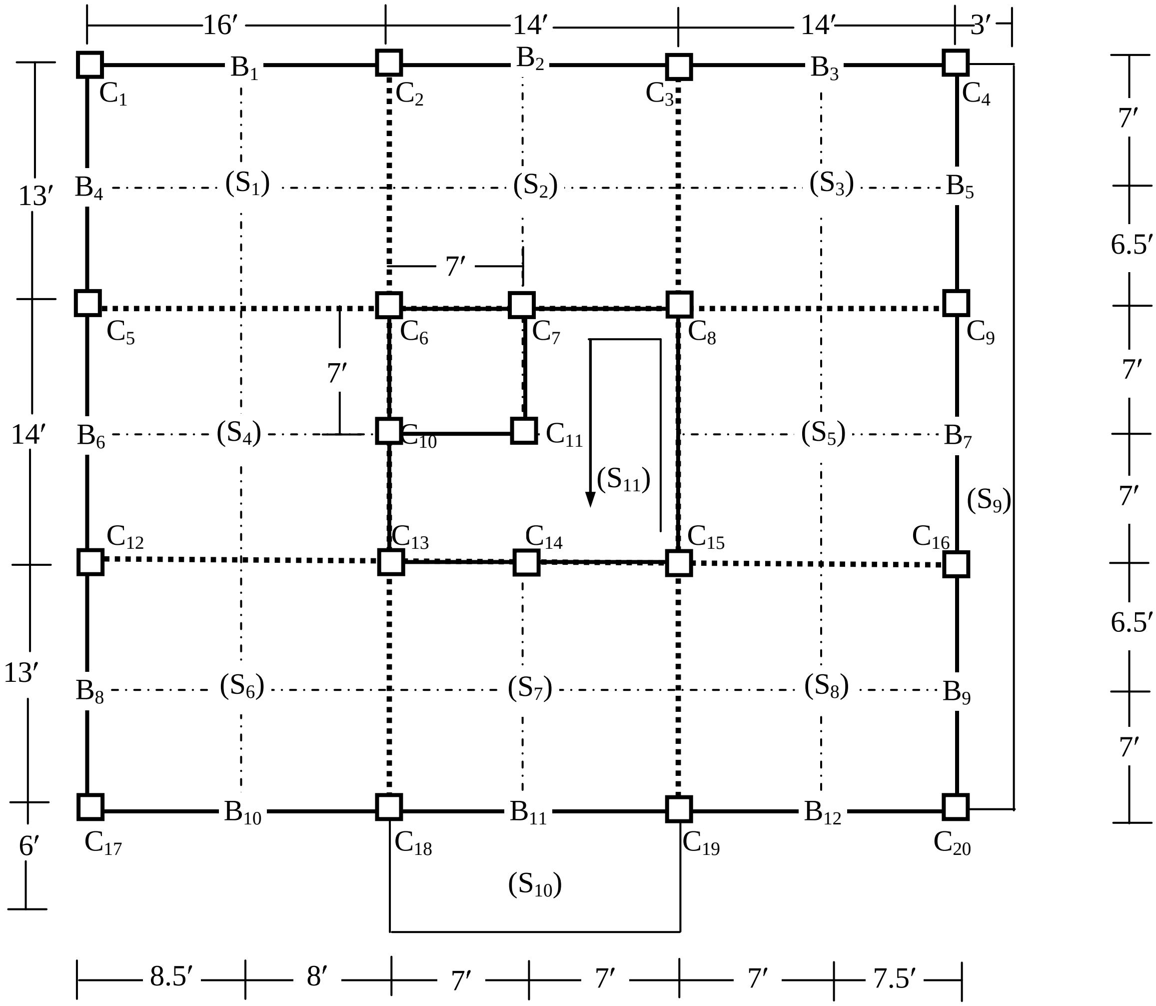
Design of Flat Slab (with edge beams) by Direct Design Method



Building Plan

Assume S = (16 + x/4)′, Building spans = (S, S–2, S–2, 3′) by (S–3, S–2, S–3, 6′)

Building Height = 4@10′ = 40′

Loads: LL = 40 psf, FF = 20 psf, RW = 20 psf [i.e., (40 + x/2), (20 + x/4), (20 + x/4) psf]

Material Properties: f'_c = 3 ksi, f_s = 20 ksi [i.e., f'_c = (3 + x/20) ksi, f_s = (20 + x/4) ksi

Design of Slabs

Maximum Clear Span = 15′

Slab with edge beam, f_y = 40 ksi

$\Rightarrow$ Slab thickness = $L_n(0.8 + f_y/200)/36 = 15\times(0.8 + 40/200)\times12/36 = 5''$; i.e., assume 6″ thick slab

$\therefore$ Self weight = $6\times150/12 = 75$ psf

$\therefore$ Total load on slab = 75 + 20 + 20 + 40 = 155 psf = 0.155 ksf

For design, n = 9, k = 0.378, j = 0.874, R = 0.223 ksi

d = 5″ (or 4.5″ for M_{min})

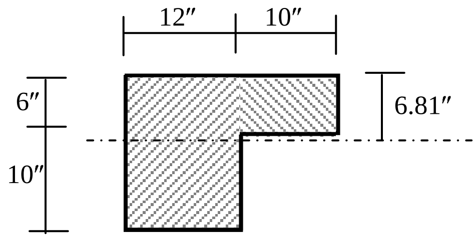
$A_s = M/f_sjd = M\times12/(20\times0.874\times5) = M/7.28$ (or M/6.56 for M_{min})

$\therefore M_{c(max)} = Rbd^2 = 0.223\times1\times5^2 = 5.57$ k′/′

And, allowable punching shear stress, $\tau_{punch} = 2\sqrt{f_c'} = 2\sqrt{(3/1000)} = 0.110$ ksi

