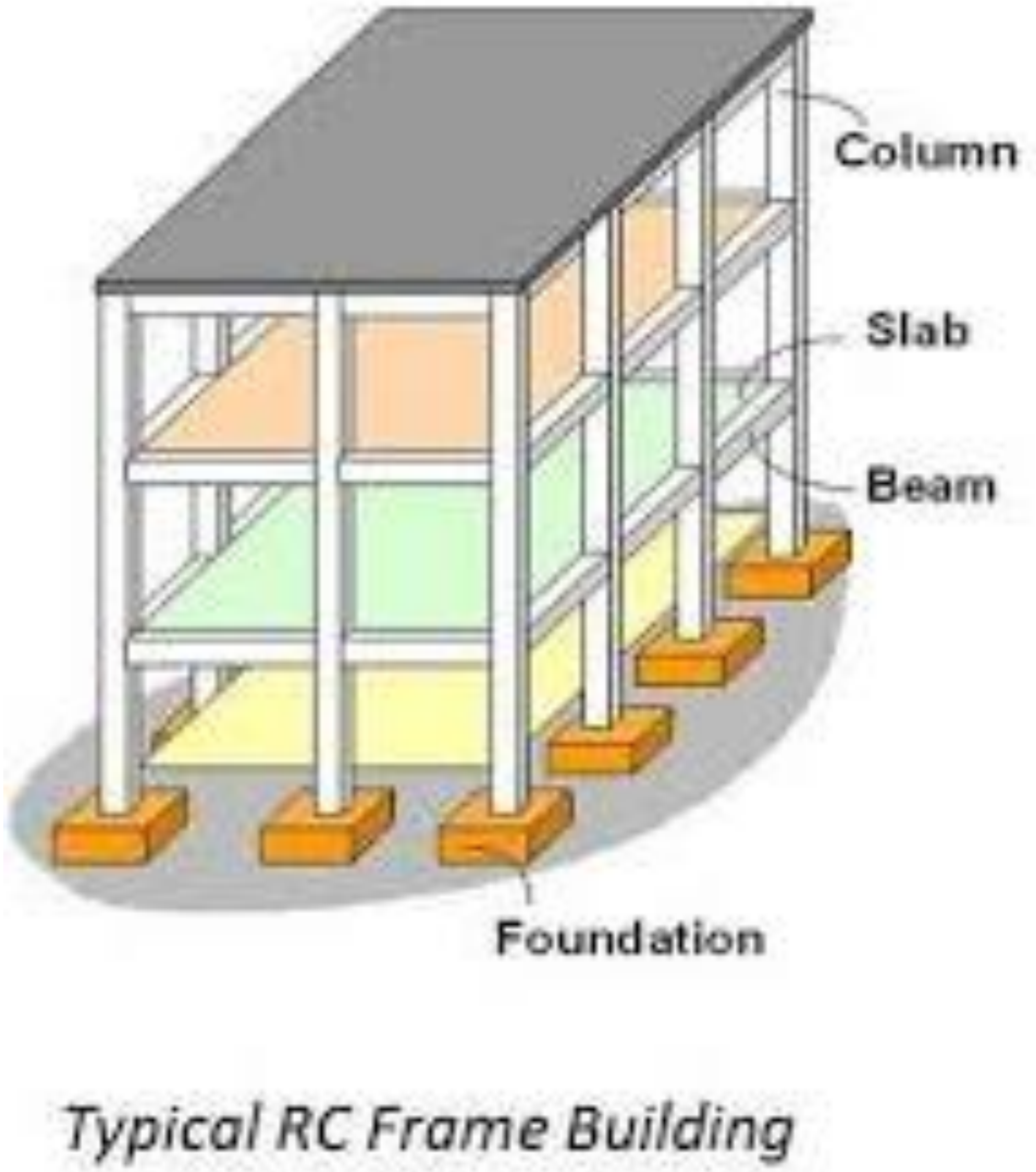
Direct Design Method

Prof. Dr. Khattab Saleem Abdul-Razzaq

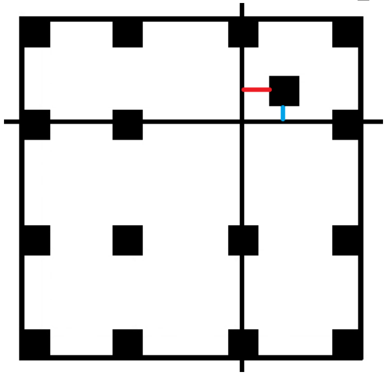
Direct Design Method



ا.د.خطاب / ديالى

Direct Design Method: **Limitations**

1. There must be at least **<u>three continuous spans in each direction</u>**. If there are fewer panels, the interior negative moments tend to be too small.
2. Panels should be rectangular and the ratio of longer/ shorter spans within the panel **<u>must not exceed 2</u>** otherwise one way actions will prevail.
3. In each direction, successive span lengths must not differ by more than **<u>one third</u>** of the largest span length.
4. Column offset of more than **<u>10% of the span</u>** (in the direction of offset) from either axis between centreline of successive column is not permitted.
5. This method is applicable for slab that subjected to **<u>gravity load</u>** only.
6. Unfactored service live load should not to be more than two times unfactored dead load (**L/D≤2**).
7. If beams were used, beam relative stiffness between two perpendicular directions ($\frac{\propto_1 l_2^2}{\propto_2 l_1^2}$) must be between 0.2-0.5.



Note: I is calculated for uncracked section.

Note: Shear is considered zero between strips.

5.3—Load factors and combinations

5.3.1 Required strength U shall be at least equal to the effects of factored loads in Table 5.3.1, with exceptions and additions in 5.3.3 through 5.3.12.

Design strength = **nominal** strength × strength reduction **factor**

Table 5.3.1—Load combinations

Load combination	Equation	Primary load
$U = 1.4D$	(5.3.1a)	D
$U = 1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$	(5.3.1b)	L
$U = 1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.5W)$	(5.3.1c)	L_r or S or R
$U = 1.2D + 1.0W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$	(5.3.1d)	W
$U = 1.2D + 1.0E + 1.0L + 0.2S$	(5.3.1e)	E
$U = 0.9D + 1.0W$	(5.3.1f)	W
$U = 0.9D + 1.0E$	(5.3.1g)	E

D = effect of service dead load

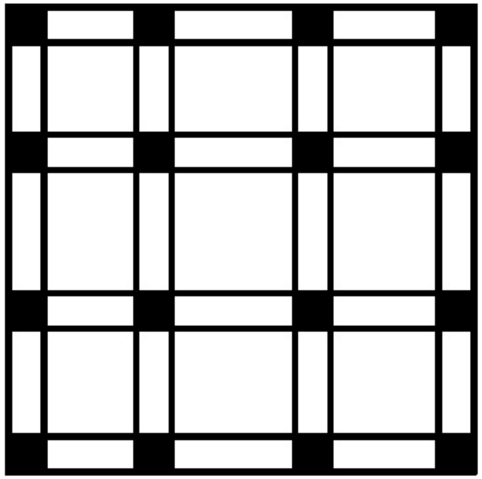
L = effect of service live load

S = effect of service snow load

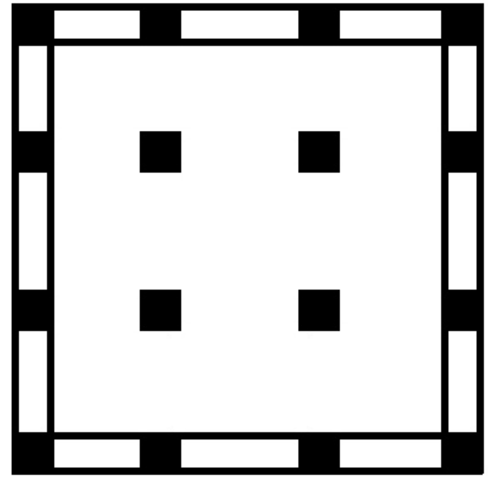
R = cumulative load effect of service rain load

