Two-Way Floor Systems:

Dr Jamal Zalatimo

Flat slab floor – there is a drop panel or a column capital

Flat plate floor – none, and shear strength is obtained by the embedment of multiple-U stirrups or structural steel devices (shearhead)

Two-way slabs on beams – beams are used along the column lines.

ACI- General Design Concept:

Vertical cuts are made through the entire building along lines midway between the columns, (Fig 16.2.1) longitudinal & transverse.

A typical rigid frame consists of: the columns above and below the floor, and the floor system. "Equivalent frame".

For gravity load only, moments and shears may be determined; (a) approximately (coefficients of the direct design method)

(b) structural analysis (equivalent frame method)

ACI- :

$$\frac{M_{neg}(left) + M_{neg}(right)}{2} + M_{pos} \geq \left[M_0 = \frac{W_u L_2 L_n^2}{8} \right]$$

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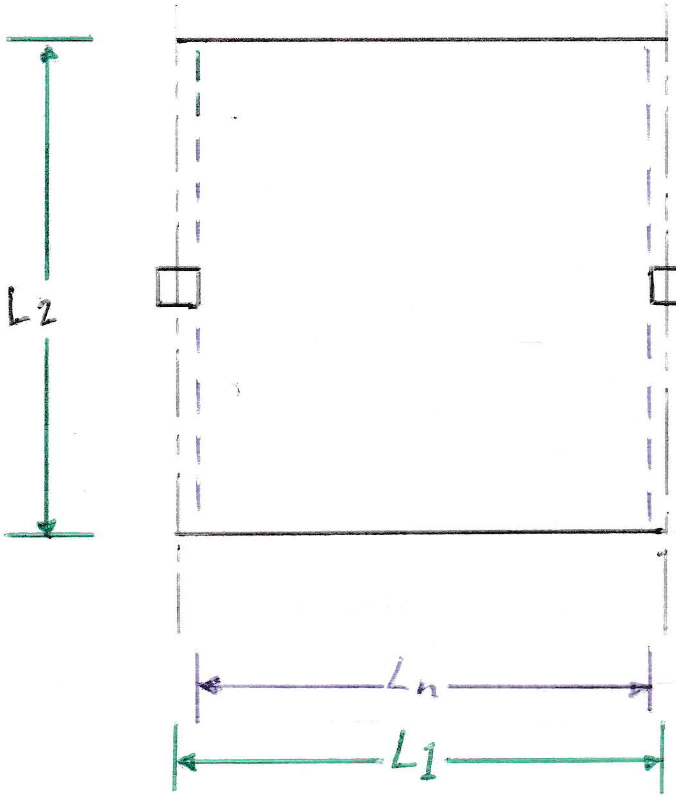
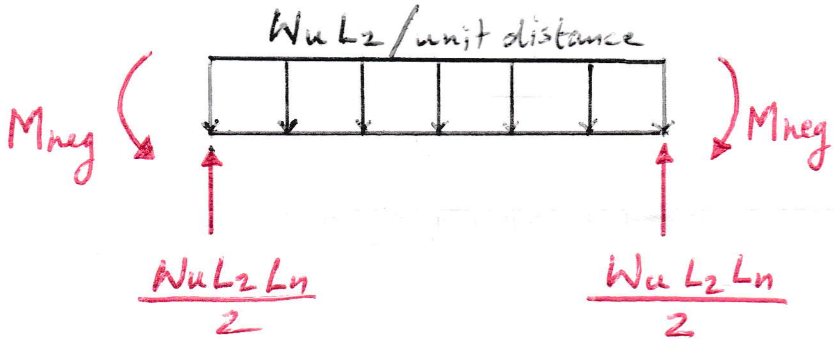
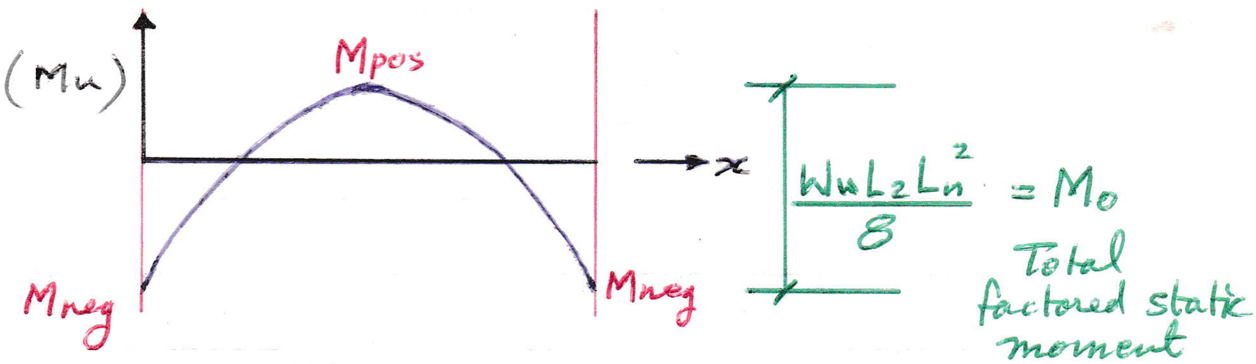
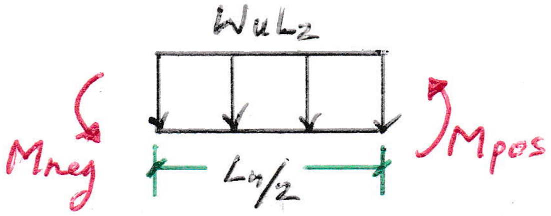


