular panel and not on any of the adjacent panels. In this

Table 5.4 Coefficients for live-load positive moments in slabs†

$M_{a,pos,ll} = C_{a,ll} w l_a^2$ where w = total uniform live load
$M_{b,pos,ll} = C_{b,ll} w l_b^2$

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,ll}$	0.036	0.027	0.027	0.032	0.032	0.035	0.032	0.028	0.030
	$C_{b,ll}$	0.036	0.027	0.032	0.032	0.027	0.032	0.035	0.030	0.028
0.95	$C_{a,ll}$	0.040	0.030	0.031	0.035	0.034	0.038	0.036	0.031	0.032
	$C_{b,ll}$	0.033	0.025	0.029	0.029	0.024	0.029	0.032	0.027	0.025
0.90	$C_{a,ll}$	0.045	0.034	0.035	0.039	0.037	0.042	0.040	0.035	0.036
	$C_{b,ll}$	0.029	0.022	0.027	0.026	0.021	0.025	0.029	0.024	0.022
0.85	$C_{a,ll}$	0.050	0.037	0.040	0.043	0.041	0.046	0.045	0.040	0.039
	$C_{b,ll}$	0.026	0.019	0.024	0.023	0.019	0.022	0.026	0.022	0.020
0.80	$C_{a,ll}$	0.056	0.041	0.045	0.048	0.044	0.051	0.051	0.044	0.042
	$C_{b,ll}$	0.023	0.017	0.022	0.020	0.016	0.019	0.023	0.019	0.017
0.75	$C_{a,ll}$	0.061	0.045	0.051	0.052	0.047	0.055	0.056	0.049	0.046
	$C_{b,ll}$	0.019	0.014	0.019	0.016	0.013	0.016	0.020	0.016	0.013
0.70	$C_{a,ll}$	0.068	0.049	0.057	0.057	0.051	0.060	0.063	0.054	0.050
	$C_{b,ll}$	0.016	0.012	0.016	0.014	0.011	0.013	0.017	0.014	0.011
0.65	$C_{a,ll}$	0.074	0.053	0.064	0.062	0.055	0.064	0.070	0.059	0.054
	$C_{b,ll}$	0.013	0.010	0.014	0.011	0.009	0.010	0.014	0.011	0.009
0.60	$C_{a,ll}$	0.081	0.058	0.071	0.067	0.059	0.068	0.077	0.065	0.059
	$C_{b,ll}$	0.010	0.007	0.011	0.009	0.007	0.008	0.011	0.009	0.007
0.55	$C_{a,ll}$	0.088	0.062	0.080	0.072	0.063	0.073	0.085	0.070	0.063
	$C_{b,ll}$	0.008	0.006	0.009	0.007	0.005	0.006	0.009	0.007	0.006
0.50	$C_{a,ll}$	0.095	0.066	0.088	0.077	0.067	0.078	0.092	0.076	0.067
	$C_{b,ll}$	0.006	0.004	0.007	0.005	0.004	0.005	0.007	0.005	0.004

†A crosshatched edge indicates that the slab continues across, or is fixed at, the support; an unmarked edge indicates a support at which torsional resistance is negligible.

case, some rotation will occur at all continuous edges. As an approximation it is assumed that there is 50 percent restraint for calculating these live-load moments. The corresponding coefficients are given in Table 5.4. Finally, for computing shear in the slab and loads on the supporting beams, Table 5.5 gives the fractions of the total load w which are transmitted in the two directions.

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Table 5.3 Coefficients for dead-load positive moments in slabs†

$M_{a,pos,dl} = C_{a,dl}wl_a^2$ where w = total uniform dead load
$M_{b,pos,dl} = C_{b,dl}wl_b^2$

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,dl}$	0.036	0.018	0.018	0.027	0.027	0.033	0.027	0.020	0.023
	$C_{b,dl}$	0.036	0.018	0.027	0.027	0.018	0.027	0.033	0.023	0.020
0.95	$C_{a,dl}$	0.040	0.020	0.021	0.030	0.028	0.036	0.031	0.022	0.024
	$C_{b,dl}$	0.033	0.016	0.025	0.024	0.015	0.024	0.031	0.021	0.017
0.90	$C_{a,dl}$	0.045	0.022	0.025	0.033	0.029	0.039	0.035	0.025	0.026
	$C_{b,dl}$	0.029	0.014	0.024	0.022	0.013	0.021	0.028	0.019	0.015
0.85	$C_{a,dl}$	0.050	0.024	0.029	0.036	0.031	0.042	0.040	0.029	0.028
	$C_{b,dl}$	0.026	0.012	0.022	0.019	0.011	0.017	0.025	0.017	0.013
0.80	$C_{a,dl}$	0.056	0.026	0.034	0.039	0.032	0.045	0.045	0.032	0.029
	$C_{b,dl}$	0.023	0.011	0.020	0.016	0.009	0.015	0.022	0.015	0.010
0.75	$C_{a,dl}$	0.061	0.028	0.040	0.043	0.033	0.048	0.051	0.036	0.031
	$C_{b,dl}$	0.019	0.009	0.018	0.013	0.007	0.012	0.020	0.013	0.007
0.70	$C_{a,dl}$	0.068	0.030	0.046	0.046	0.035	0.051	0.058	0.040	0.033
	$C_{b,dl}$	0.016	0.007	0.016	0.011	0.005	0.009	0.017	0.011	0.006
0.65	$C_{a,dl}$	0.074	0.032	0.054	0.050	0.036	0.054	0.065	0.044	0.034
	$C_{b,dl}$	0.013	0.006	0.014	0.009	0.004	0.007	0.014	0.009	0.005
0.60	$C_{a,dl}$	0.081	0.034	0.062	0.053	0.037	0.056	0.073	0.048	0.036
	$C_{b,dl}$	0.010	0.004	0.011	0.007	0.003	0.006	0.012	0.007	0.004
0.55	$C_{a,dl}$	0.088	0.035	0.071	0.056	0.038	0.058	0.081	0.052	0.037
	$C_{b,dl}$	0.008	0.003	0.009	0.005	0.002	0.004	0.009	0.005	0.003
0.50	$C_{a,dl}$	0.095	0.037	0.080	0.059	0.039	0.061	0.089	0.056	0.038
	$C_{b,dl}$	0.006	0.002	0.007	0.004	0.001	0.003	0.007	0.004	0.002

†A crosshatched edge indicates that the slab continues across, or is fixed at, the support; an unmarked edge indicates a support at which torsional resistance is negligible.

edges if *dead load* alone is acting, because the loads on both adjacent panels tend to produce opposite rotations which cancel, or nearly so. For this condition, the continuous edges can be regarded as fixed, and the appropriate coefficients for the dead-load moments are given in Table 5.3. On the other hand, the maximum *live-load moments* are obtained when live load is placed only on the particular panel and not on any of the adjacent panels. In this

Table 5.4 Coefficients for live-l

$M_{a,pos,ll} = C_{a,ll}wl_a^2$ where w = total
$M_{b,pos,ll} = C_{b,ll}wl_b^2$

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case
1.00	$C_{a,ll}$	0.036	0.027	0.027
	$C_{b,ll}$	0.036	0.027	0.032
0.95	$C_{a,ll}$	0.040	0.030	0.031
	$C_{b,ll}$	0.033	0.025	0.029
0.90	$C_{a,ll}$	0.045	0.034	0.035
	$C_{b,ll}$	0.029	0.022	0.027
0.85	$C_{a,ll}$	0.050	0.037	0.040
	$C_{b,ll}$	0.026	0.019	0.024
0.80	$C_{a,ll}$	0.056	0.041	0.045
	$C_{b,ll}$	0.023	0.017	0.022
0.75	$C_{a,ll}$	0.061	0.045	0.051
	$C_{b,ll}$	0.019	0.014	0.019
0.70	$C_{a,ll}$	0.068	0.049	0.057
	$C_{b,ll}$	0.016	0.012	0.016
0.65	$C_{a,ll}$	0.074	0.053	0.064
	$C_{b,ll}$	0.013	0.010	0.014
0.60	$C_{a,ll}$	0.081	0.058	0.071
	$C_{b,ll}$	0.010	0.007	0.011
0.55	$C_{a,ll}$	0.088	0.062	0.080
	$C_{b,ll}$	0.008	0.006	0.009
0.50	$C_{a,ll}$	0.095	0.066	0.088
	$C_{b,ll}$	0.006	0.004	0.007