W = effect of wind load

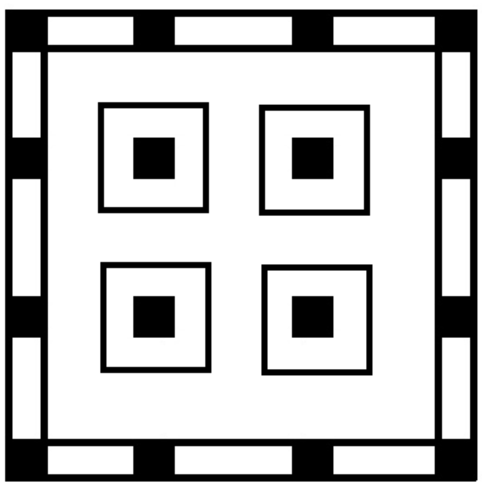
E = effect of horizontal and vertical earthquake-induced forces



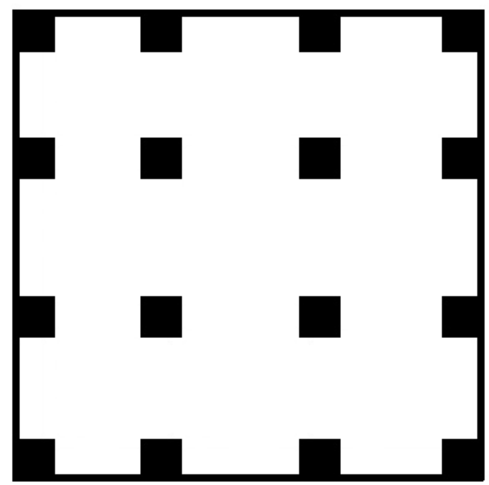
rc slab with beams between all supports, with edge beam



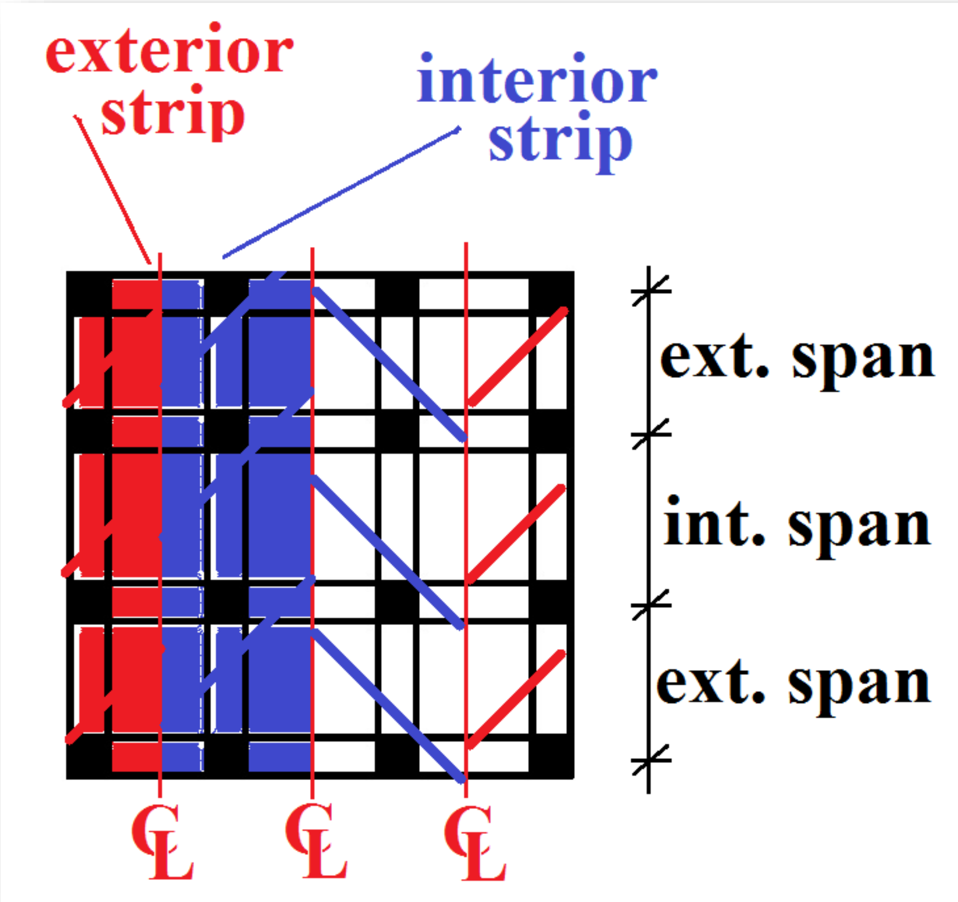
rc slab without internal beams, with edge beam