W_u = factored floor load per unit area

$L_n \geq 0.65 L_1$

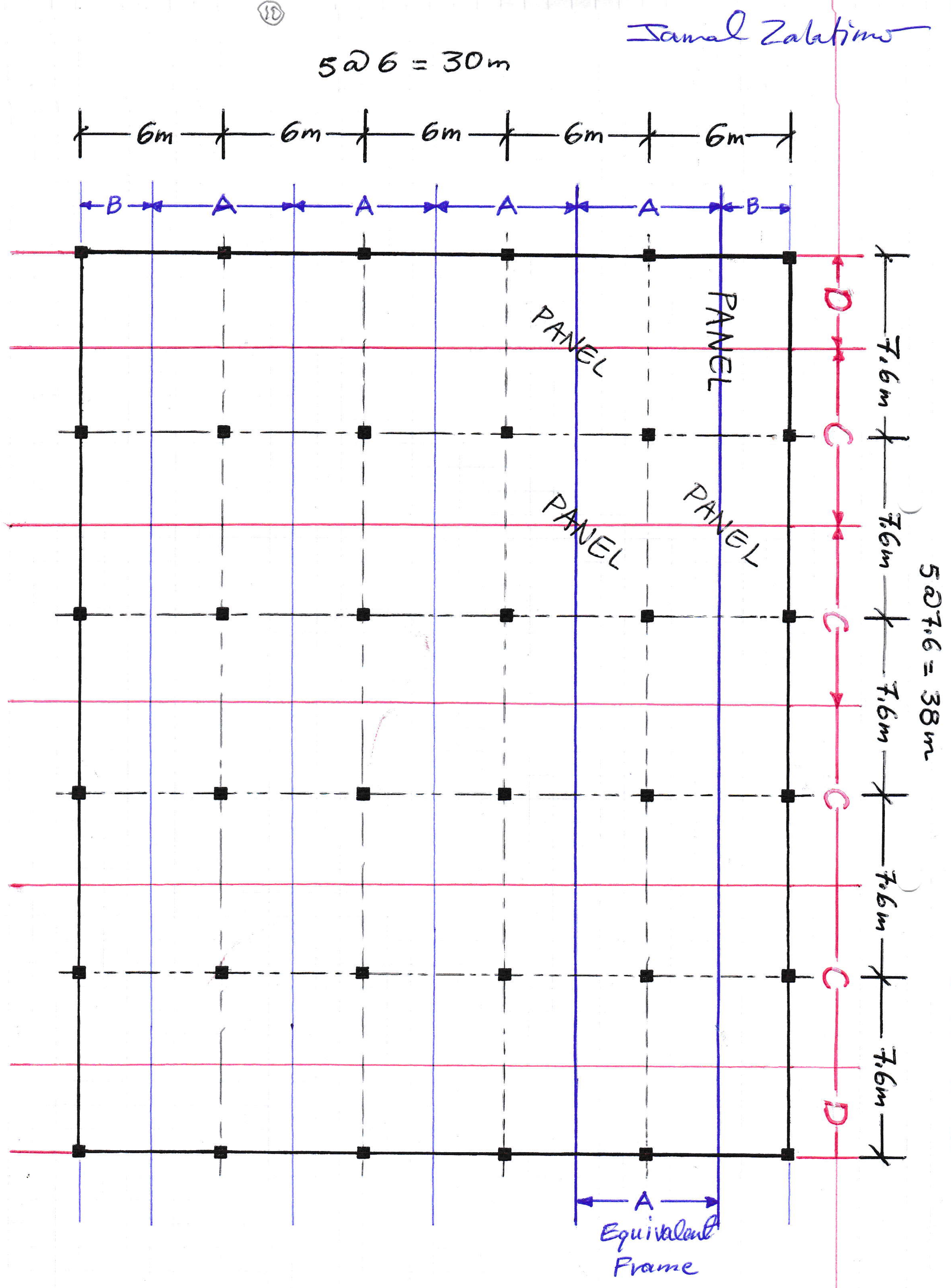






$$M_{neg} + M_{pos} = W_u L_2 \left(\frac{L_n}{2}\right)\left(\frac{L_n}{4}\right)$$

$$= \frac{W_u L_2 L_n^2}{8}$$



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5@6 = 30m
6m
6m
6m
6m
6m
B
A
A
A
A
B
PANEL
PANEL
PANEL
PANEL
D
C
C
C
C
D
7.6m
7.6m
7.6m
7.6m
7.6m
5@7.6 = 38m
A
Equivalent Frame