†A crosshatched edge indicates tha
unmarked edge indicates a support at

case, some rotation will occur a
is assumed that there is 50 pe
moments. The corresponding c
computing shear in the slab a
gives the fractions of the tota
directions.

ents in slabs†

[illegible]

Case 6	Case 7	Case 8	Case 9
0.033 0.027	0.027 0.033	0.020 0.023	0.023 0.020
0.036 0.024	0.031 0.031	0.022 0.021	0.024 0.017
0.039 0.021	0.035 0.028	0.025 0.019	0.026 0.015
0.042 0.017	0.040 0.025	0.029 0.017	0.028 0.013
0.045 0.015	0.045 0.022	0.032 0.015	0.029 0.010
0.048 0.012	0.051 0.020	0.036 0.013	0.031 0.007
0.051 0.009	0.058 0.017	0.040 0.011	0.033 0.006
0.054 0.007	0.065 0.014	0.044 0.009	0.034 0.005
0.056 0.006	0.073 0.012	0.048 0.007	0.036 0.004
0.058 0.004	0.081 0.009	0.052 0.005	0.037 0.003
0.061 0.003	0.089 0.007	0.056 0.004	0.038 0.002

across, or is fixed at, the support; an
ance is negligible.

loads on both adjacent panels ncel, or nearly so. For this d as fixed, and the appropriate en in Table 5.3. On the other ained when live load is placed f the adjacent panels. In this

Table 5.4 Coefficients for live-load positive moments in slabs†

$M_{a,pos,ll} = C_{a,ll} w l_a^2$
$M_{b,pos,ll} = C_{b,ll} w l_b^2$ where w = total uniform live load

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,ll}$ $C_{b,ll}$	0.036 0.036	0.027 0.027	0.027 0.032	0.032 0.032	0.032 0.027	0.035 0.032	0.032 0.035	0.028 0.030	0.030 0.028
0.95	$C_{a,ll}$ $C_{b,ll}$	0.040 0.033	0.030 0.025	0.031 0.029	0.035 0.029	0.034 0.024	0.038 0.029	0.036 0.032	0.031 0.027	0.032 0.025
0.90	$C_{a,ll}$ $C_{b,ll}$	0.045 0.029	0.034 0.022	0.035 0.027	0.039 0.026	0.037 0.021	0.042 0.025	0.040 0.029	0.035 0.024	0.036 0.022
0.85	$C_{a,ll}$ $C_{b,ll}$	0.050 0.026	0.037 0.019	0.040 0.024	0.043 0.023	0.041 0.019	0.046 0.022	0.045 0.026	0.040 0.022	0.039 0.020
0.80	$C_{a,ll}$ $C_{b,ll}$	0.056 0.023	0.041 0.017	0.045 0.022	0.048 0.020	0.044 0.016	0.051 0.019	0.051 0.023	0.044 0.019	0.042 0.017
0.75	$C_{a,ll}$ $C_{b,ll}$	0.061 0.019	0.045 0.014	0.051 0.019	0.052 0.016	0.047 0.013	0.055 0.016	0.056 0.020	0.049 0.016	0.046 0.013
0.70	$C_{a,ll}$ $C_{b,ll}$	0.068 0.016	0.049 0.012	0.057 0.016	0.057 0.014	0.051 0.011	0.060 0.013	0.063 0.017	0.054 0.014	0.050 0.011
0.65	$C_{a,ll}$ $C_{b,ll}$	0.074 0.013	0.053 0.010	0.064 0.014	0.062 0.011	0.055 0.009	0.064 0.010	0.070 0.014	0.059 0.011	0.054 0.009
0.60	$C_{a,ll}$ $C_{b,ll}$	0.081 0.010	0.058 0.007	0.071 0.011	0.067 0.009	0.059 0.007	0.068 0.008	0.077 0.011	0.065 0.009	0.059 0.007
0.55	$C_{a,ll}$ $C_{b,ll}$	0.088 0.008	0.062 0.006	0.080 0.009	0.072 0.007	0.063 0.005	0.073 0.006	0.085 0.009	0.070 0.007	0.063 0.006
0.50	$C_{a,ll}$ $C_{b,ll}$	0.095 0.006	0.066 0.004	0.088 0.007	0.077 0.005	0.067 0.004	0.078 0.005	0.092 0.007	0.076 0.005	0.067 0.004

†A crosshatched edge indicates that the slab continues across, or is fixed at, the support; an unmarked edge indicates a support at which torsional resistance is negligible.

case, some rotation will occur at all continuous edges. As an approximation it is assumed that there is 50 percent restraint for calculating these live-load moments. The corresponding coefficients are given in Table 5.4. Finally, for computing shear in the slab and loads on the supporting beams, Table 5.5 gives the fractions of the total load w which are transmitted in the two directions.

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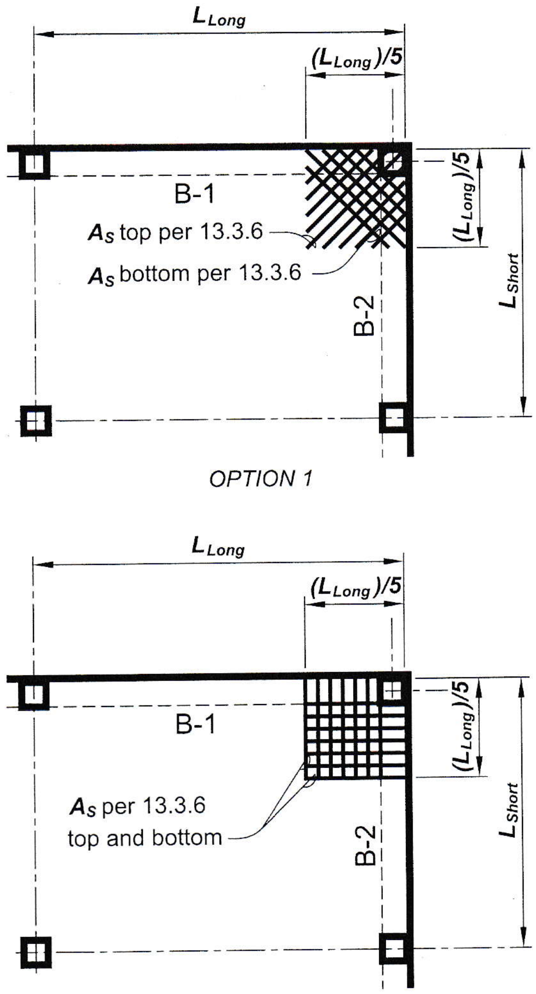
CODE

Alternatively, reinforcement shall be placed in two layers parallel to the sides of the slab in both the top and bottom of the slab.

13.3.7 — When a drop panel is used to reduce the amount of negative moment reinforcement over the column of a flat slab, the dimensions of the drop panel shall be in accordance with 13.2.5. In computing required slab reinforcement, the thickness of the drop panel below the slab shall not be assumed to be greater than one-quarter the distance from the edge of drop panel to the face of column or column capital.

COMMENTARY



Notes:

1. Applies where B-1 or B-2 has α_f >1.0
2. Max. bar spacing 2h, where h = slab thickness.

Fig. R13.3.6—Slab corner reinforcement.

13.3.8 — Details of reinforcement in slabs without beams

13.3.8.1 — In addition to the other requirements of 13.3, reinforcement in slabs without beams shall have minimum extensions as prescribed in Fig. 13.3.8.

13.3.8.2 — Where adjacent spans are unequal, extensions of negative moment reinforcement beyond the face of support as prescribed in Fig. 13.3.8 shall be based on requirements of the longer span.

R13.3.8 — Details of reinforcement in slabs without beams

In the 1989 Code, bent bars were removed from Fig. 13.3.8. This was done because bent bars are seldom used and are difficult to place properly. Bent bars are permitted, however, if they comply with 13.3.8.3. Refer to 13.4.8 of the 1983 Code.