Also, $A_{s(Temp)} = 0.0025\,bt = 0.0025\times12\times6 = 0.18$ in^2/′

Edge Beam Section and Properties



The edge beam is made of two rectangular sections 12″×16″ and 10″×6″

$\therefore\ \bar{y} = (12\times16\times8 + 10\times6\times3)/(12\times16 + 10\times6) = (1536 + 180)/(192 + 60) = 6.81''$

Moment of Inertia of external beam-slab, $I_b = 10\times6^3/3 + 12\times16^3/3 - (192 + 60)\times6.81^2 = 5419$ in^4

Torsional rigidity of edge beam, $C = (1-0.63\times12/16)\,12^3\times16/3 + (1-0.63\times6/10)\,6^3\times10/3 = 5309$ in^4

Panels in the Long Direction

Panel 1

Width = 7′; Moment of Inertia of edge slab, $I_s \cong 7\times12\times6^3/12 = 1512\ in^4$

For the edge beam along panel length; $\therefore \alpha_1 = E_{cb}I_b/E_{cs}I_s = 5419/1512 = 3.58$, for all slabs

β_t for Slab (S_1) and (S_3) = $E_{cb}C/2E_{cs}I_s = 5309/(2\times1512) = 1.76 < 2.5$, and for Slab $S_2 = 0.0$

Column strip = Short span (c/c)/4 = 13/4 = 3.25′, Middle strip = 6.5 –3.25 = 3.25′

Slab (S_1)

Slab size (= 16′×13′ c/c) = 15′×12′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times15^2/8 = 30.52$ k′

Support (d) $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 9.15$ k′, $M^+ = 0.50\ M_0 = 15.26$ k′, $M_{Int}^- = 0.70\ M_0 = 21.36$ k′

[Note: The Equivalent Frame Method does a more rational analysis in the above steps only]

$L_2/L_1 = 13/16 = 0.81$, $\alpha_1L_2/L_1 = 2.91 > 1.0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.86\ M_{Ext}^- = 7.91$ k′; i.e., 7.91×0.85 = 6.72 k′ in beam, 7.91×0.15/3.25 = 0.37 k′/′ in slab

$M_C^+ = 0.81\ M^+ = 12.30$ k′; i.e., 12.30×0.85 = 10.46 k′ in beam, 12.30×0.15/3.25 = 0.57 k′/′ in slab

$M_{CInt}^- = 0.81\ M_{Int}^- = 17.22$ k′; i.e., 17.22×0.85 = 14.64 k′ in beam, 17.22×0.15/3.25 = 0.79 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 9.15–7.91 = 1.25$ k′; i.e., 1.25/3.25 = 0.38 k′/′ in slab

$M_M^+ = 15.26–12.30 = 2.96$ k′; i.e., 2.96/3.25 = 0.91 k′/′ in slab

$M_{MInt}^- = 21.36–17.22 = 4.14$ k′; i.e., 4.14/3.25 = 1.27 k′/′ in slab

Slab (S_2)

Slab size (= 14′×13′ c/c) = 13′×12′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times13^2/8 = 22.92$ k′

Interior Support $\Rightarrow M_{Int}^- = 0.65\ M_0 = 14.90$ k′, $M^+ = 0.35\ M_0 = 8.02$ k′, $M_{Int}^- = 0.65\ M_0 = 14.90$ k′

$L_2/L_1 = 13/14 = 0.93$, $\alpha_1L_2/L_1 = 3.33 > 1.0$

$\therefore$ Total column strip moments are

$M_{CInt}^- = 0.77\ M_{Int}^- = 11.49$ k′; i.e., 11.49×0.85 = 9.77 k′ in beam, 11.49×0.15/3.25 = 0.53 k′/′ in slab

$M_C^+ = 0.77\ M^+ = 6.19$ k′; i.e., 6.19×0.85 = 5.26 k′ in beam, 6.19×0.15/3.25 = 0.29 k′/′ in slab

$M_{CInt}^- = 0.77\ M_{Int}^- = 11.49$ k′; i.e., 11.49×0.85 = 9.77 k′ in beam, 11.49×0.15/3.25 = 0.53 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MInt}^- = 14.90–11.49 = 3.41$ k′; i.e., 3.41/3.25 = 1.05 k′/′ in slab

$M_M^+ = 8.02–6.19 = 1.83$ k′; i.e., 1.83/3.25 = 0.56 k′/′ in slab

$M_{MInt}^- = 14.90–11.49 = 3.41$ k′; i.e., 3.41/3.25 = 1.05 k′/′ in slab

Slab (S_3)

Slab size (= 14′×13′ c/c) = 13′×12′

Column strip = 3.25′, Middle strip = 3.25′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times13^2/8 = 22.92$ k′

Support (d) $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 6.88$ k′, $M^+ = 0.50\ M_0 = 11.46$ k′, $M_{Int}^- = 0.70\ M_0 = 16.04$ k′

$L_2/L_1 = 13/14 = 0.93$, $\alpha_1L_2/L_1 = 3.33 > 1.0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.84\ M_{Ext}^- = 5.77$ k′; i.e., 5.77×0.85 = 4.91 k′ in beam, 5.77×0.15/3.25 = 0.27 k′/′ in slab

$M_C^+ = 0.77\ M^+ = 8.84$ k′; i.e., 8.84×0.85 = 7.51 k′ in beam, 8.84×0.15/3.25 = 0.41 k′/′ in slab