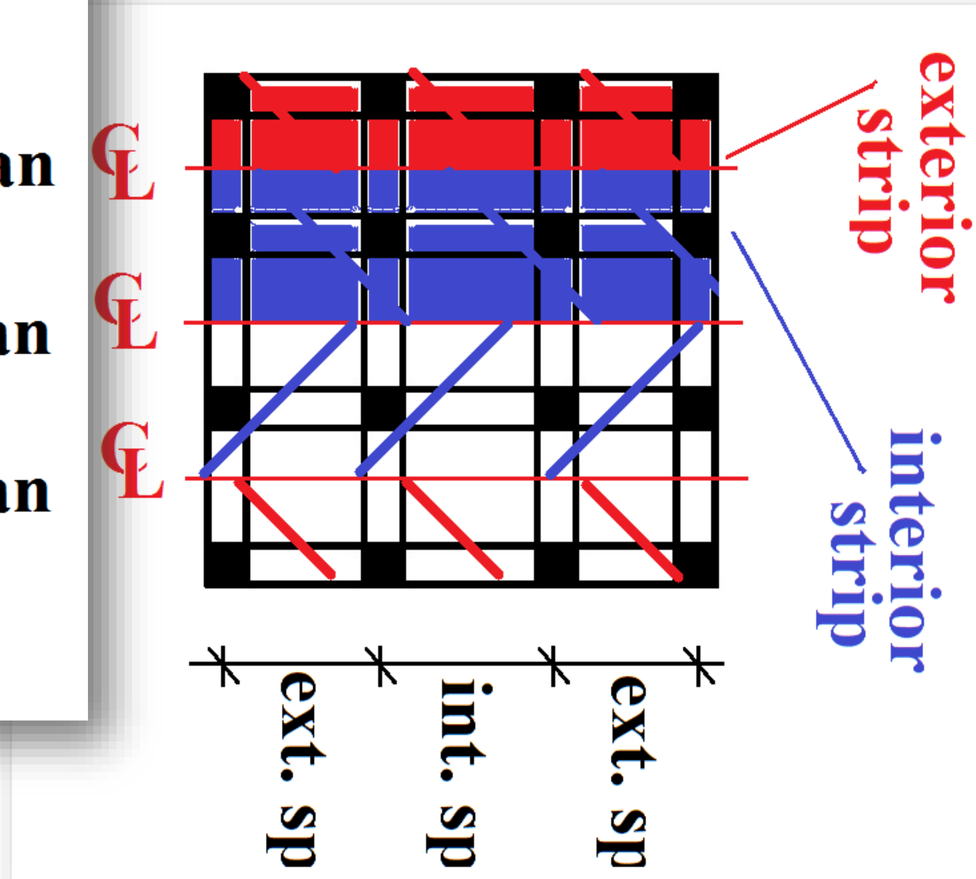


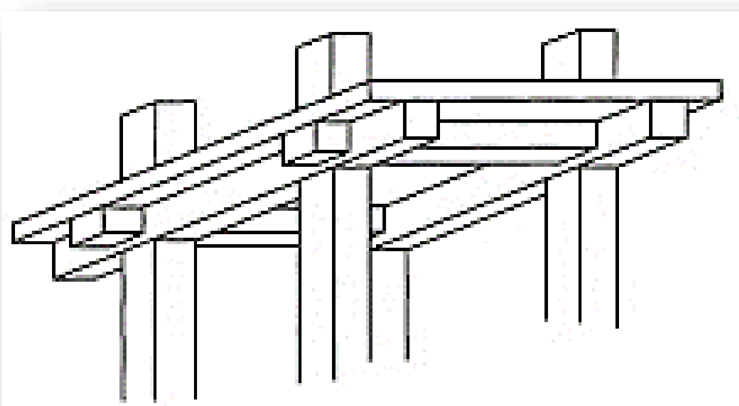
rc slab with drop panels, with edge beam