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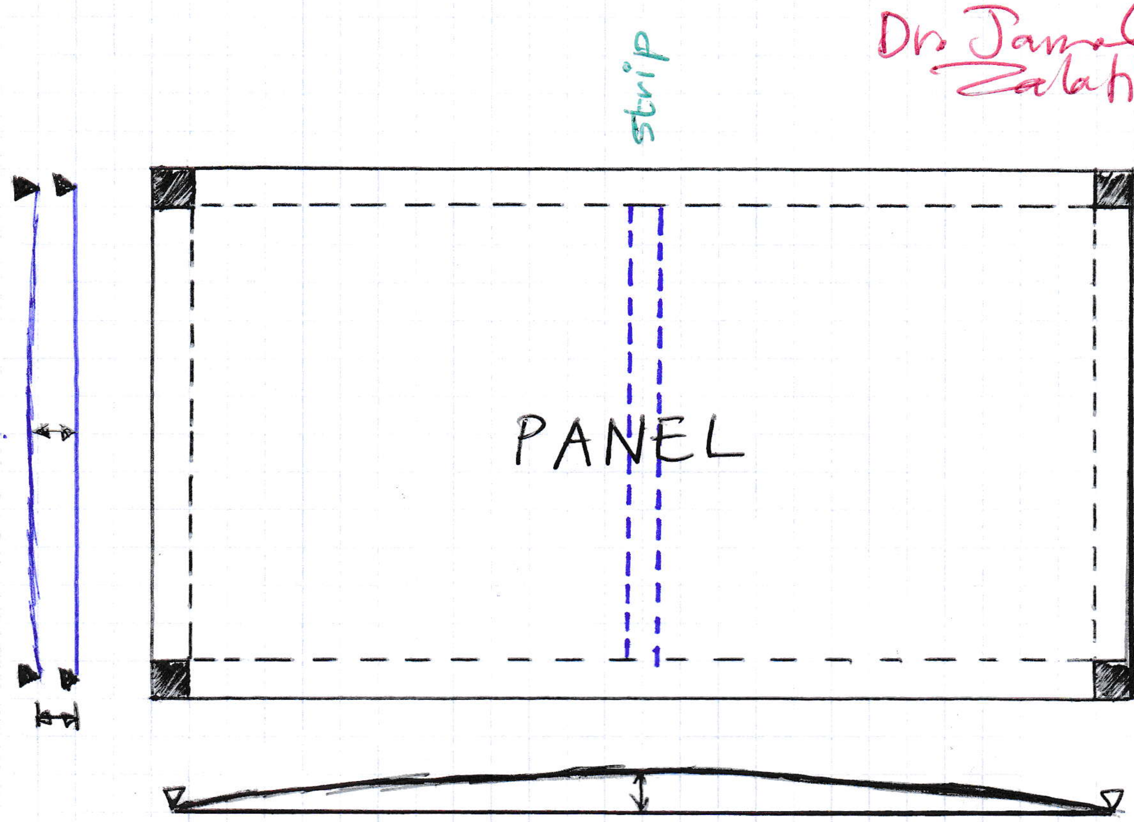

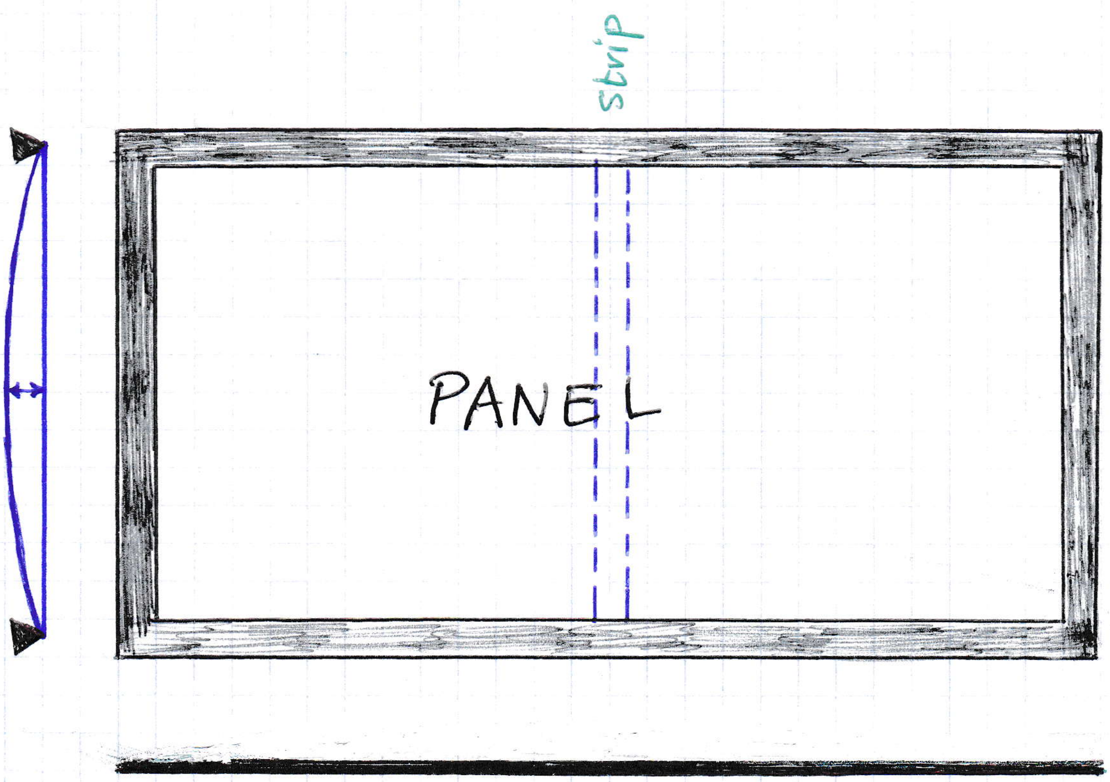

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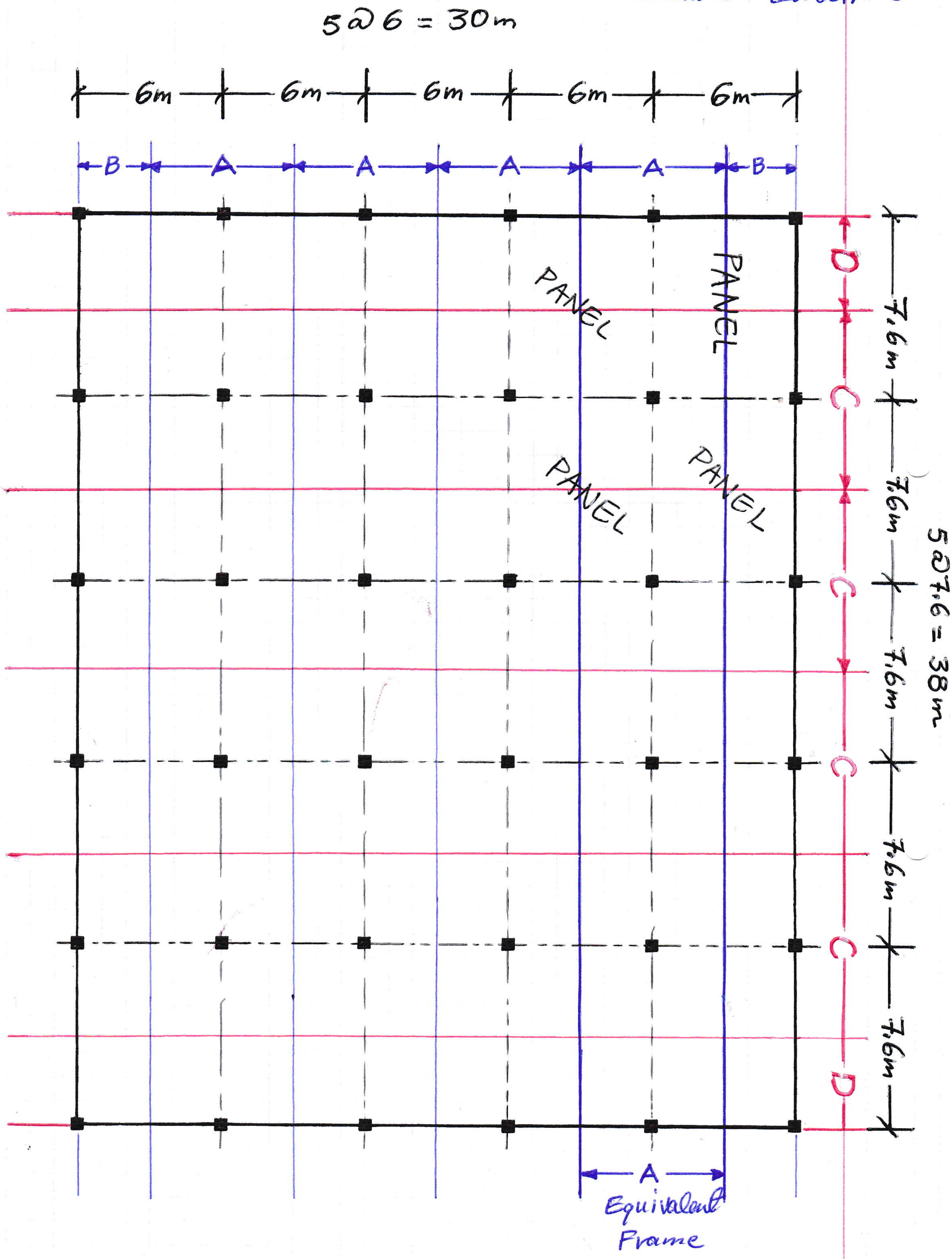