$M_{CInt}^- = 0.77\ M_{Int}^- = 12.38$ k′; i.e., 12.38×0.85 = 10.52 k′ in beam, 12.38×0.15/3.25 = 0.57 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 6.88–5.77 = 1.10$ k′; i.e., 1.10/3.25 = 0.34 k′/′ in slab

$M_M^+ = 11.46–8.84 = 2.62$ k′; i.e., 2.62/3.25 = 0.81 k′/′ in slab

$M_{MInt}^- = 16.04–12.38 = 3.67$ k′; i.e., 3.67/3.25 = 1.13 k′/′ in slab

Panel 2

Width = 6.5′; In case of Slab (S_2), the design for Panel 2 is similar to the design for Panel 1

For Slab (S_1) and Slab (S_3), Moment of Inertia of edge slab, $I_s \cong 6.5\times12\times6^3/12 = 1404$ in^4

For these two slabs, no beam along panel length; $\therefore \alpha_1 = 0$

Transverse edge beam $\Rightarrow \beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1404) = 1.89 < 2.5$

Column strip = 3.25′, Middle strip = 6.5 –3.25 = 3.25′

Slab (S_1)

Slab size (= 16′×13′ c/c) = 15′×12′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times6.5\times15^2/8 = 28.34$ k′

Support (d) $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 8.50$ k′, $M^+ = 0.50\ M_0 = 14.17$ k′, $M_{Int}^- = 0.70\ M_0 = 19.84$ k′

$L_2/L_1 = 13/16 = 0.81$, $\alpha_1L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.81\ M_{Ext}^- = 6.89$ k′; i.e., 6.89/3.25 = 2.12 k′/′ in slab

$M_C^+ = 0.60\ M^+ = 8.50$ k′; i.e., 8.50/3.25 = 2.62 k′/′ in slab

$M_{CInt}^- = 0.75\ M_{Int}^- = 14.88$ k′; i.e., 14.88/3.25 = 4.58 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 8.50–6.89 = 1.61$ k′; i.e., 1.61/3.25 = 0.49 k′/′ in slab

$M_M^+ = 14.17–8.50 = 5.67$ k′; i.e., 5.67/3.25 = 1.74 k′/′ in slab

M_{MInt}^{-} = 19.84–14.88 = 4.96 k′; i.e., 4.96/3.25 = 1.53 k′/′ in slab

Slab (S_2)

Similar to Slab (S_2) of Panel 1.

Slab (S_3)

Slab size (= 14′×13′ c/c) = 13′×12′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times6.5\times13^2/8 = 21.28$ k′

Support (d) $\Rightarrow M_{Ext}^{-} = 0.30\ M_0 = 6.39$ k′, $M^{+} = 0.50\ M_0 = 10.64$ k′, $M_{Int}^{-} = 0.70\ M_0 = 14.90$ k′

$L_2/L_1 = 13/14 = 0.93$, $\alpha_1 L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^{-} = 0.81\ M_{Ext}^{-} = 5.18$ k′; i.e., 5.18/3.25 = 1.59 k′/′ in slab

$M_C^{+} = 0.60\ M^{+} = 6.39$ k′; i.e., 6.39/3.25 = 1.97 k′/′ in slab

$M_{CInt}^{-} = 0.75\ M_{Int}^{-} = 11.17$ k′; i.e., 11.17/3.25 = 3.44 k′/′ in slab

$\therefore$ Total middle strip moments are

M_{MExt}^{-} = 6.39–5.18 = 1.21 k′; i.e., 1.21/3.25 = 0.37 k′/′ in slab

M_M^{+} = 10.64–6.39 = 4.26 k′; i.e., 4.26/3.25 = 1.31 k′/′ in slab

M_{MInt}^{-} = 14.90–11.17 = 3.72 k′; i.e., 3.72/3.25 = 1.15 k′/′ in slab

Panel 3

Width = 7′; Moment of Inertia of edge slab, $I_s \cong 7\times12\times6^3/12 = 1512$ in^4

No beam along panel length; $\therefore \alpha_1 = 0$

$\beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1512) = 1.76 < 2.5$

Column strip = 3.5′, Middle strip = 7 –3.5 = 3.5′

Slab (S_4)

Slab size (= 16′×14′ c/c) = 15′×13′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times15^2/8 = 28.34$ k′

Simple Support $\Rightarrow M_{Ext}^{-} = 0.30\ M_0 = 9.15$ k′, $M^{+} = 0.70\ M_0 = 21.36$ k′, $M_{Int}^{-} = 0.30\ M_0 = 9.15$ k′

$L_2/L_1 = 14/16 = 0.88$, $\alpha_1 L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^{-} = 0.82\ M_{Ext}^{-} = 7.55$ k′; i.e., 7.55/3.5 = 2.16 k′/′ in slab

$M_C^{+} = 0.60\ M^{+} = 12.82$ k′; i.e., 12.82/3.5 = 3.66 k′/′ in slab

$M_{CExt}^{-} = 0.82\ M_{Ext}^{-} = 7.55$ k′; i.e., 7.55/3.5 = 2.16 k′/′ in slab

$\therefore$ Total middle strip moments are

M_{MExt}^{-} = 9.15–7.55 = 1.61 k′; i.e., 1.61/3.5 = 0.46 k′/′ in slab

$M_M^+ = 21.36–12.82 = 8.54$ k′; i.e., 8.54/3.5 = 2.44 k′/′ in slab

$M_{MExt}^- = 9.15–7.55 = 1.61$ k′; i.e., 1.619/3.5 = 0.46 k′/′ in slab

Slab (S_5)

Slab size (= 14′×14′ c/c) = 13′×13′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times13^2/8 = 22.92$ k′

Simple Support $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 6.88$ k′, $M^+ = 0.70\ M_0 = 16.04$ k′, $M_{Int}^- = 0.30\ M_0 = 6.88$ k′