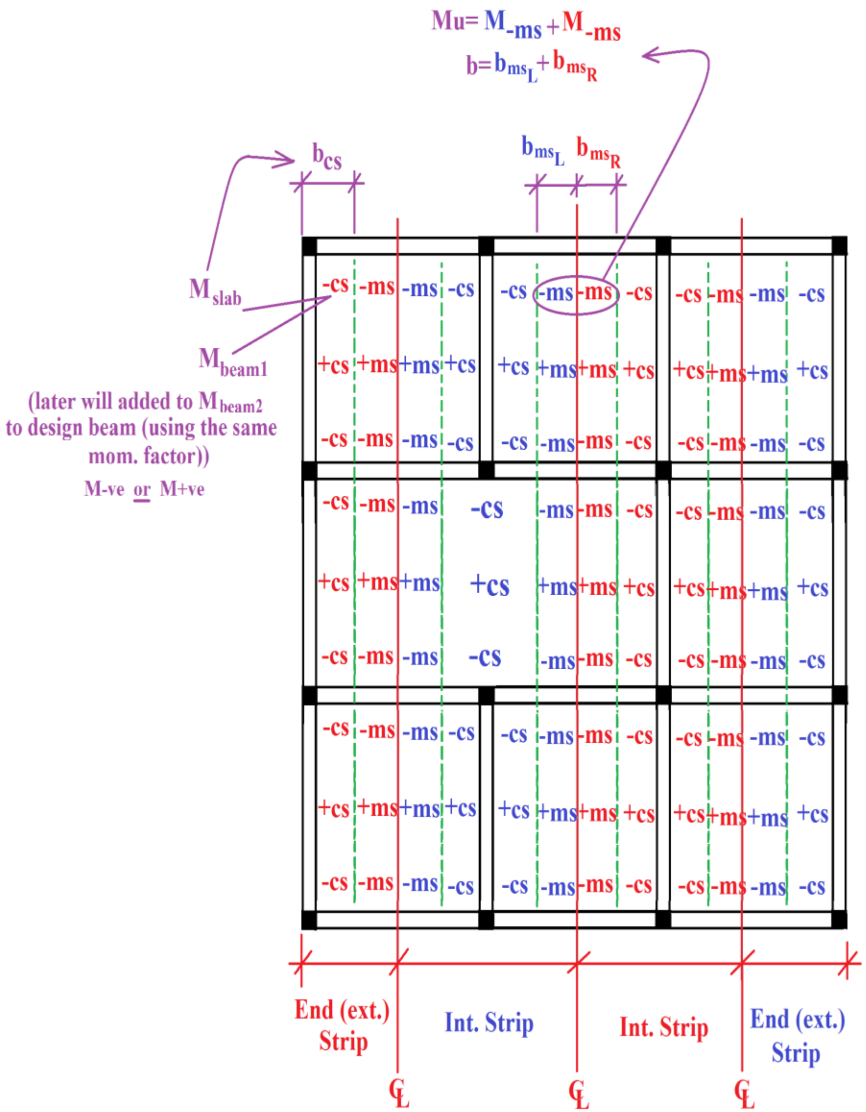


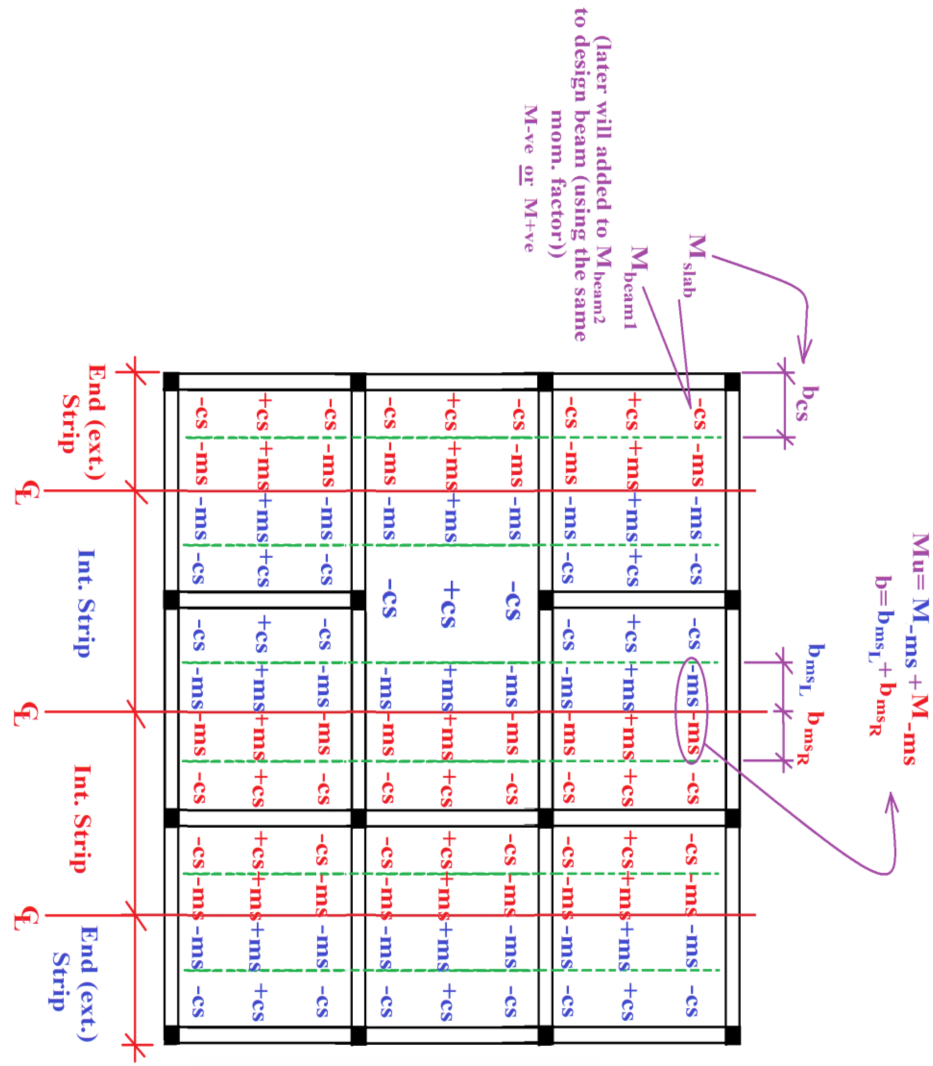
rc flat plate slab

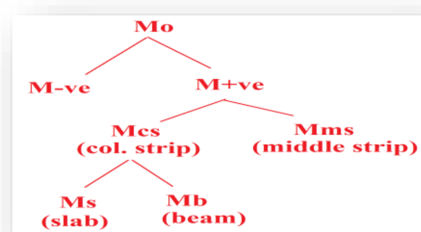

exterior strip
interior strip
ext. span
int. span
ext. span
CL
CL
CL

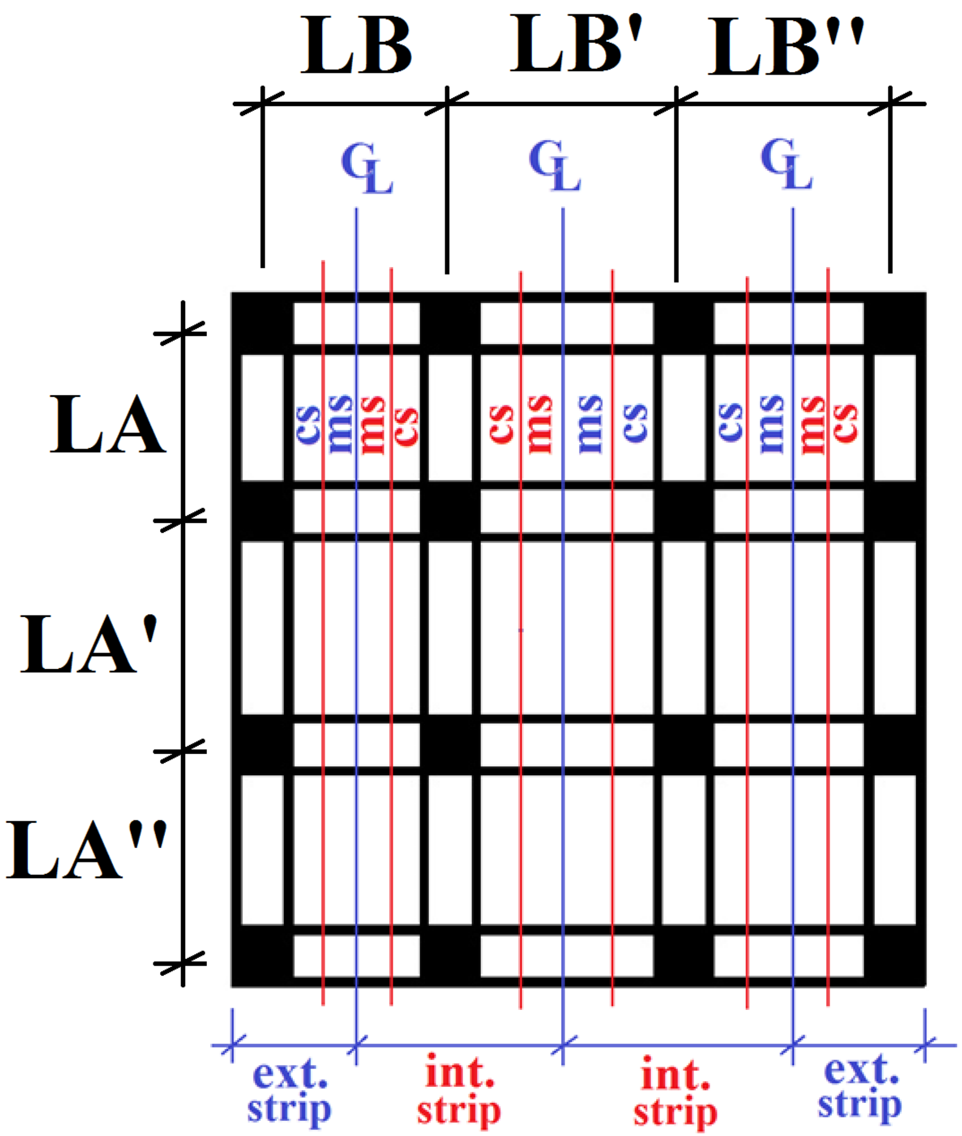

CL
CL
CL
exterior strip
interior strip
ext. sp
int. sp
ext. sp




Mu= M-ms + M-ms
b=bmsL + bmsR
bcs
bmsL bmsR
Mslab
Mbeam1
(later will added to Mbeam2
to design beam (using the same
mom. factor))
M-ve or M+ve
End (ext.) Strip
Int. Strip
Int. Strip
End (ext.) Strip
CL