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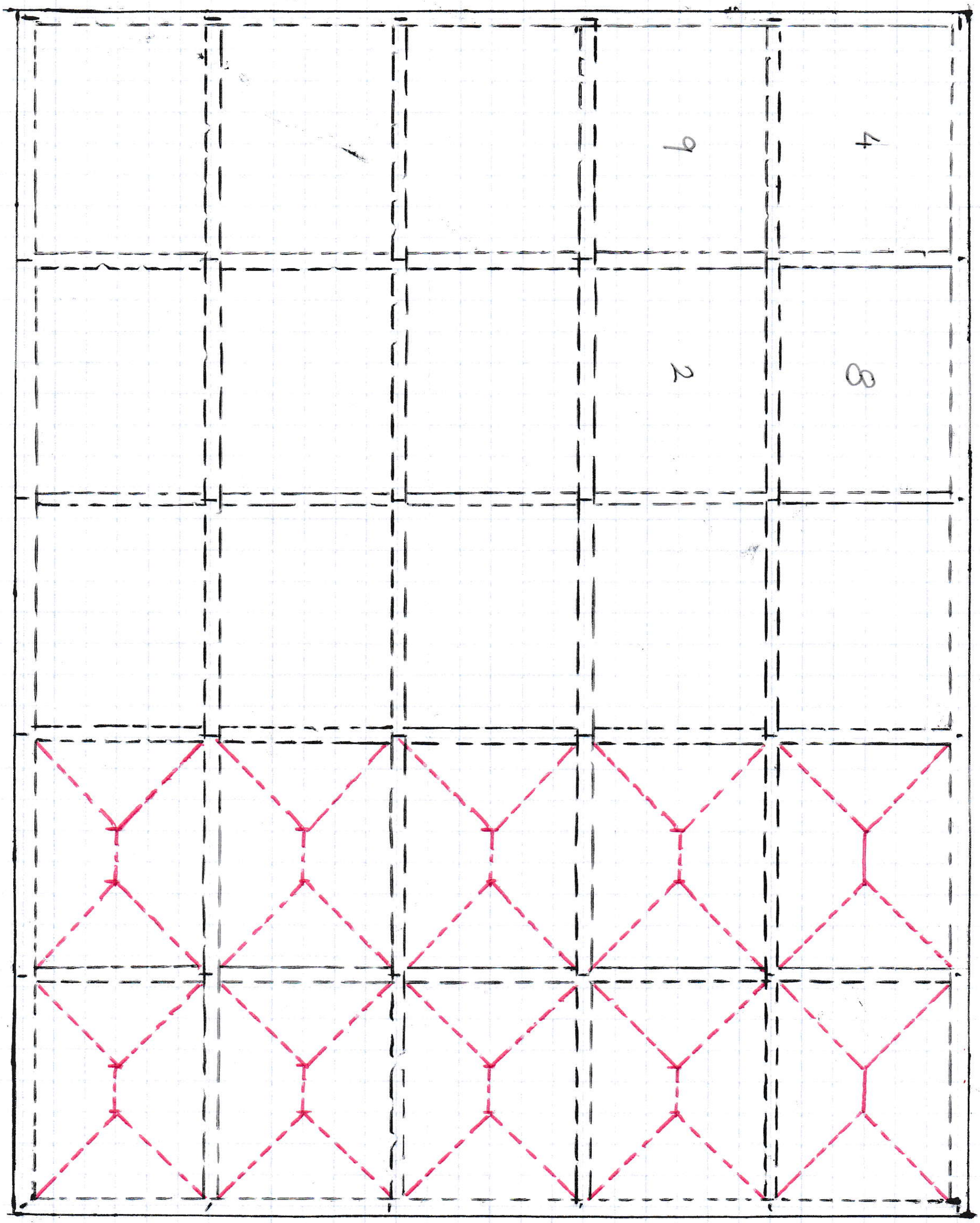

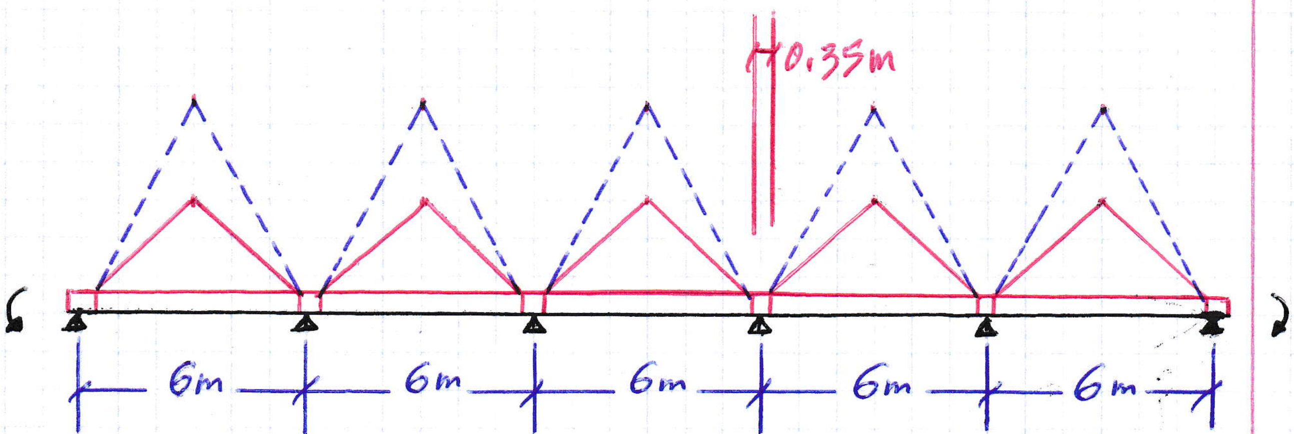

Example:

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Slab thickness = 17 cm

$LL = 0.69\ t/m^2$

$DL = 0.17 \times 2.4 = 0.408\ t/m^2$

Storey height = 3.70 m

$f'_c = 20\ MPa$, $f_y = 280\ MPa$

$$W_u = \underbrace{1.2(0.408)}_{0.49\ t/m^2} + \underbrace{1.6(0.69)}_{1.10\ t/m^2} = 1.59\ t/m^2$$

$$m = \frac{l_a}{l_b} = \frac{5.65}{7.30} = 0.774$$

use $m = 0.75$

For the short direction: Case 4 Negative

$C_{a,neg} = 0.076$

However, case 9 must also be checked,

$C_{a,neg} = 0.078$ Controls,

(Short) $M_{u,-ve} = 0.078(1.59)(5.65)^2 = 3.96\ t.m$

For the long direction:

$C_{b,neg} = 0.024$

Again, case 8 must also be checked,

$C_{b,neg} = 0.036$ Controls,

(long) $M_{u,-ve} = 0.036(1.59)(7.30)^2 = 3.05\ t.m$

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For the short direction: Case 4 Positive

$Ca, dl = 0.043$

$Ca, ll = 0.052$

$Mu, +ve, dl = 0.043\,(0.49)(5.65)^2 = 0.67\ t.m$

$Mu, +ve, ll = 0.052\,(1.10)(5.65)^2 = 1.83\ t.m$

(Short) Mu, +ve, short   Total, +ve $= 2.50\ t.m$

For the long direction:

$C_b, dl = 0.013$

$C_b, ll = 0.016$

$Mu, +ve, dl = 0.013\,(0.49)(7.30)^2 = 0.34\ t.m$

$Mu, +ve, ll = 0.016\,(1.10)(7.30)^2 = 0.94\ t.m$

(long) Mu, +ve, long   Total, +ve $= 1.28\ t.m$

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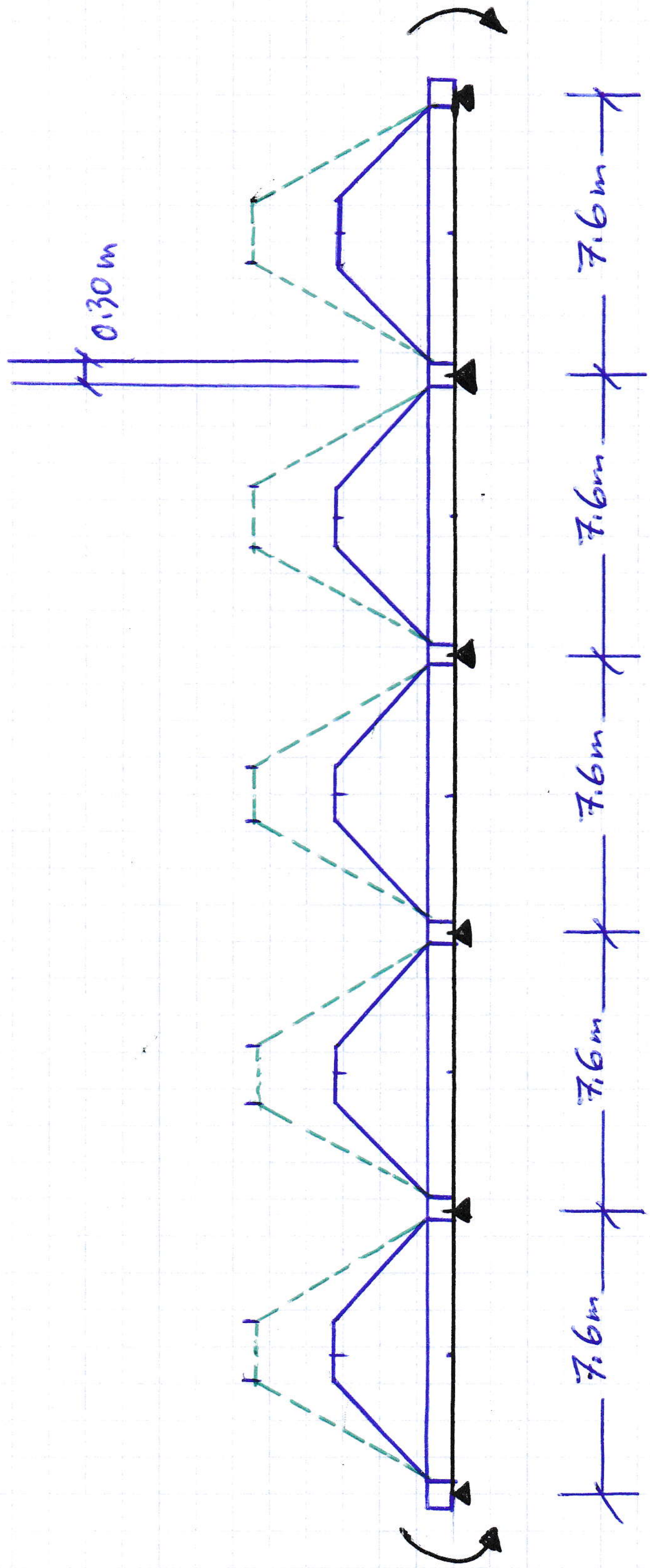

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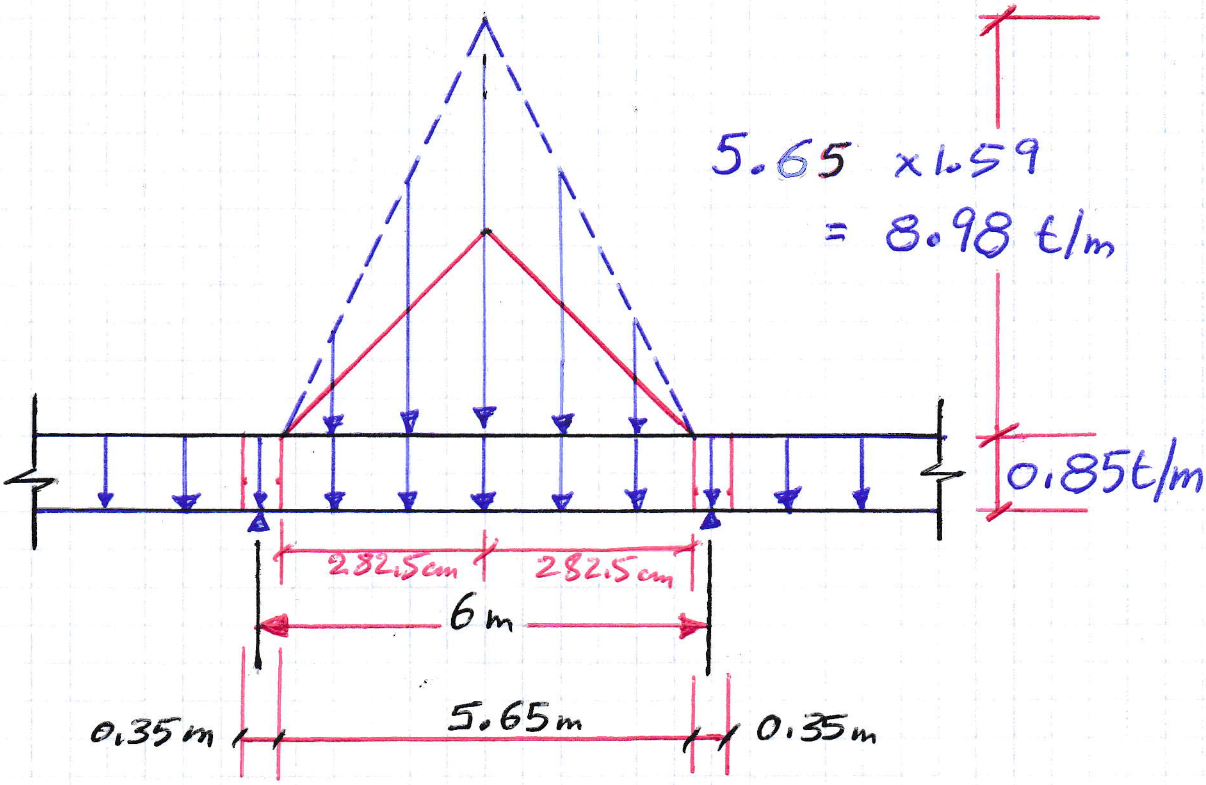
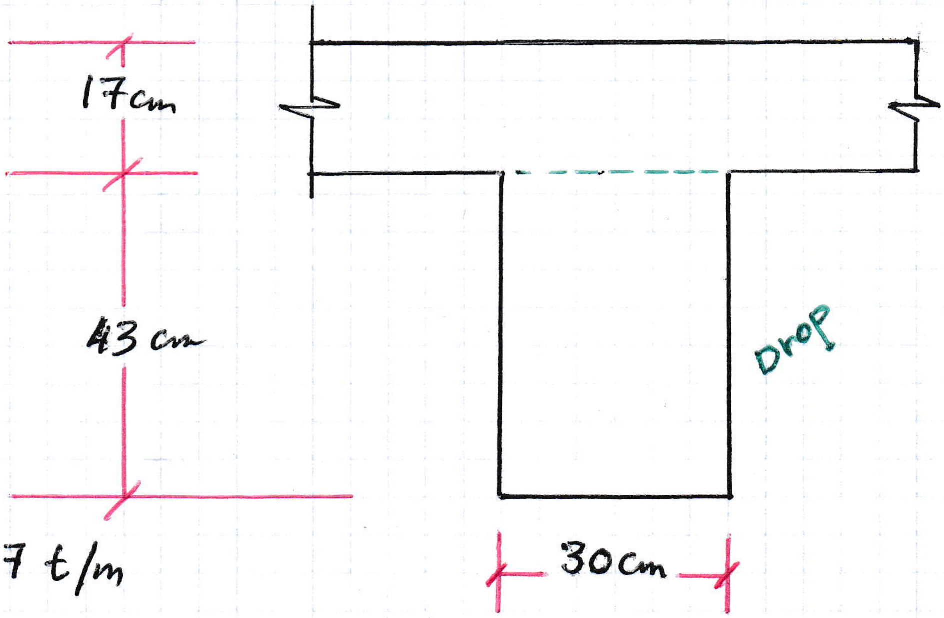