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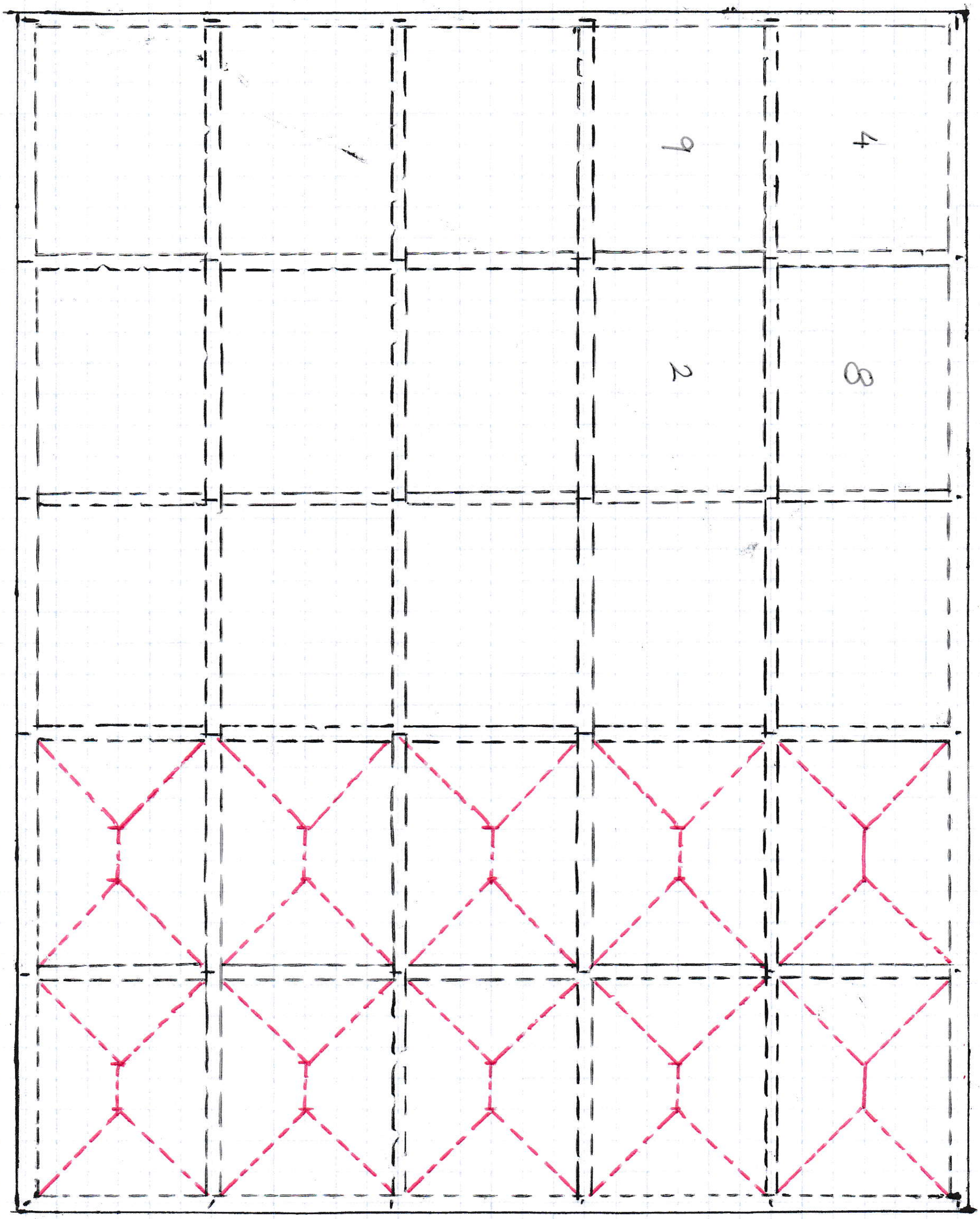
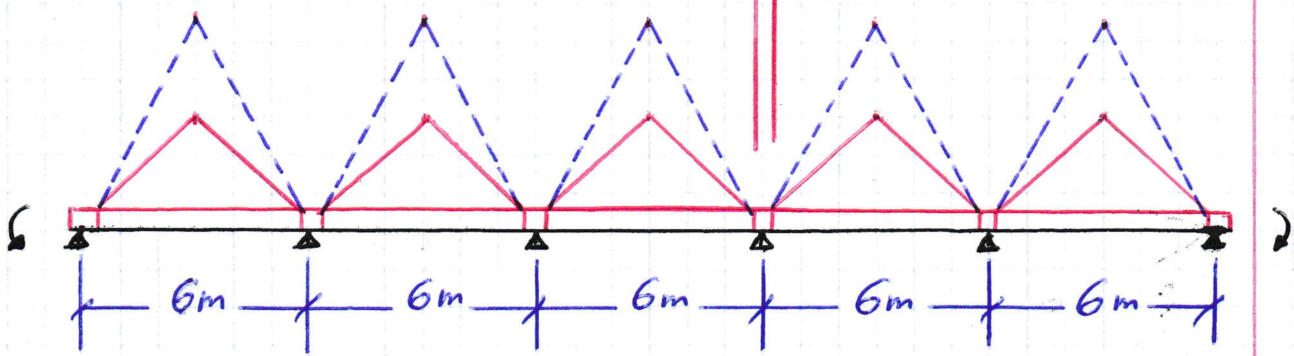
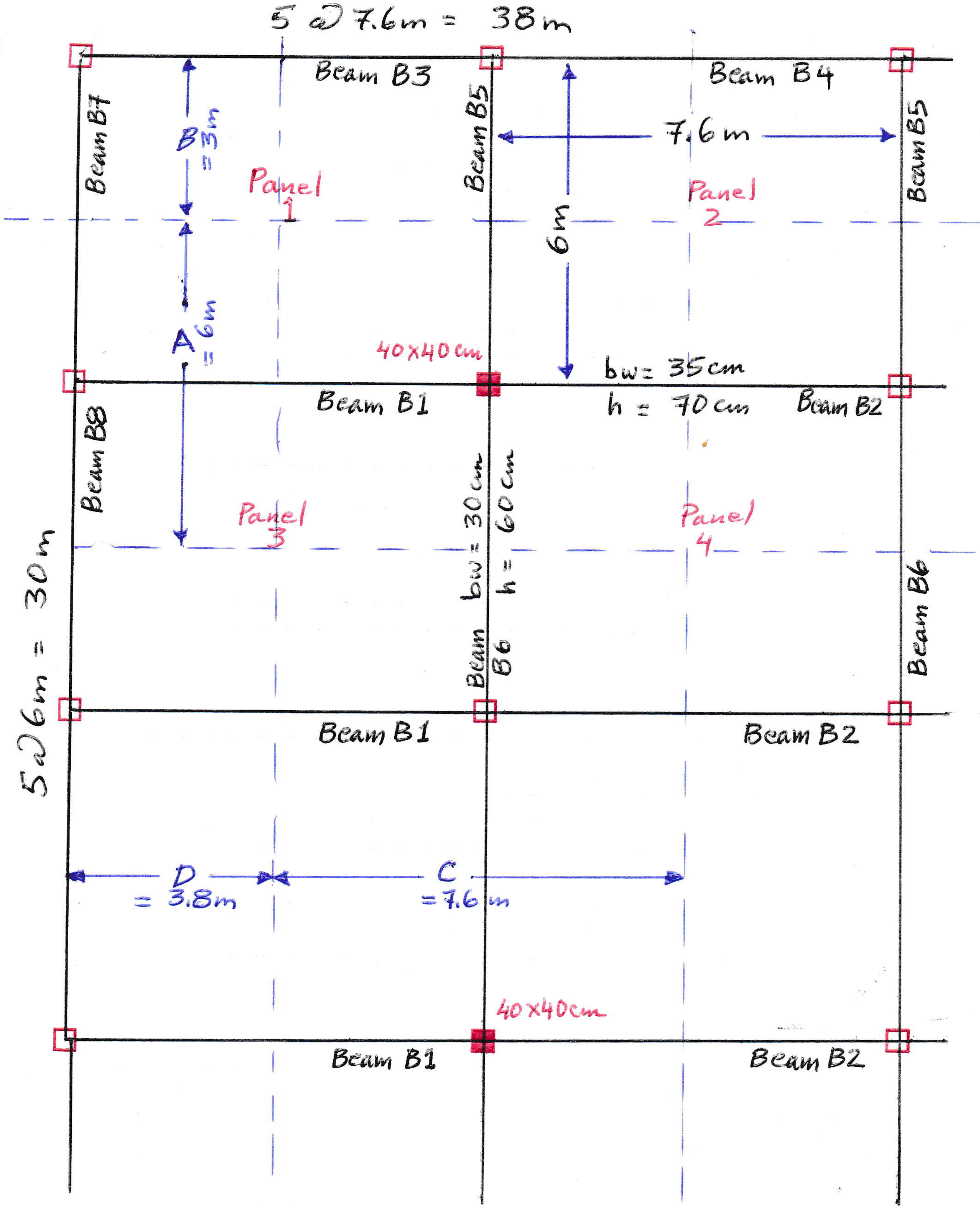