$L_2/L_1 = 14/14 = 1.00$, $\alpha_1L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.82\ M_{Ext}^- = 5.67$ k′; i.e., 5.67/3.5 = 1.62 k′/′ in slab

$M_C^+ = 0.60\ M^+ = 9.63$ k′; i.e., 9.63/3.5 = 2.75 k′/′ in slab

$M_{CExt}^- = 0.82\ M_{Ext}^- = 5.67$ k′; i.e., 5.67/3.5 = 1.62 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 6.88–5.67 = 1.21$ k′; i.e., 1.21/3.5 = 0.34 k′/′ in slab

$M_M^+ = 16.04–9.63 = 6.42$ k′; i.e., 6.42/3.5 = 1.83 k′/′ in slab

$M_{MExt}^- = 6.88–5.67 = 1.21$ k′; i.e., 1.21/3.5 = 0.34 k′/′ in slab

Panel 4

Similar to Panel 3.

Panel 5

Similar to Panel 2.

Panel 6

Similar to Panel 1.

Panels in the Short Direction

Panel 7

Width = 8.5′; Moment of Inertia of edge slab, $I_s \cong 8.5\times12\times6^3/12 = 1836$ in^4

For the edge beam along panel length; $\therefore \alpha_1 = E_{cb}I_b/E_{cs}I_s = 5419/1836 = 2.95$, for all the slabs

For Slab (S_1) and (S_6), $\beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1836) = 1.45 < 2.5$, while $\beta_t = 0$ for Slab (S_4).

Slab (S_1)

Slab size (= 13′×16′ c/c) = 12′×15′

Column strip = Short span (c/c)/4 = 13/4 = 3.25′, Middle strip = 8 –3.25 = 4.75′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times8.5\times12^2/8 = 23.72$ k′

Support (d) $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 7.11$ k′, $M^+ = 0.50\ M_0 = 11.86$ k′, $M_{Int}^- = 0.70\ M_0 = 16.60$ k′

$L_2/L_1 = 16/13 = 1.23$, $\alpha_1L_2/L_1 = 3.63 > 1.0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.82\ M_{Ext}^- = 5.80$ k′; i.e., 5.80×0.85 = 4.93 k′ in beam, 5.80×0.15/3.25 = 0.27 k′/′ in slab

$M_C^+ = 0.68\ M^+ = 8.07$ k′; i.e., 8.07×0.85 = 6.86 k′ in beam, 8.07×0.15/3.25 = 0.37 k′/′ in slab

$M_{CInt}^- = 0.68\ M_{Int}^- = 11.30$ k′; i.e., 11.30×0.85 = 9.61 k′ in beam, 11.30×0.15/3.25 = 0.52 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 7.11–5.80 = 1.31$ k′; i.e., 1.31/4.75 = 0.28 k′/′ in slab

$M_M^+ = 11.86–8.07 = 3.79$ k′; i.e., 3.79/4.75 = 0.80 k′/′ in slab

$M_{MInt}^- = 16.60–11.30 = 5.30$ k′; i.e., 5.30/4.75 = 1.12 k′/′ in slab

Slab (S_4)

Slab size (= 14′×16′ c/c) = 13′×15′

Column strip = Short span (c/c)/4 = 14/4 = 3.5′, Middle strip = 8 –3.5 = 4.5′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times8.5\times13^2/8 = 27.83$ k′

Interior Support $\Rightarrow M_{Int}^- = 0.65\ M_0 = 18.09$ k′, $M^+ = 0.35\ M_0 = 9.74$ k′, $M_{Int}^- = 0.65\ M_0 = 18.09$ k′

$L_2/L_1 = 16/14 = 1.14$, $\alpha_1L_2/L_1 = 3.37 > 1.0$

$\therefore$ Total column strip moments are

$M_{CInt}^- = 0.71\ M_{Int}^- = 12.79$ k′; i.e., 12.79×0.85 = 10.87 k′ in beam, 12.79×0.15/3.5 = 0.55 k′/′ in slab

$M_C^+ = 0.71\ M^+ = 6.89$ k′; i.e., 6.89×0.85 = 5.86 k′ in beam, 6.89×0.15/3.5 = 0.30 k′/′ in slab

$M_{CInt}^- = 0.71\ M_{Int}^- = 12.79$ k′; i.e., 12.79×0.85 = 10.87 k′ in beam, 12.79×0.15/3.5 = 0.55 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MInt}^- = 18.09–12.79 = 5.30$ k′; i.e., 5.30/4.5 = 1.18 k′/′ in slab

$M_M^+ = 9.74–6.89 = 2.85$ k′; i.e., 2.85/4.5 = 0.63 k′/′ in slab

$M_{MInt}^- = 18.09–12.79 = 5.30$ k′; i.e., 5.30/4.5 = 1.18 k′/′ in slab

Slab (S_6)

Similar to Slab (S_1).