Drop = 60 − 17 = 43 cm



W_{drop},
$= 0.43 \times 0.30 \times 2.4$
$= 0.31$ t/m

$W_{drop, factored}$,
$= 1.2(0.31) = 0.37$ t/m

As for the 17cm thick slab,
$W_u = 0.30 \times 1.59 = 0.48$ t/m

Total $= 0.37 + 0.48 = 0.85$ t/m

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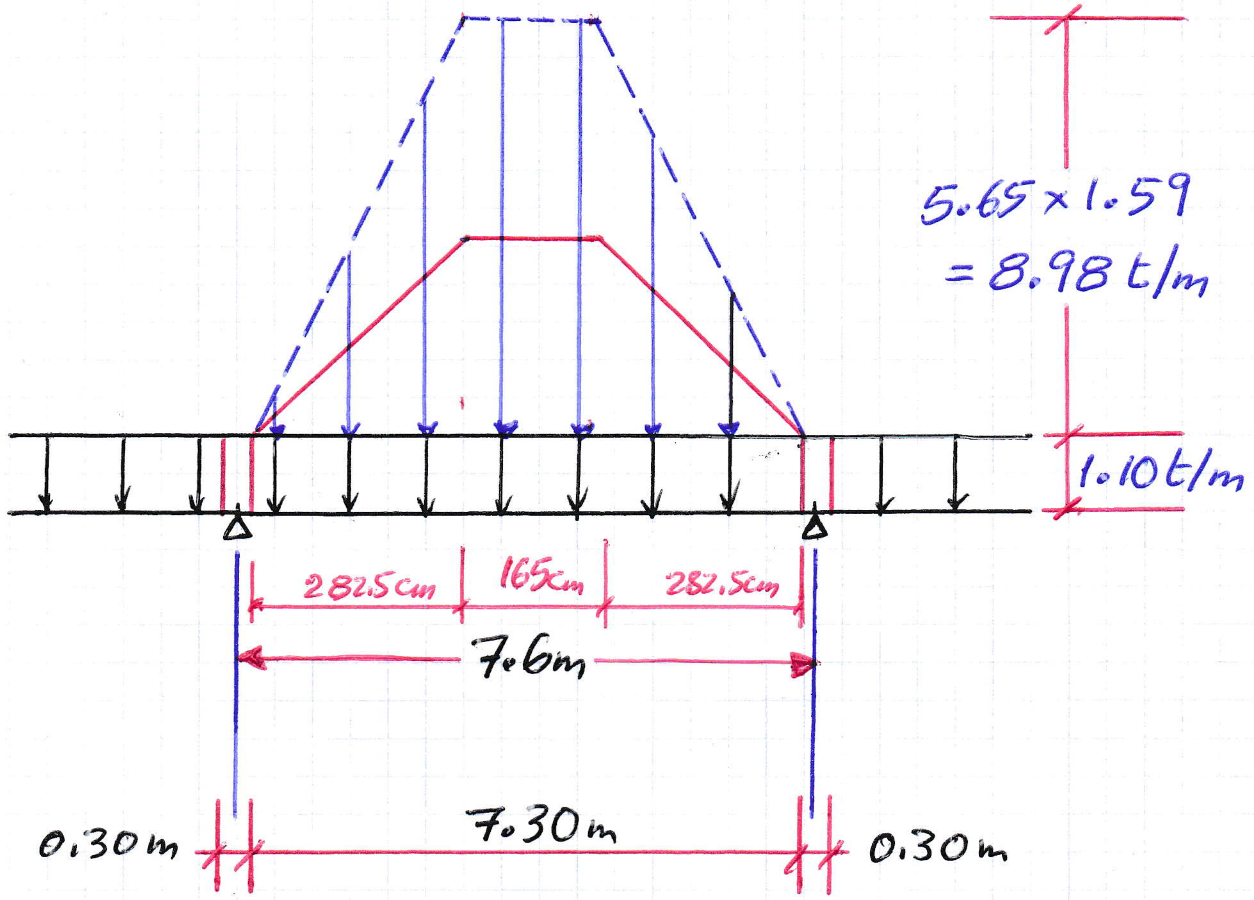