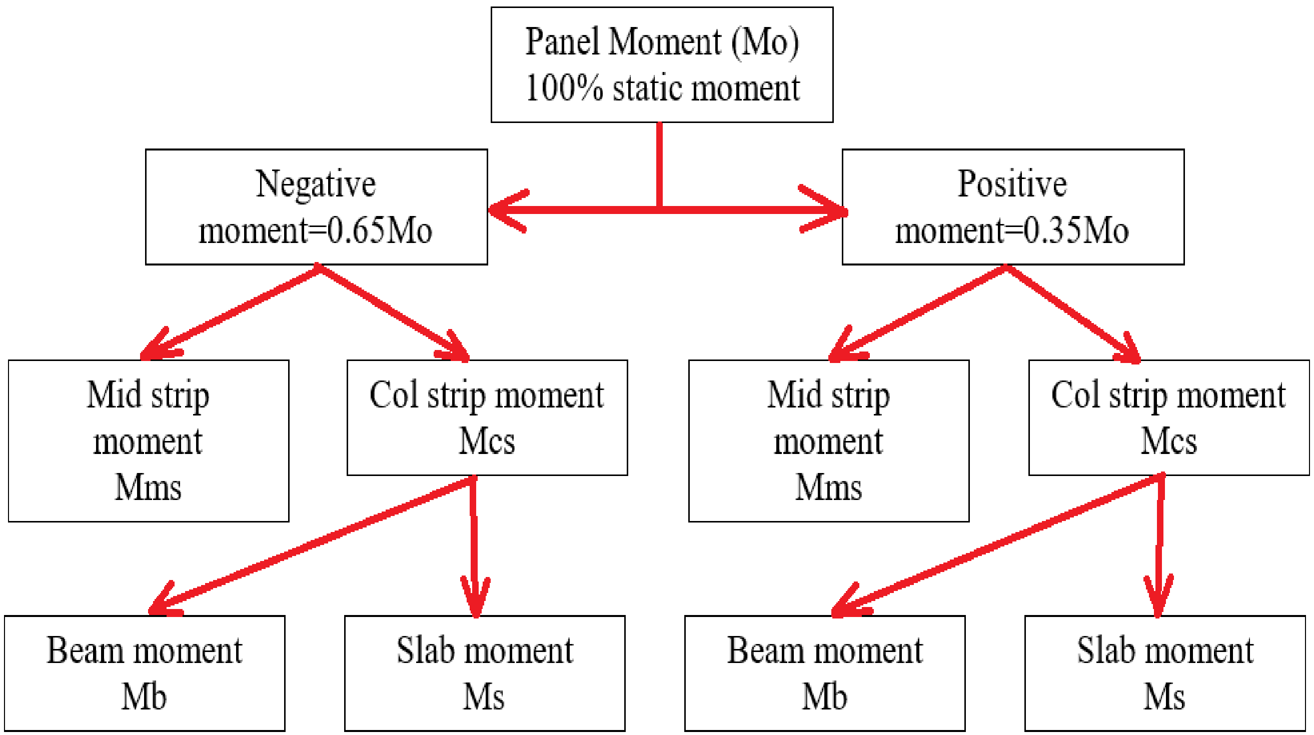

(later will added to Mbeam2
to design beam (using the same
mom. factor))
M-ve or M+ve
Mbeam1
Mslab
bcs
End (ext.) Strip
Int. Strip
Int. Strip
End (ext.) Strip
CL
bmsL bmsR
Mu= M-ms + M-ms
b=bmsL + bmsR

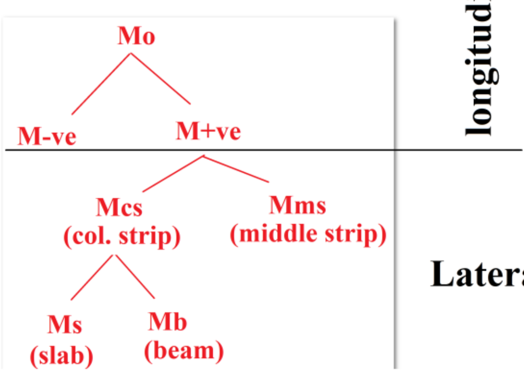

Mo
M-ve
M+ve
Mcs
(col. strip)
Mms
(middle strip)
Ms
(slab)
Mb
(beam)



- End (ext.) strip width= from centreline to the end of building
- Mid strip width=the distance between centrelines
- $Width\ of\ cs = min\left\{\frac{LB}{4},\frac{LA}{4},\frac{LA'}{4},\frac{LA''}{4}\right\}$
- Width of ms=strip width – width of cs

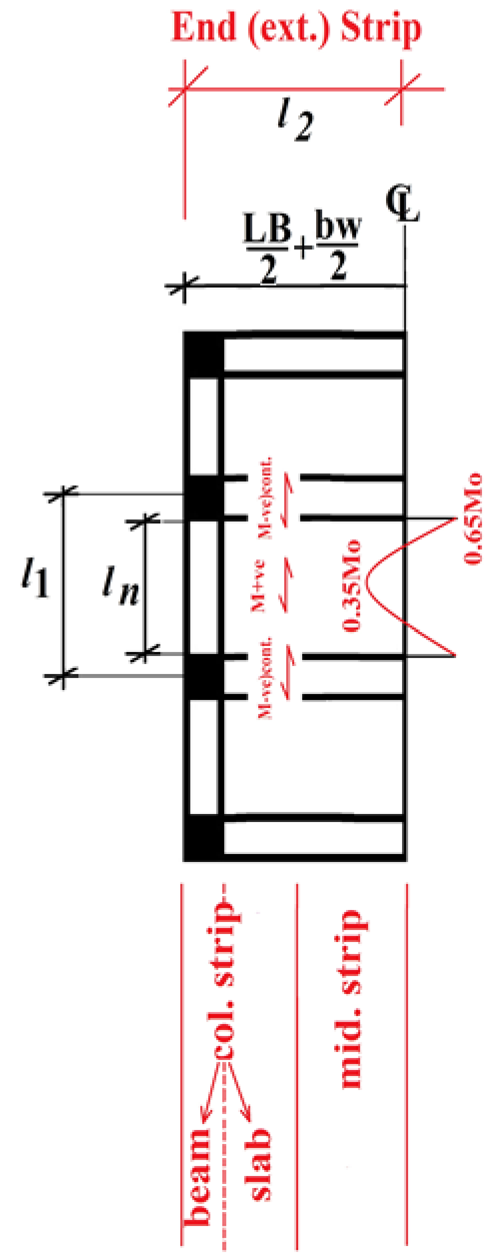
Internal Panel





longitudinal distribution of moments

Lateral distribution of moments



1-End (ext.) strip

1-1 End strip / middle span (M+ve=0.35Mo & M-ve=0.65Mo)

End strip width= from centreline to the end of building

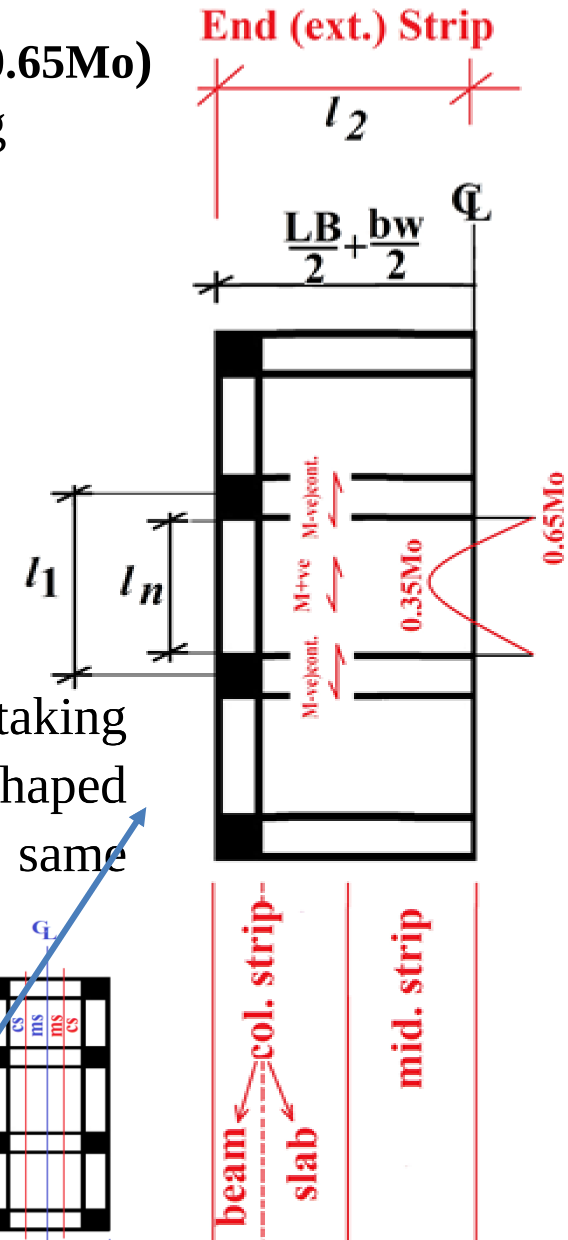
$$width\ of\ cs = min\left\{\frac{LB}{4}, \frac{LA}{4}, \frac{LA'}{4}, \frac{LA''}{4}\right\}$$

Width of ms=strip width – width of cs

Analysis of middle span $\quad M_o = \frac{(w_u * l_2) * l_n^2}{8}$

l_2 is the strip width

l_n is the clear span under consideration ($l_n \geq 0.65\ l_{c/c}$), taking into consideration that circular or regular polygon shaped support shall be treated as square support with the same area.