Two-Way Slab with Beams:

Dr Jamal Zalatimo



Slab = 17cm thick.

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Example:

Slab thickness = 17 cm

$f_c' = 20\,MPa$

$LL = 0.69\ t/m^2$

$f_y = 280\,MPa$

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

Storey height = 3.70 m

Determine Mo for each of the four equivalent rigid frames.

$$W_u = 1.2(0.408) + 1.6(0.69) = 1.59\ t/m^2$$

Note: L_n : Dr. Jamal Zadat...

ACI - (minimum thickness)
face to face of beams

ACI - (statical moment on the slab-frame segment)

L_n shall extend from face to face of columns, capitals, brackets or walls.

For frame A:

$$M_o = \frac{1}{8} w_u L_2 L_n^2$$

$$= \frac{1}{8}(1.591)(6\,m)(7.6 - 0.4)^2$$

$$= 61.86 \text{ t.m}$$

Frame B:

$$M_o = 30.93 \text{ t.m}$$

For frame C:

$$M_o = \frac{1}{8}(1.591)(7.6)(6 - 0.4)^2$$

$$= 47.40 \text{ t.m}$$

Frame D:

$$M_o = 23.70 \text{ t.m}$$

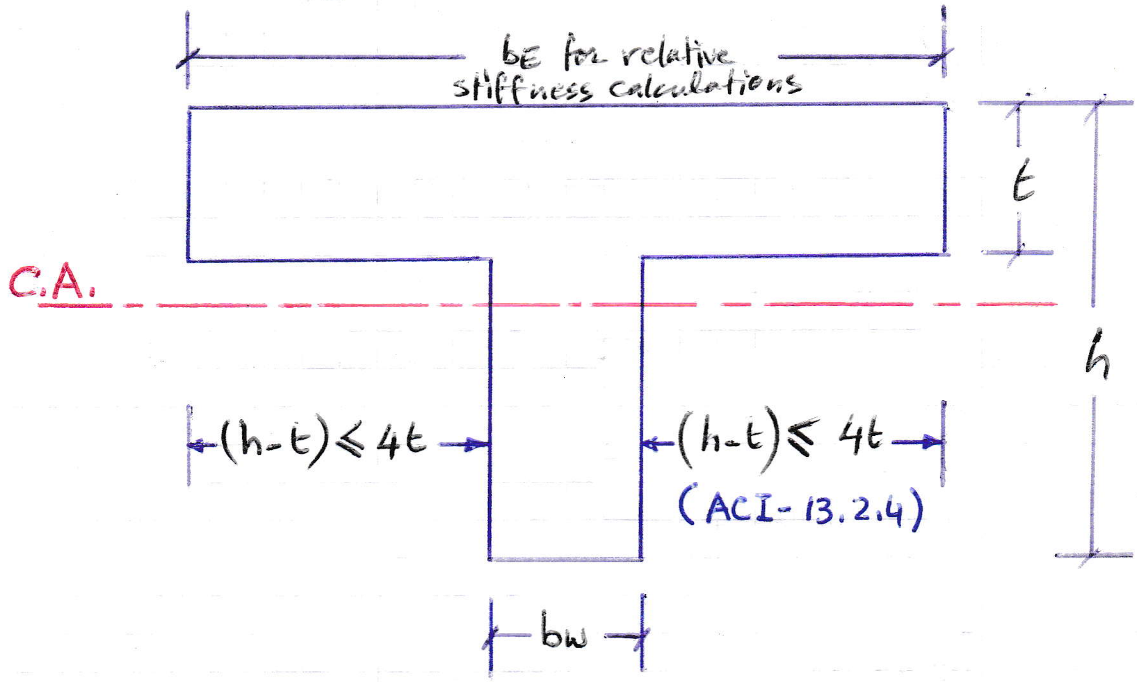
Ratio of Flexural Stiffnesses of Longitudinal Beam to Slab:

When beams are used along the column lines, design is affected by the relative size of the beam to the thickness of the slab.

$$\alpha = \frac{E_{cb} I_b}{E_{cs} I_s}$$

b = beam
s = slab

$$I_b = k \frac{b_w h^3}{12}$$ (about its own centroidal axis)



Note: $k \approx 1.0 + 0.2\left(\frac{b_E}{b_w}\right)$ for $2 < \frac{b_E}{b_w} < 4$ and $0.2 < \frac{t}{h} < 0.5$

More accurate values of k in terms of $\frac{b_E}{b_w}$ and $\frac{t}{h}$ may be obtained from Table 16.4.1 or Fig. 16.4.3, or equation 16.4.2 b.