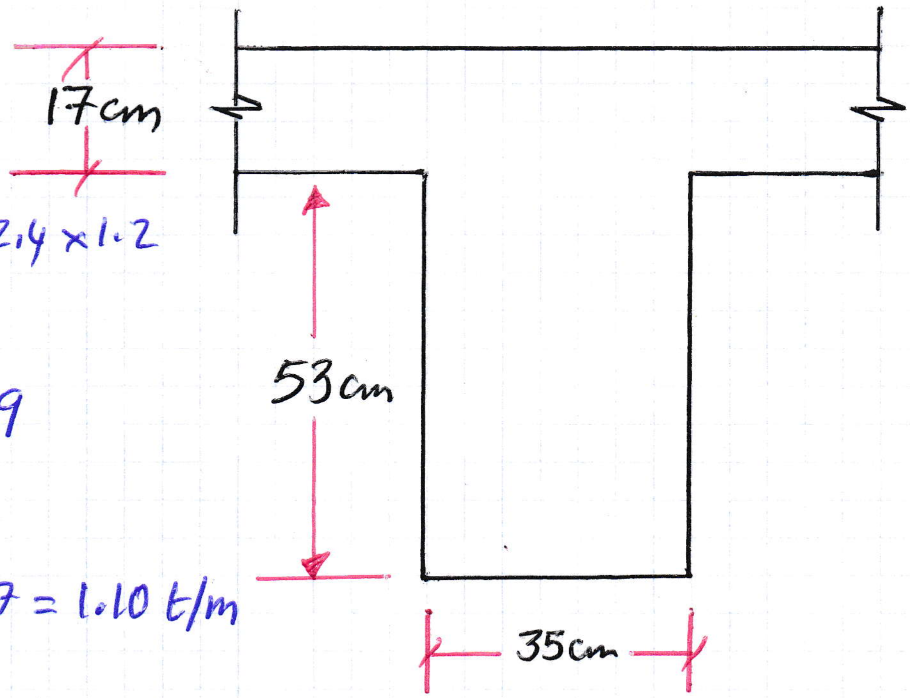

Drop = $0.53 \times 0.35 \times 2.4 \times 1.2$
$= 0.53\ t/m$

Slab = 0.35×1.59
$= 0.57\ t/m$

Total = $0.53 + 0.57 = 1.10\ t/m$

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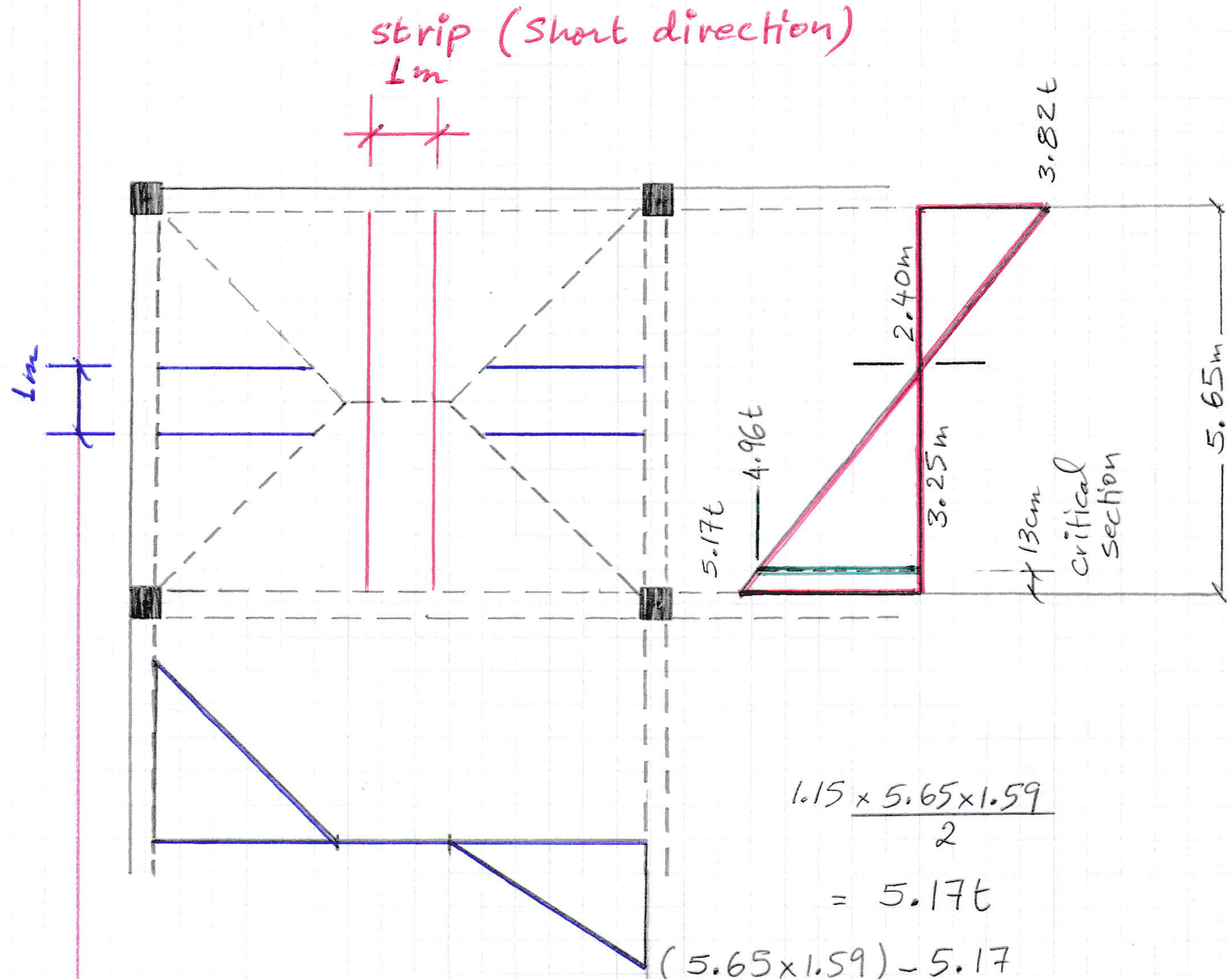
Checking the Adequacy of the slab Thickness for Shear



$$\frac{1.15 \times 5.65 \times 1.59}{2}$$

$= 5.17t$

$(5.65 \times 1.59) - 5.17$

$= 3.82t$

The difference between the end moments is smaller in the long direction

$d_{slab} = 17 - 4 = 13 \text{ cm}$

V_u (critical section)

$= 4.96t$

$$\phi V_c = 0.75\,(0.17)(1)\frac{\sqrt{20}}{100}(100)(13)$$

$= 7.41\ t$

$\therefore\ \phi V_c > V_u$

7.41t 4.96t

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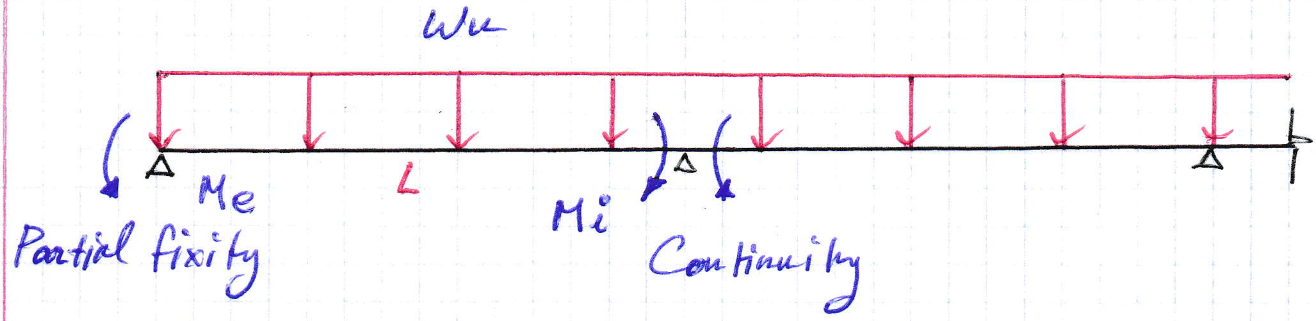

$\frac{W_u L}{2}$ $\frac{W_u L}{2}$

$M_i > M_e$

$\frac{M_i - M_e}{l}$

total Shear forces

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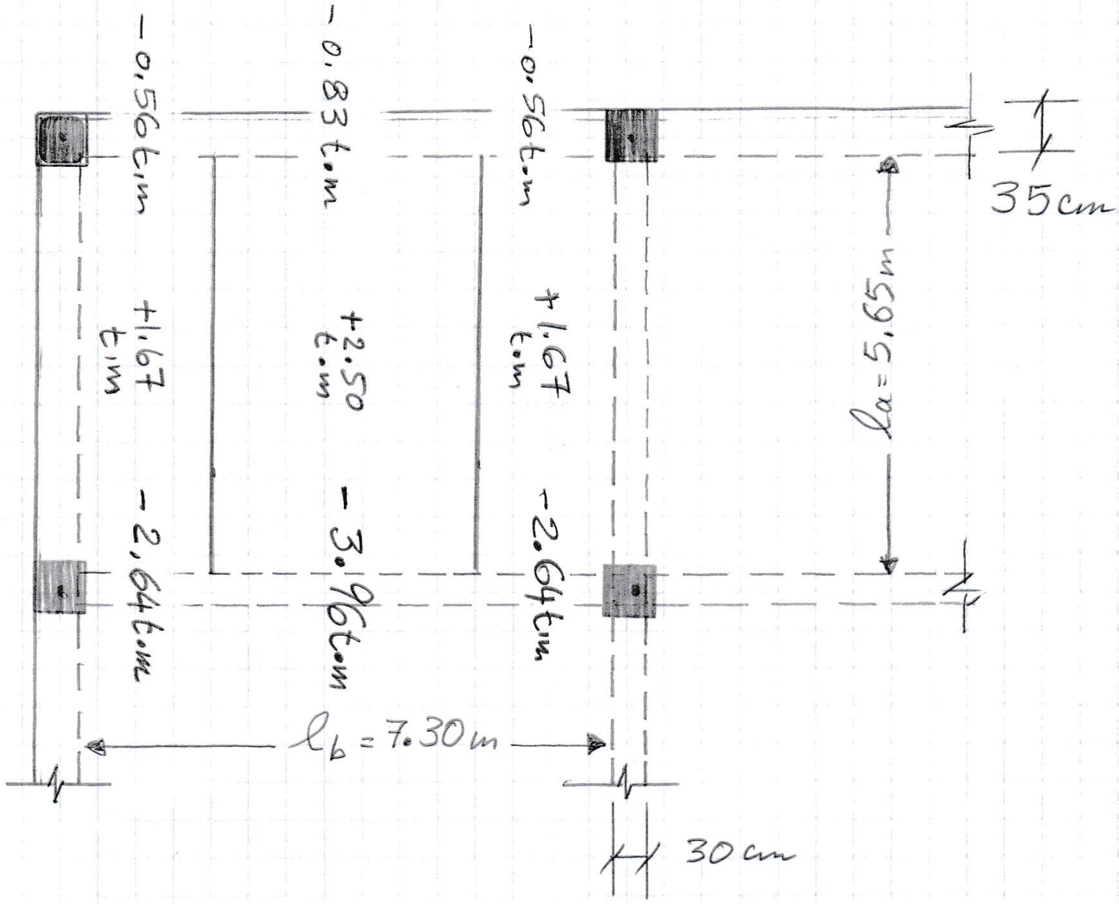