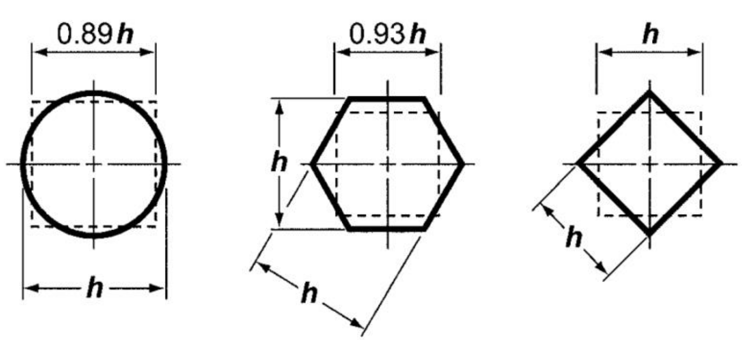
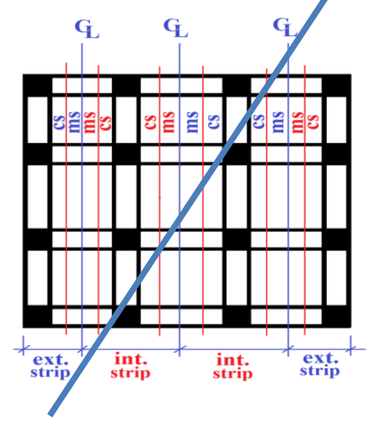


Fig. R8.10.1.3—Examples of equivalent square section for supporting members.



$$relative\ stiffness\ \propto = \frac{Ec_b * I_b}{Ec_s * I_s}$$

$$I_s = \frac{l_2 * h^3}{12} \qquad E=4700\sqrt{f'c}$$

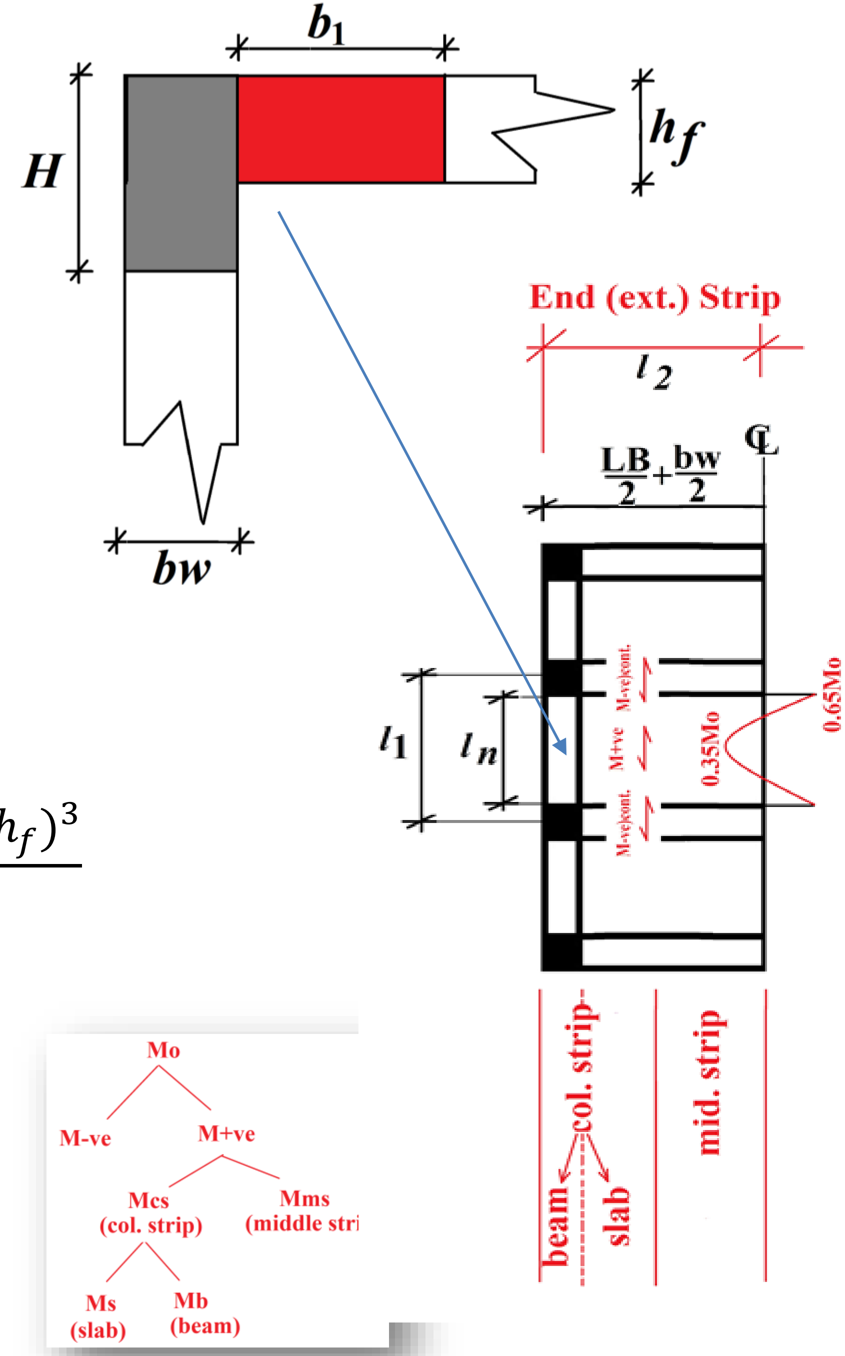
I_b is calculated after drawing the beam:

$$b_1 = min\begin{Bmatrix} H - h_f \\ 4\ h_f \end{Bmatrix}$$

$$\bar{y} = \frac{b_w * \frac{H^2}{2} + b_1 * \frac{h_f^2}{2}}{b_w * H + b_1 * h_f}$$

$$I_b = \frac{(b_w + b_1)\ (\bar{y})^3}{3} + \frac{b_w\ (H - \bar{y})^3}{3} - \frac{b_1\ (\bar{y} - h_f)^3}{3}$$