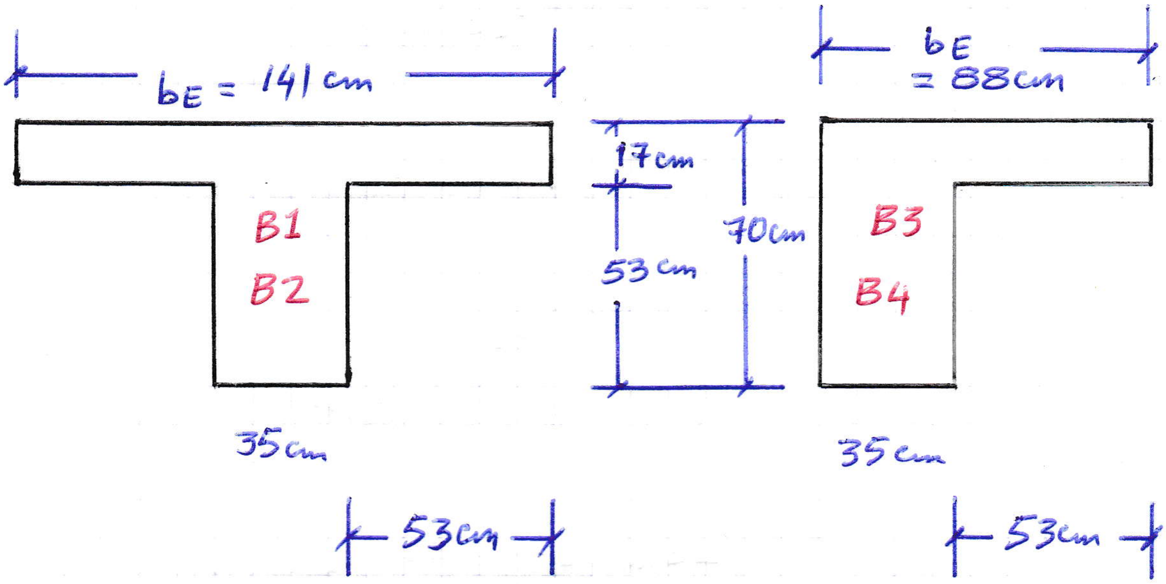
$$k = \frac{1 + \left[\frac{b_E}{b_w} - 1\right]\left[\frac{t}{h}\right]\left[4 - 6\left(\frac{t}{h}\right) + 4\left(\frac{t}{h}\right)^2 + \left(\frac{b_E}{b_w} - 1\right)\left(\frac{t}{h}\right)^3\right]}{1 + \left(\frac{b_E}{b_w} - 1\right)\left(\frac{t}{h}\right)}$$

Example 16.4.1:

Determine α for all beams around panels 1, 2, 3, and 4.

a) Interior long beams – B1, B2

Slab = 17 cm, b_w = 35 cm, $h_{overall}$ = 70 cm



$$h - t \leq 4t$$

$$70 - 17 \leq 4 \times 17$$

$$53\text{ cm} \leq 68\text{ cm}$$

Controls

Note that approximations in the determination of α are acceptable

$$\frac{b_E}{b_w} = \frac{141}{35} = 4.03 \quad , \quad \frac{t}{h} = \frac{17}{70} = 0.243$$

$$k = \frac{1 + (0.736)(2.822)}{1 + 0.736} = 1.772$$

$$I_b = 1.772\,\frac{(35)(70^3)}{12} = 1.773 \times 10^6\ \text{cm}^4$$

$$I_s = \frac{(600)(17^3)}{12} = 2.457 \times 10^5\ \text{cm}^4$$

$$\longrightarrow \alpha = 7.22$$

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b) Exterior long beams, B3, B4

$$\frac{b_E}{b_w} = \frac{88}{35} = 2.51 \quad , \quad \frac{t}{h} = 0.243$$

$$k = \frac{1 + (0.367)(2.800)}{1 + 0.367} = 1.483$$

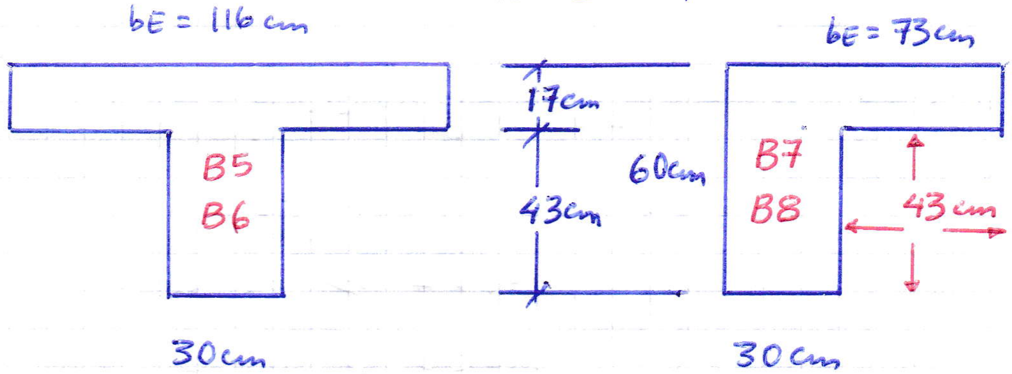
$$I_b = 1.483 \frac{(35)(70)^3}{12} = 1.484 \times 10^6 \text{ cm}^4$$

$$I_s = \frac{(300)(17^3)}{12} = 1.228 \times 10^5 \text{ cm}^4$$

$$\longrightarrow \alpha = \frac{I_b}{I_s} = 12.08$$

c) Interior short Beams, B5, B6

$b_w = 30$ cm, $h = 60$ cm



$$\frac{b_E}{b_w} = \frac{116}{30} = 3.87 \quad , \quad \frac{t}{h} = \frac{17}{60} = 0.283$$

$$k = \frac{1 + (0.812)(2.687)}{1 + 0.812} = 1.756$$

$$I_b = 1.756 \frac{(30)(60^3)}{12} = 9.482 \times 10^5 \text{ cm}^4$$

$$I_s = \frac{(760)(17)^3}{12} = 3.112 \times 10^5 \text{ cm}^4$$

$$\longrightarrow \alpha = 3.05$$

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d) Exterior short beams, B7, B8

$$\frac{b_E}{b_w} = \frac{73}{30} = 2.43 \quad , \quad \frac{t}{h} = 0.283$$

$$k = \frac{1 + (0.405)(2.655)}{1 + 0.405} = 1.477$$

$$I_b = 1.477 \frac{(30)(60^3)}{12} = 7.976 \times 10^5 \ cm^4$$

$$I_s = \frac{(380)(17)^3}{12} = 1.556 \times 10^5 \ cm^4$$

$\longrightarrow \alpha = 5.13$

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Two-Way Slab with Beams:

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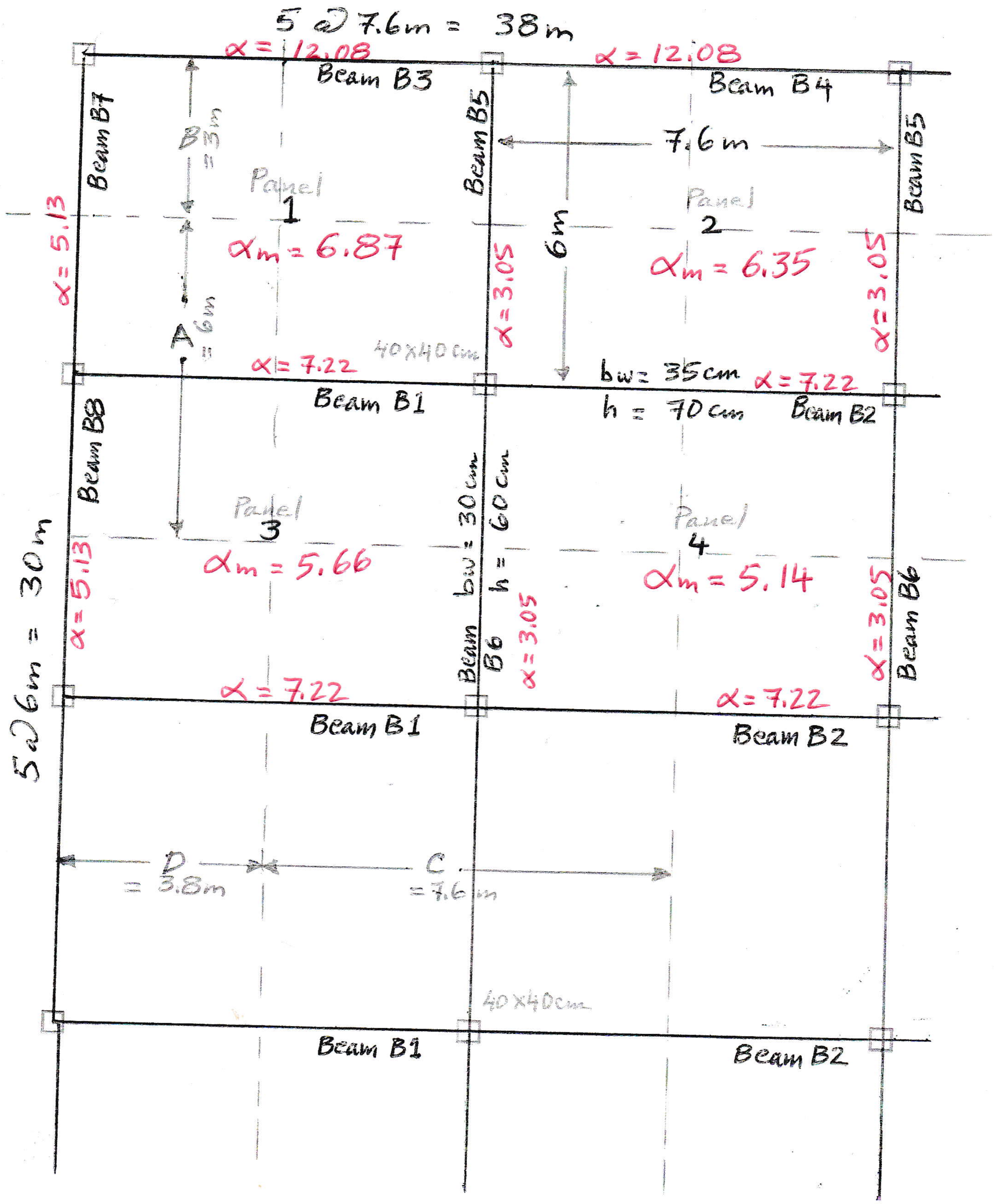

Slab = 17cm thick.

Note: all α_m values are well above 2.0.

Minimum Slab Thickness:

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For Slabs Without interior beams:

Table ______ of the ACI-code and:
Table 16.5.1 page 635

for slabs without drop panels, $h_{min} \geq 12$ cm

slabs with drop panels, $h_{min} \geq 10$ cm

Note: α in the Table is for the edge beams.

For slabs with interior beams:

$$0.2 < \alpha_m \leq 2.0 \;, \quad h_{min} = \frac{L_n\left(0.8 + \frac{f_y}{1400}\right)}{36 + 5\beta(\alpha_m - 0.2)} \geq 12 \text{ cm}$$

$$\alpha_m > 2.0 \;, \quad h_{min} = \frac{L_n\left(0.8 + \frac{f_y}{1400}\right)}{36 + 9\beta} \geq 9 \text{ cm}$$

α_m = average value of α for all beams on edges of a panel.

β = ratio of clear spans in long to short direction. L_n/S_n

The diameter of the column capital is usually about 25% of the average span length between columns. The effective column capital is that portion within a tapered wedge with a 90° vertex (Fig. 16.6.1).

A drop panel must extend from the centerline of supports $\geq l/6$,

the projection of the panel below the slab $\geq \frac{t}{4}$ (t = slab thickness outside of the drop)

Used in flat slabs and flat plates.

For determining reinforcement, the projection is taken: actual $\leq \frac{1}{4}$ distance between edge of drop panel and the edge of column or capital.

13a

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For slabs supported by interior beams, the edge beam must have $\alpha \geq 0.80$, otherwise: increase min thickness by 10% in the panel having the discontinuous edge.

Example 16.6.1:

For the two-way slab with beams, determine the minimum thickness requirement for deflection control.

Note that Ln for these calculations is taken face to face of supporting beams.