Panel 8

Width = 8′; In case of Slab (S_4), the design for Panel 8 is similar to the design for Panel 7

For Slab (S_1) and Slab (S_6), Moment of Inertia of edge slab, $I_s \cong 8\times12\times6^3/12 = 1728$ in^4

No beam along panel length; $\therefore \alpha_1 = 0$

$\beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1728) = 1.54 < 2.5$

Slab (S_1)

Slab size (= 13′×16′ c/c) = 15′×12′

Column strip = 3.25′, Middle strip = 8 –3.25 = 4.75′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times8\times12^2/8 = 22.32$ k′

Support (d) $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 6.70$ k′, $M^+ = 0.50\ M_0 = 11.16$ k′, $M_{Int}^- = 0.70\ M_0 = 15.62$ k′

$L_2/L_1 = 16/13 = 1.23$, $\alpha_1L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.85\ M_{Ext}^- = 5.67$ k′; i.e., 5.67/3.25 = 1.74 k′/′ in slab

$M_C^+ = 0.60\ M^+ = 6.70$ k′; i.e., 6.70/3.25 = 2.06 k′/′ in slab

$M_{CInt}^- = 0.75\ M_{Int}^- = 11.72$ k′; i.e., 11.72/3.25 = 3.61 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 6.70–5.67 = 1.03$ k′; i.e., 1.03/4.75 = 0.22 k′/′ in slab

$M_M^+ = 11.16–6.70 = 4.46$ k′; i.e., 4.46/4.75 = 0.94 k′/′ in slab

$M_{MInt}^- = 15.62–11.72 = 3.91$ k′; i.e., 3.91/4.75 = 0.82 k′/′ in slab

Slab (S_4)

Similar to Slab (S_4) of Panel 7.

Slab (S_6)

Similar to Slab (S_1).

Panel 9

Width = 7′; Moment of Inertia of edge slab, $I_s \cong 7\times12\times6^3/12 = 1512$ in^4

No beam along panel length; $\therefore \alpha_1 = 0$

$\beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1512) = 1.76 < 2.5$

Slab (S_2)

Slab size (= 13′×14′ c/c) = 12′×13′

Column strip = 3.25′, Middle strip = 7–3.25 = 3.75′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times12^2/8 = 19.53$ k′

Simple Support $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 5.86$ k′, $M^+ = 0.70\ M_0 = 13.67$ k′, $M_{Ext}^- = 0.30\ M_0 = 5.86$ k′

$L_2/L_1 = 14/13 = 1.08$, $\alpha_1L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.82\ M_{Ext}^- = 4.83$ k′; i.e., 4.83/3.25 = 1.49 k′/′ in slab

$M_C^+ = 0.60\ M^+ = 8.20$ k′; i.e., 8.20/3.25 = 2.52 k′/′ in slab

$M_{CExt}^- = 0.82\ M_{Ext}^- = 4.83$ k′; i.e., 4.83/3.25 = 1.49 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^- = 5.86–4.83 = 1.03$ k′; i.e., 1.03/3.75 = 0.27 k′/′ in slab

$M_M^+ = 13.67–8.20 = 5.47$ k′; i.e., 5.47/3.75 = 1.46 k′/′ in slab

$M_{MExt}^- = 5.86–4.83 = 1.03$ k′; i.e., 1.03/3.75 = 0.27 k′/′ in slab

Slab (S_7)

Similar to Slab (S_2).

Panel 10

Similar to Panel 9.

Panel 11

Width = 7′; Moment of Inertia of edge slab, $I_s \cong 7\times12\times6^3/12 = 1512$ in^4

For Slab (S_3) and (S_8), no beam along panel length; $\therefore \alpha_1 = 0$

$\beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1512) = 1.76 < 2.5$ for Slab (S_3) and (S_8)

Slab (S_3)

Slab size (= 13′×14′ c/c) = 12′×13′

Column strip = 3.25′, Middle strip = 7 –3.25 = 3.75′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7\times12^2/8 = 19.53$ k′

Support (d) $\Rightarrow M_{Ext}^- = 0.30\ M_0 = 5.86$ k′, $M^+ = 0.50\ M_0 = 9.77$ k′, $M_{Int}^- = 0.70\ M_0 = 13.67$ k′

$L_2/L_1 = 14/13 = 1.08$, $\alpha_1L_2/L_1 = 0$

$\therefore$ Total column strip moments are

$M_{CExt}^- = 0.82\ M_{Ext}^- = 4.83$ k′; i.e., 4.83/3.25 = 1.49 k′/′ in slab

$M_C^+ = 0.60\ M^+ = 5.86$ k′; i.e., 5.86/3.25 = 1.80 k′/′ in slab

$M_{CInt}^- = 0.75\ M_{Int}^- = 10.25$ k′; i.e., 10.25/3.25 = 3.15 k′/′ in slab

$\therefore$ Total middle strip moments are

M_{MExt}^{-} = 5.86–4.83 = 1.03 k′; i.e., 1.03/3.75 = 0.27 k′/′ in slab

M_M^{+} = 9.77–5.86 = 3.91 k′; i.e., 3.91/3.75 = 1.04 k′/′ in slab

M_{MInt}^{-} = 13.67–10.25 = 3.42 k′; i.e., 3.42/3.75 = 0.91 k′/′ in slab

Slab (S_5)

Moment of Inertia of edge slab, $I_s \cong 7.5\times12\times6^3/12 = 1620$ in^4

$\therefore \alpha_1 = 5419/1620 = 3.34$

No edge beam ⇒ $\beta_t = 0$

Slab size (= 14′×14′ c/c) = 13′×13′

Column strip = 14/4 = 3.5′, Middle strip = 7 –3.5 = 4.5′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7.5\times13^2/8 = 24.56$ k′

Interior Support ⇒ $M_{Int}^{-} = 0.65\ M_0$ = 15.96 k′, $M^{+} = 0.35\ M_0$ = 8.60 k′, $M_{Int}^{-} = 0.65\ M_0$ = 15.96 k′

$L_2/L_1 = 14/14 = 1.00$, $\alpha_1L_2/L_1 = 3.34 > 1.0$

∴ Total column strip moments are

$M_{CInt}^{-} = 0.75\ M_{Int}^{-}$ = 11.97 k′; i.e., 11.97×0.85 = 10.18 k′ in beam, 11.97×0.15/3.5 = 0.51 k′/′ in slab