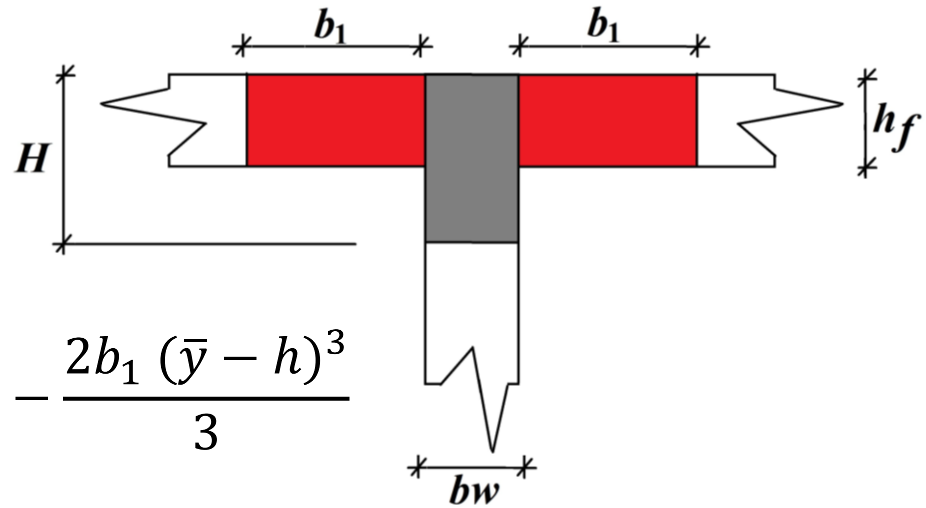
- To find $Mcs)_{+ve}$, use Table 8.10.5.5
- To find $Mcs)_{-ve/int.}$, use Table 8.10.5.1
- To find $Mcs)_{beam}$, use Table 8.10.5.7.1



Note:

$$\bar{y} = \frac{2b_1 * h_f \ \dfrac{h_f}{2} + H * b_w * \ \dfrac{H}{2}}{2b_1 * h + H * b_w}$$

$$I_b = (2b_1 + b_w) \ \frac{(\bar{y})^3}{3} + b_w \frac{(H - \bar{y})^3}{3} - \frac{2b_1 \ (\bar{y} - h)^3}{3}$$



Note: other sections of beams

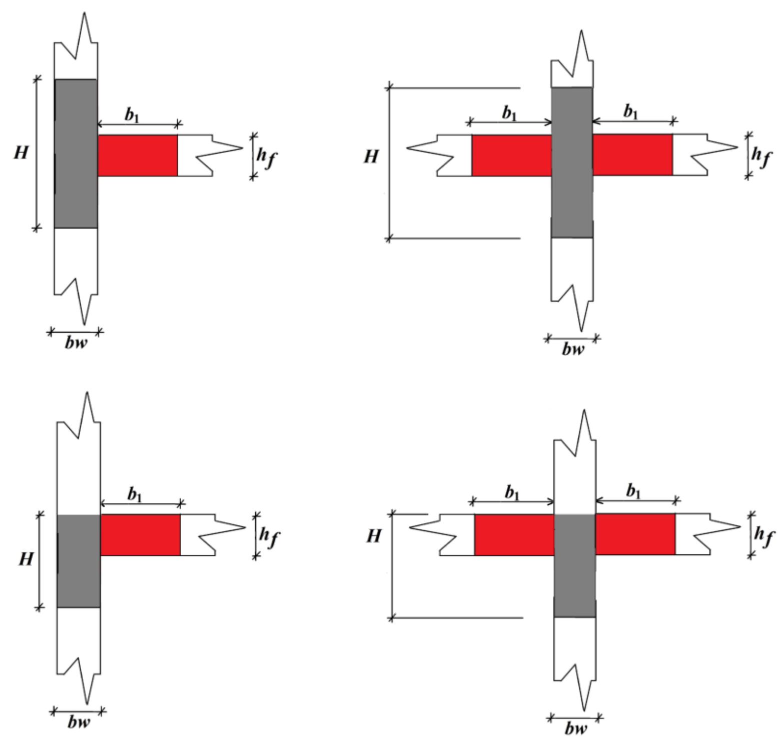


Table 8.10.5.5—Portion of positive M_u in column strip

$\alpha_{f1}\ell_2/\ell_1$	ℓ_2/ℓ_1 0.5	1.0	2.0
0	0.60	0.60	0.60
≥1.0	0.90	0.75	0.45

Note: Linear interpolations shall be made between values shown.

Table 8.10.5.1—Portion of interior negative M_u in column strip

$\alpha_{f1}\ell_2/\ell_1$	ℓ_2/ℓ_1 0.5	1.0	2.0
0	0.75	0.75	0.75
≥1.0	0.90	0.75	0.45

Note: Linear interpolations shall be made between values shown.

Table 8.10.5.2—Portion of exterior negative M_u in column strip

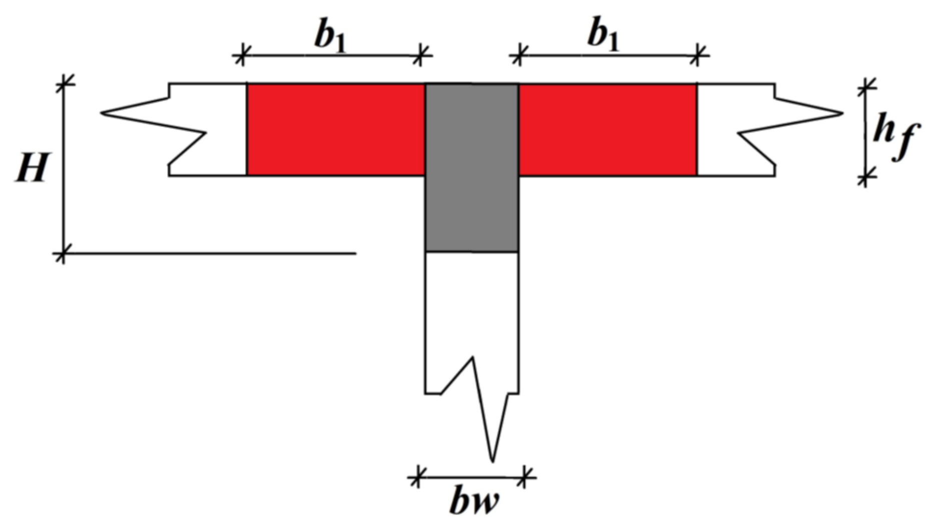
$\alpha_{f1}\ell_2/\ell_1$	β_t	ℓ_2/ℓ_1 0.5	1.0	2.0
0	0	1.0	1.0	1.0
	≥2.5	0.75	0.75	0.75
≥1.0	0	1.0	1.0	1.0
	≥2.5	0.90	0.75	0.45

Note: Linear interpolations shall be made between values shown. β_t is calculated using Eq. (8.10.5.2a), where C is calculated using Eq. (8.10.5.2b).

Table 8.10.5.7.1—Portion of column strip M_u in beams

$\alpha_{f1}\ell_2/\ell_1$	Distribution coefficient
0	0
≥1.0	0.85

Note: Linear interpolation shall be made between values shown.