$\therefore$ $L_n = 7.6m - 0.30 = 7.3m$

$S_n = 6.0m - 0.35 = 5.65m$

$\beta = L_n / S_n = 7.3/5.65 = 1.292$

$$h_{min} = \frac{L_n(0.8 + f_y/1400)}{36 + 9\beta} \geq 9\ cm$$

note that the edge beams have $\alpha > 0.80$

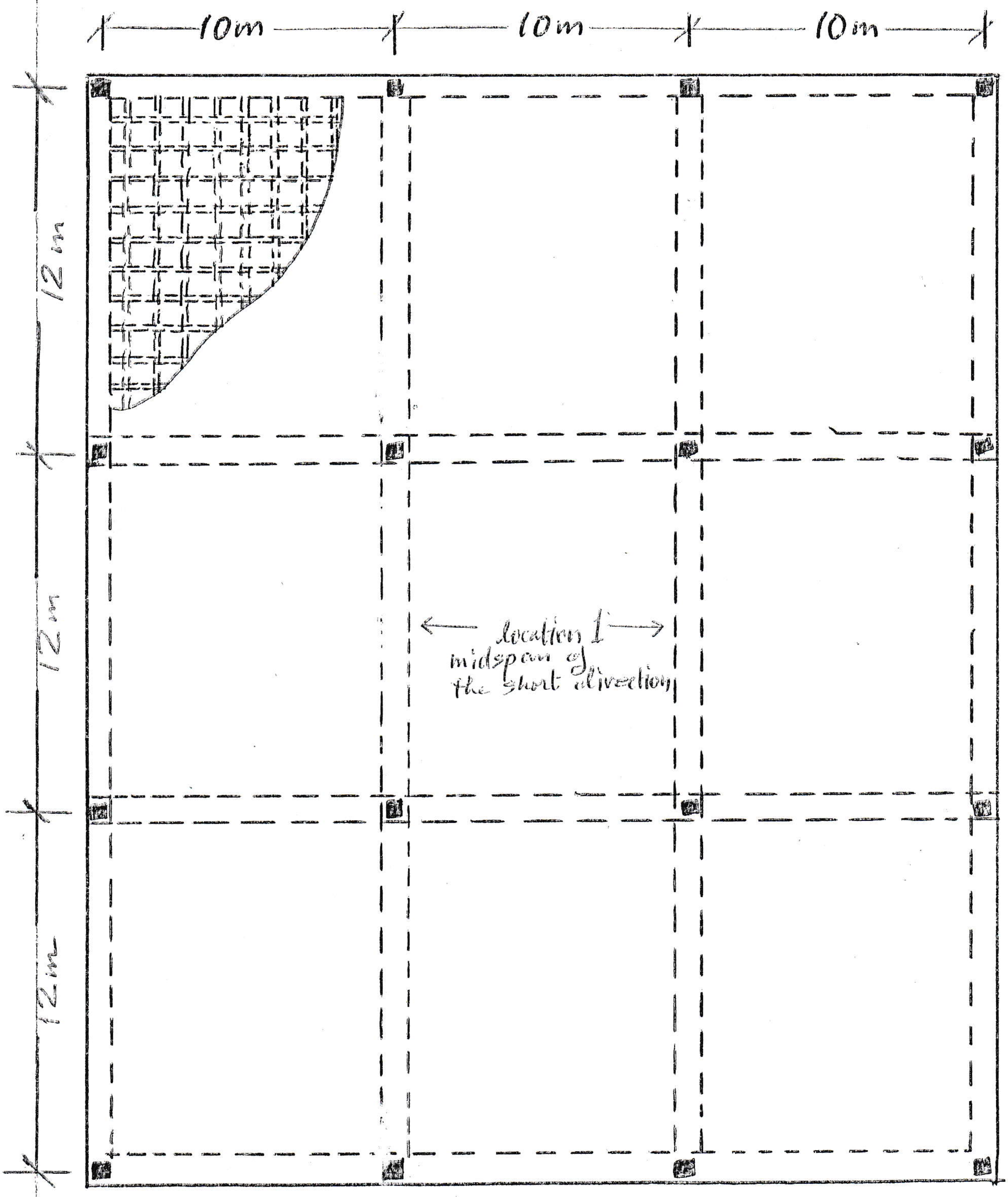
$$h_{min} = \frac{7.3(0.8 + 280/1400)}{36 + 9(1.292)} \geq 9cm$$

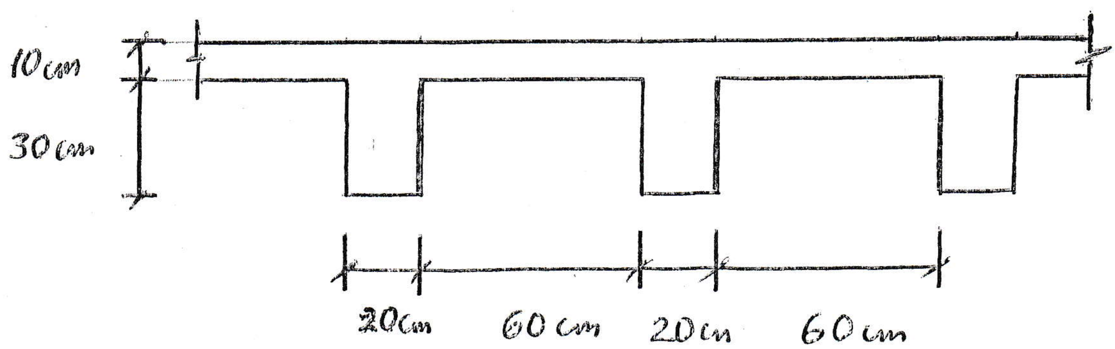
$= 0.153m = 15.3\ cm \geq 9\ cm$

$\therefore$ The slab thickness used (17cm) compares well with this result.