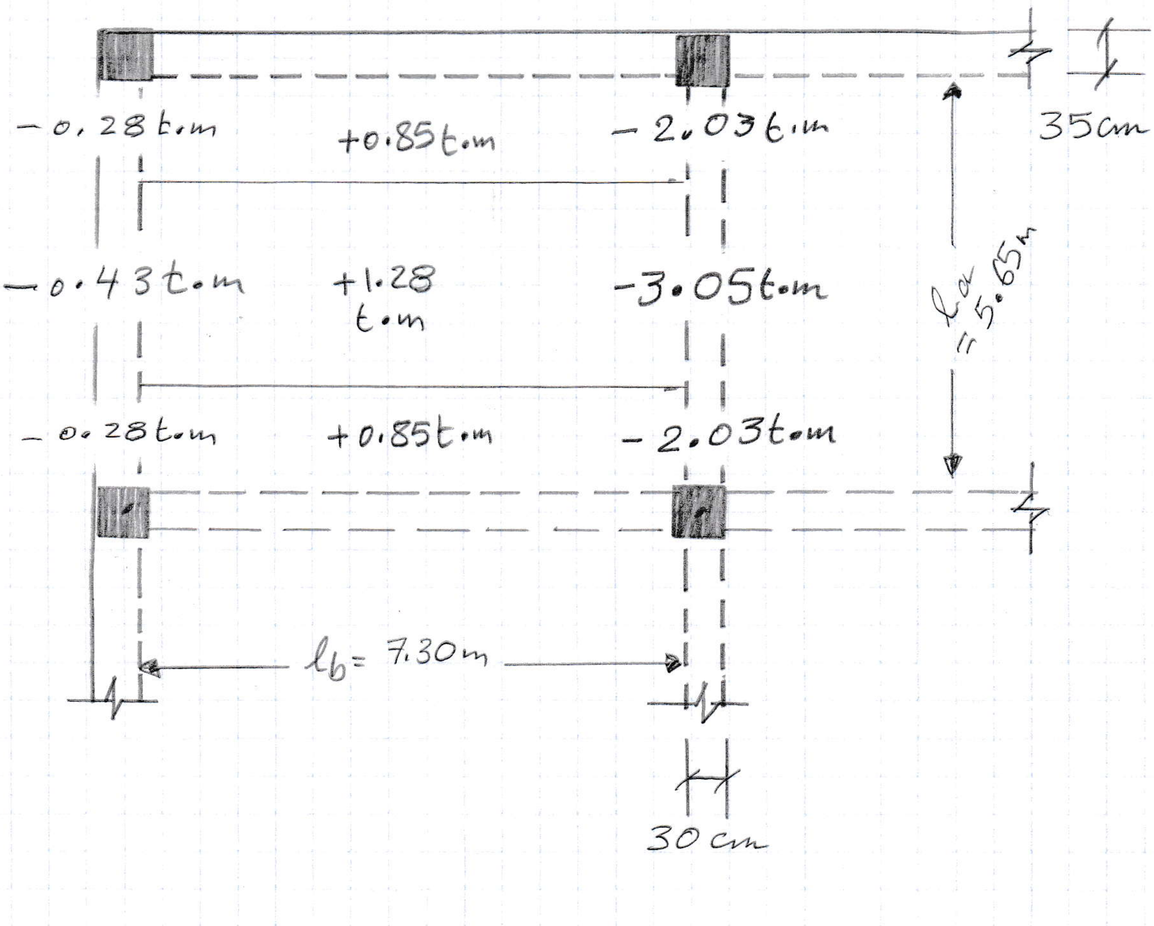

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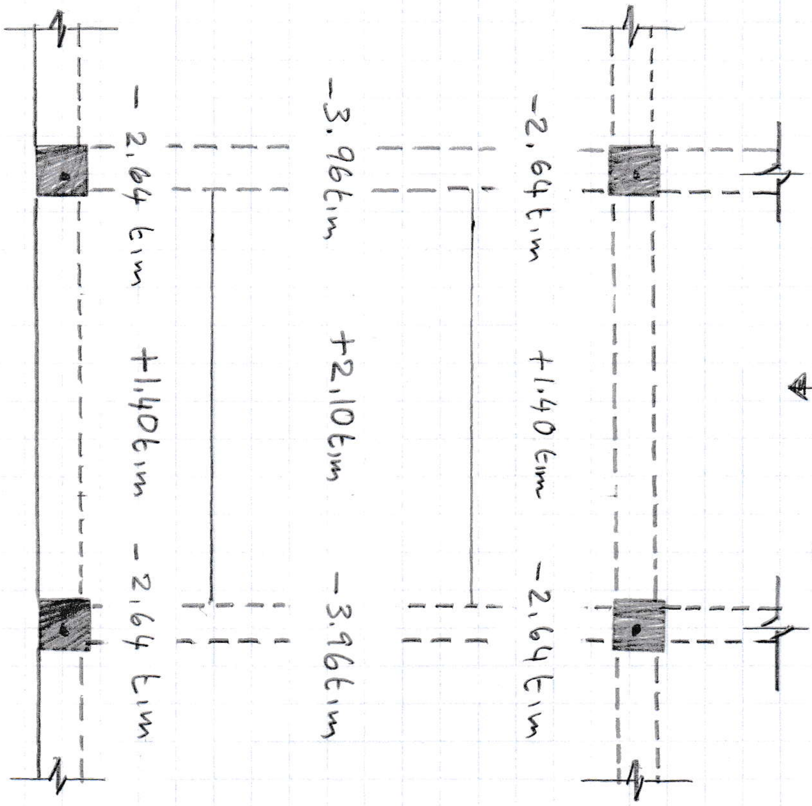
Case 9

Factored $DL = 0.49\ t/m^2$
Factored $LL = 1.10\ t/m^2$
Total $W_u = 1.59\ t/m^2$

$l_a = 5.65\ m$
$l_b = 7.30\ m$

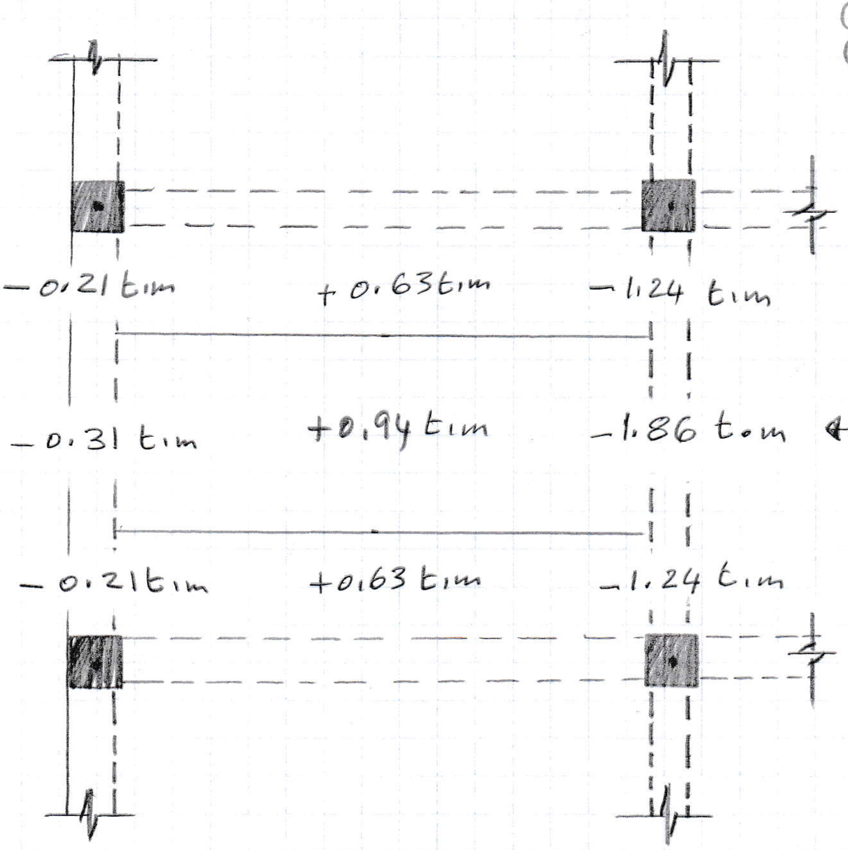


case 2

(+ve)	0.031	DL	0.48 t.m
(+ve)	0.046	LL	1.62 t.m
			2.10 t.m

(−ve) 0.014
0.022

(+ve)	0.007	DL	0.18
(+ve)	0.013	LL	0.76
			0.94 t.m



case 2