$M_C^{+} = 0.75\ M^{+}$ = 6.45 k′; i.e., 6.45×0.85 = 5.45 k′ in beam, 6.45×0.15/3.5 = 0.28 k′/′ in slab

$M_{CInt}^{-} = 0.75\ M_{Int}^{-}$ = 11.97 k′; i.e., 11.97×0.85 = 10.18 k′ in beam, 11.97×0.15/3.5 = 0.51 k′/′ in slab

∴ Total middle strip moments are

M_{MInt}^{-} = 15.96–11.97 = 3.99 k′; i.e., 3.99/3.5 = 1.14 k′/′ in slab

M_M^{+} = 8.60–6.45 = 2.15 k′; i.e., 2.15/3.5 = 0.61 k′/′ in slab

M_{MInt}^{-} = 15.96–11.97 = 3.99 k′; i.e., 3.99/3.5 = 1.14 k′/′ in slab

Slab (S_8)

Similar to Slab (S_3).

Panel 12

Width = 7.5′; Moment of Inertia of edge slab, $I_s \cong 7.5\times12\times6^3/12 = 1620$ in^4

For the edge beam along panel length; $\therefore \alpha_1 = E_{cb}I_b/E_{cs}I_s = 5419/1620 = 3.34$, for all the slabs

For Slab (S_3) and (S_8), $\beta_t = E_{cb}C/2E_{cs}I_s = 5309/(2\times1620) = 1.64 < 2.5$, while $\beta_t = 0$ for Slab (S_5).

Slab (S_3)

Slab size (= 13′×14′ c/c) = 12′×13′

Column strip = 13/4 = 3.25′, Middle strip = 7 –3.25 = 3.75′

$\therefore M_0 = wL_2L_n^2/8 = 0.155\times7.5\times12^2/8 = 20.93$ k′

Support (d) ⇒ $M_{Ext}^{-} = 0.30\ M_0$ = 6.28 k′, $M^{+} = 0.50\ M_0$ = 10.46 k′, $M_{Int}^{-} = 0.70\ M_0$ = 14.65 k′

$L_2/L_1 = 14/13 = 1.08$, $\alpha_1L_2/L_1 = 3.60 > 1.0$

$\therefore$ Total column strip moments are

$M_{CExt}^{-} = 0.82\ M_{Ext}^{-} = 5.15$ k′; i.e., 5.15×0.85 = 4.38 k′ in beam, 5.15×0.15/3.25 = 0.24 k′/′ in slab

$M_C^{+} = 0.73\ M^{+} = 7.61$ k′; i.e., 7.61×0.85 = 6.46 k′ in beam, 7.61×0.15/3.25 = 0.35 k′/′ in slab

$M_{CInt}^{-} = 0.73\ M_{Int}^{-} = 10.65$ k′; i.e., 10.65×0.85 = 9.05 k′ in beam, 10.65×0.15/3.25 = 0.49 k′/′ in slab

$\therefore$ Total middle strip moments are

$M_{MExt}^{-} = 6.28 – 5.15 = 1.12$ k′; i.e., 1.12/3.75 = 0.30 k′/′ in slab

$M_M^{+} = 10.46 – 7.61 = 2.86$ k′; i.e., 2.86/3.75 = 0.76 k′/′ in slab

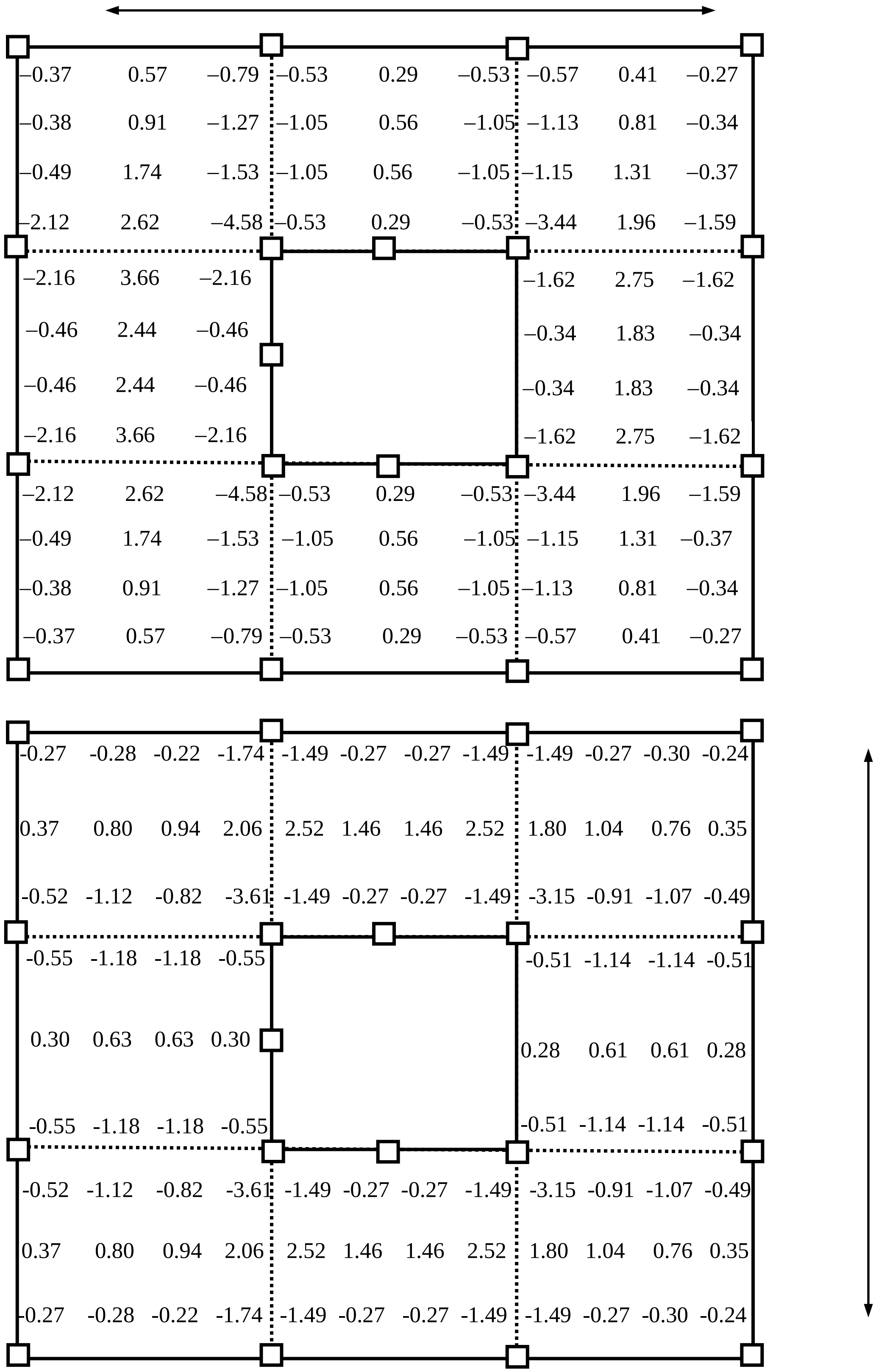
$M_{MInt}^{-} = 14.65 – 10.65 = 4.00$ k′; i.e., 4.00/3.75 = 1.07 k′/′ in slab