③

Dr. Jamal Zalatimo (4)





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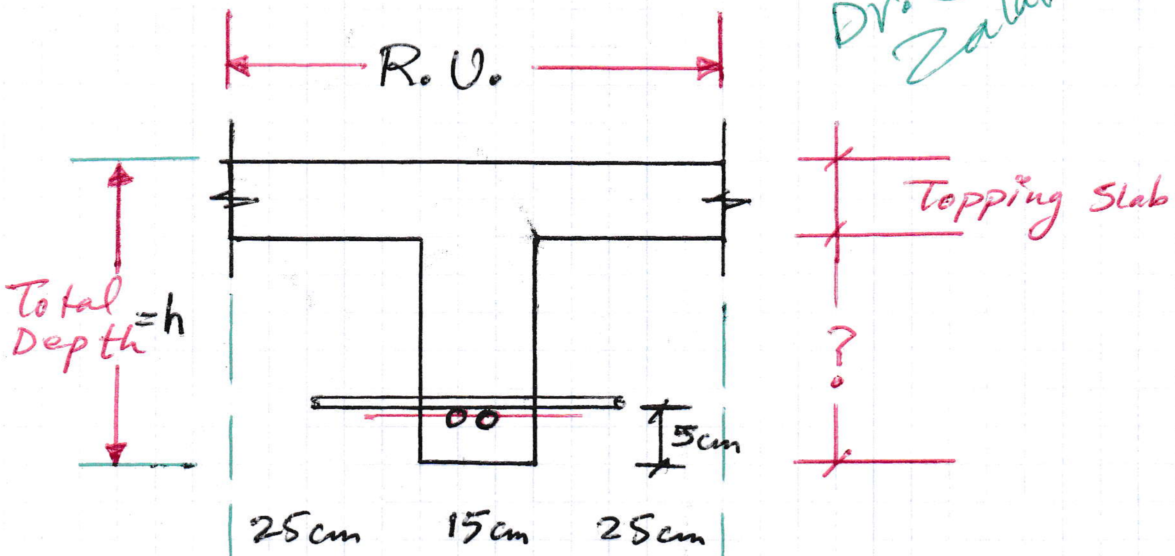
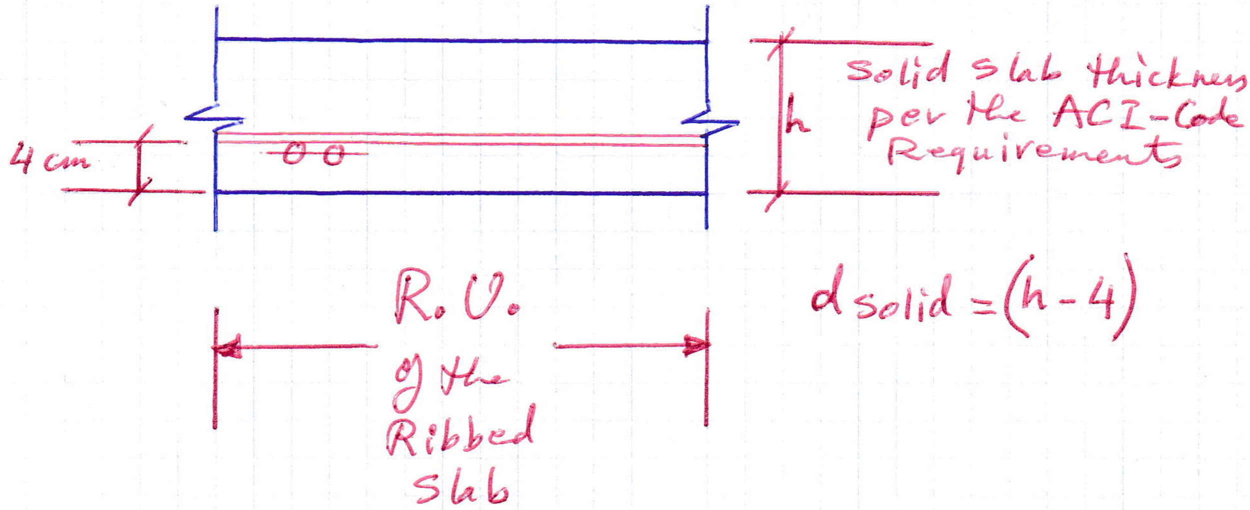


$d_{rib} = (h - 5)$



$I_{rib} \geq I_{solid}$

Iterations are required

Begin with a total depth for the ribbed slab $= \dfrac{\text{Depth for the solid slab}}{0.80}$

CODE

COMMENTARY

weight concrete. Deflections should be calculated for such situations.

8.3.1.1 For nonprestressed slabs without interior beams spanning between supports on all sides, having a maximum ratio of long-to-short span of 2, overall slab thickness h shall not be less than the limits in Table 8.3.1.1, and shall be at least the value in (a) or (b), unless the calculated deflection limits of 8.3.2 are satisfied:

(a) Slabs without drop panels as given in 8.2.4... 125 mm.
(b) Slabs with drop panels as given in 8.2.4........ 100 mm.

Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

[1]ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2]For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3]Drop panels as given in 8.2.4.

[4]Slabs with beams between columns along exterior edges. Exterior panels shall be considered to be without edge beams if α_f is less than 0.8. The value of α_f for the edge beam shall be calculated in accordance with 8.10.2.7.

R8.3.1.1 The minimum thicknesses in Table 8.3.1.1 are those that have been developed through the years.

8.3.1.2 For nonprestressed slabs with beams spanning between supports on all sides, overall slab thickness h shall satisfy the limits in Table 8.3.1.2, unless the calculated deflection limits of 8.3.2 are satisfied.

Table 8.3.1.2—Minimum thickness of nonprestressed two-way slabs with beams spanning between supports on all sides

α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \le 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \le 2.0$	Greater of:	$\dfrac{\ell_n\left(0.8+\dfrac{f_y}{1400}\right)}{36+5\beta\left(\alpha_{fm}-0.2\right)}$	(b)[2],[3]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\dfrac{\ell_n\left(0.8+\dfrac{f_y}{1400}\right)}{36+9\beta}$	(d)[2],[3]
		90	(e)

[1]α_{fm} is the average value of α_f for all beams on edges of a panel and α_f shall be calculated in accordance with 8.10.2.7.

[2]ℓ_n is the clear span in the long direction, measured face-to-face of beams (mm).

[3]β is the ratio of clear spans in long to short directions of slab.

R8.3.1.2 For panels having a ratio of long-to-short span greater than 2, the use of expressions (b) and (d) of Table 8.3.1.2, which give the minimum thickness as a fraction of the long span, may give unreasonable results. For such panels, the rules applying to one-way construction in 7.3.1 should be used.

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