Slab (S_5)

Similar to Slab (S_5) of Panel 11.

Slab (S_8)

Similar to Slab (S_3).



<u>Design Moments (k′/′) in the Long and Short Direction</u>

Design of Slabs in Long and Short Direction

Flexural Design

The maximum bending moment $M_{(max)}$ is 4.58 k′/′ in Slab (S_1) of Panel 2

$M_{(max)}$ = 4.58 k′/′< $M_{c(max)}$ (= 5.57 k′/′); ∴ OK

∴ If not, increase the slab thickness at least at relevant locations.

$A_s = M/f_s jd = M/7.28$ (or M/6.56 for M_{min}^{+})

Also, the bar spacing needs to be ≤ 2 times the slab thickness.

Punching Shear

The most critical column for punching shear is C_6.

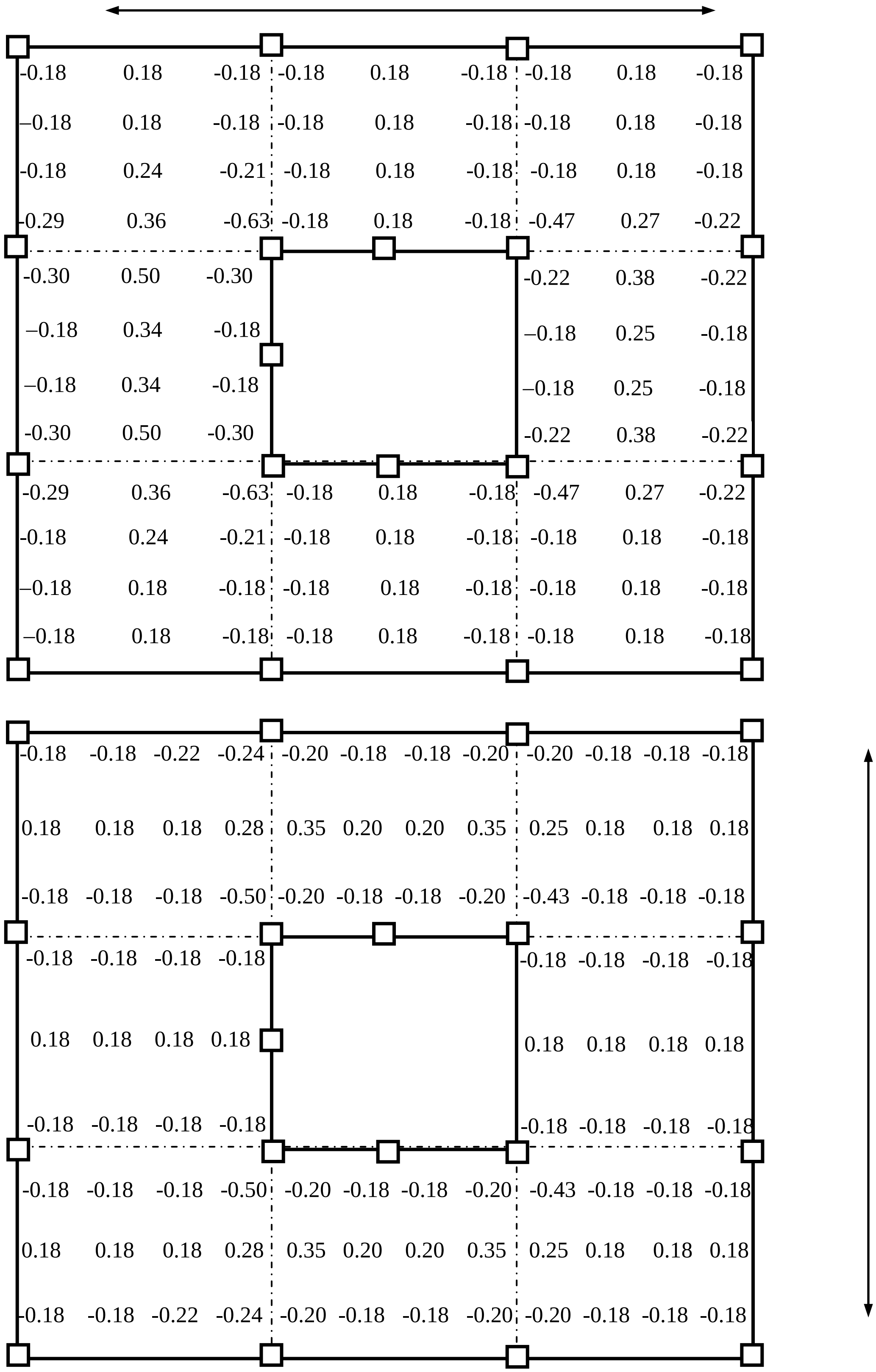
d = 5″ ⇒ Punching perimeter for (12″×12″) column = 3×(12″+5″) = 51″ (considering one hollow side)

∴ Punching area = 51″×5″ = 255 in^2

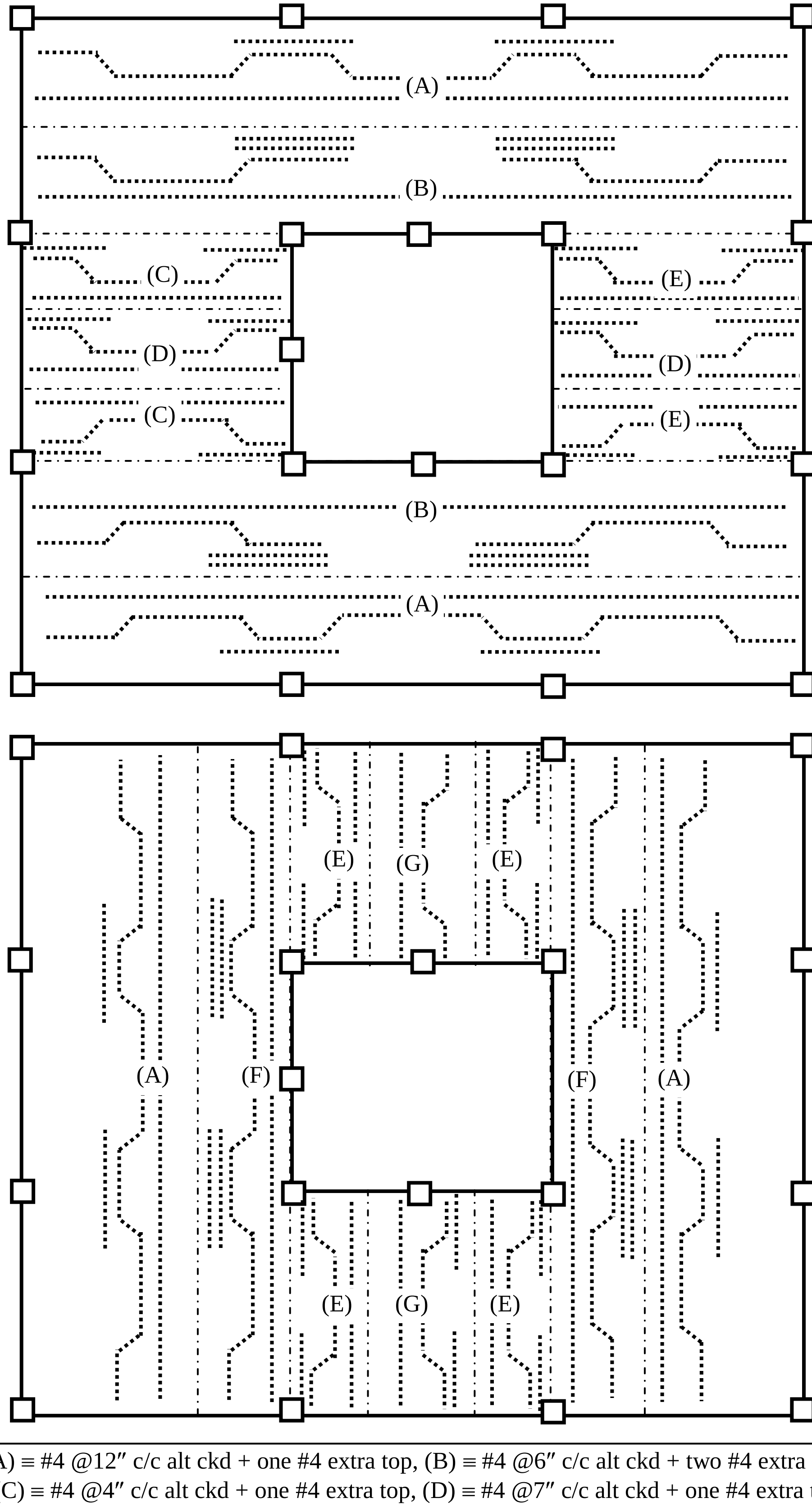
Punching Shear force = 0.155× {(8+7)×(6.5+7)–7×7} = 23.79 kips

∴ Punching shear stress = 23.79/255 = 0.093 ksi < 0.110 ksi, OK

If not, increase the slab thickness or add drop panel or/and column capital.



Design Reinforcements ($in^2/'$) in the Long and Short Direction



(A) ≡ #4 @12″ c/c alt ckd + one #4 extra top, (B) ≡ #4 @6″ c/c alt ckd + two #4 extra tops, (C) ≡ #4 @4″ c/c alt ckd + one #4 extra top, (D) ≡ #4 @7″ c/c alt ckd + one #4 extra top, (E) ≡ #4 @6″ c/c alt ckd + one #4 extra top, (F) ≡ #4 @8″ c/c alt ckd + two #4 extra tops, (G) ≡ #4 @12″ c/c alt ckd + one #4 extra top