Note:

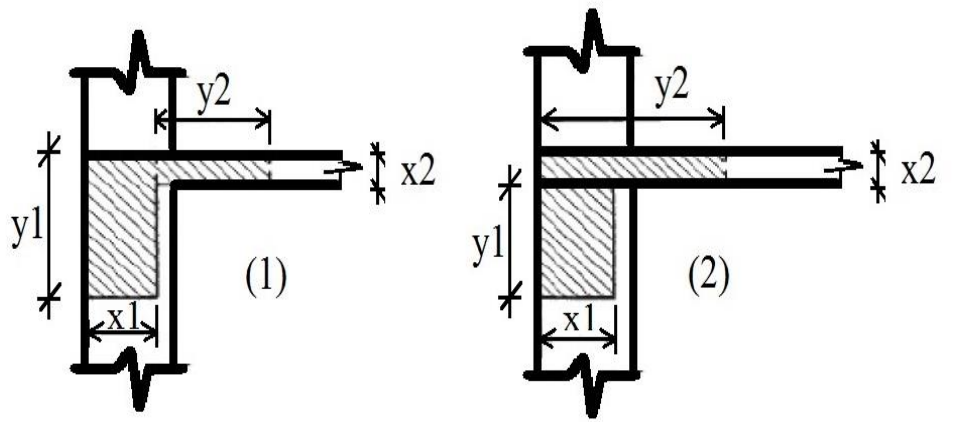
$$\bar{y} = \frac{2b_1 * h_f \frac{h_f}{2} + H * b_w * \frac{H}{2}}{2b_1 * h + H * b_w}$$

$$I_b = (2b_1 + b_w)\,\frac{(\bar{y})^3}{3} + b_w \frac{(H - \bar{y})^3}{3} - \frac{2b_1\,(\bar{y} - h)^3}{3}$$

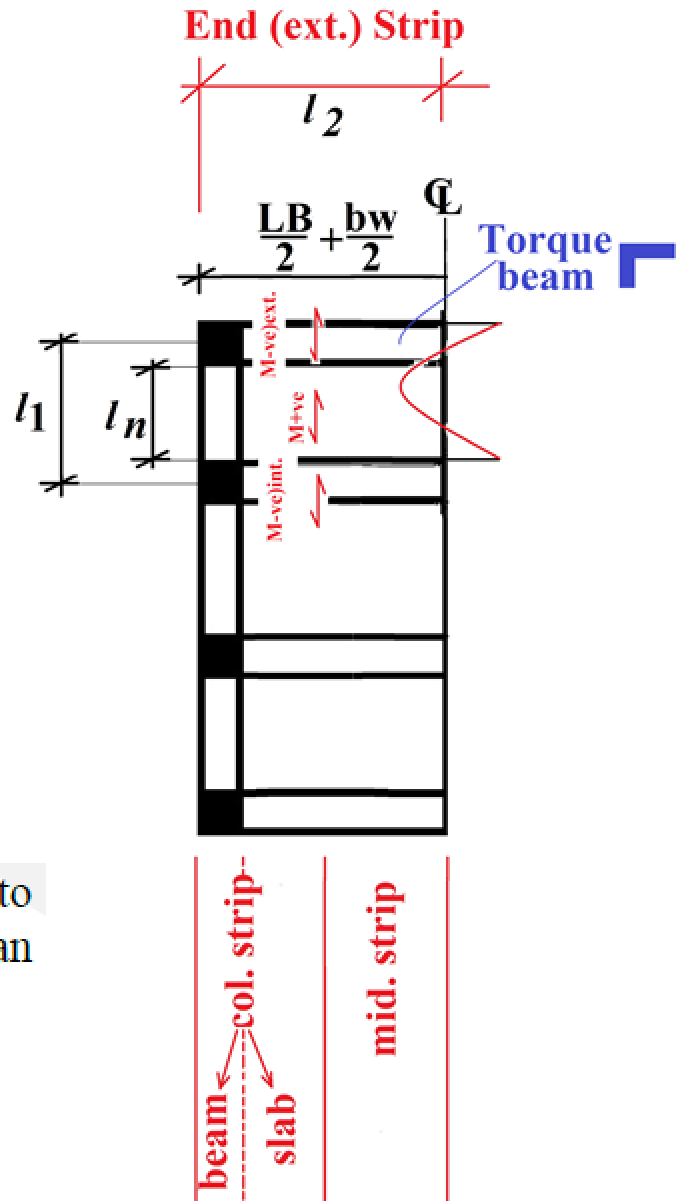
1-2 End strip / end span (M+ve & M-ve from Table 8.10.4.2)

Torque beam:

$$C = \sum \left(1 - 0.63\frac{x}{y}\right)\frac{x^3 y}{3} \qquad \beta_t = \frac{E_b\, C}{2\, I_s\, E_s}$$



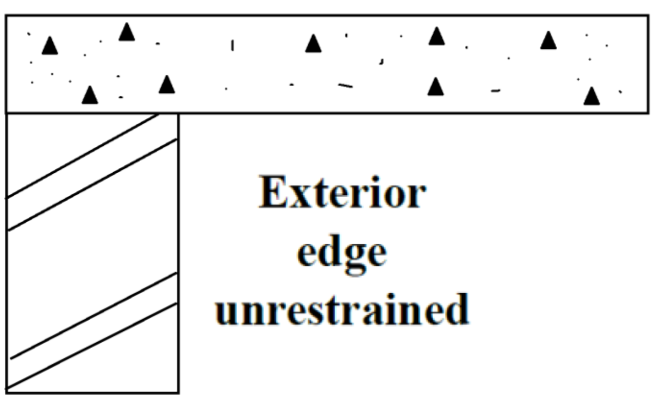
Use larger C computed in (1) and (2)



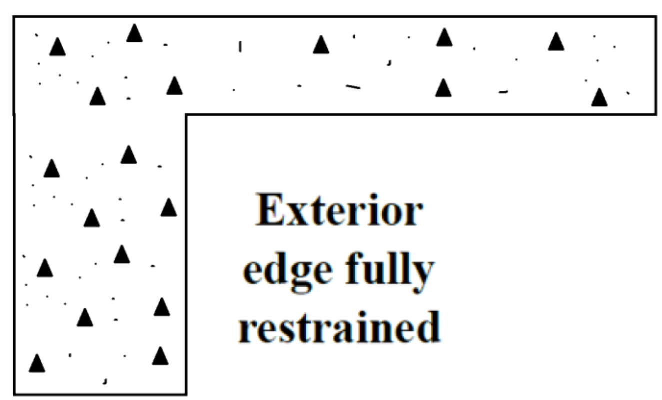
β_t = ratio of torsional stiffness of edge beam section to flexural stiffness of a width of slab equal to span length of beam, center-to-center of supports

Table 8.10.4.2—Distribution coefficients for end spans

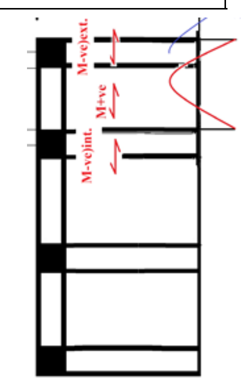
	Exterior edge unrestrained	Slab with beams between all supports	Slab without beams between interior supports		Exterior edge fully restrained
			Without edge beam	With edge beam	
Interior negative	0.75	0.70	0.70	0.70	0.65
Positive	0.63	0.57	0.52	0.50	0.35
Exterior negative	0	0.16	0.26	0.30	0.65



Exterior edge unrestrained



Exterior edge fully restrained



ا.د.خطاب / ديالى

Design Procedure:

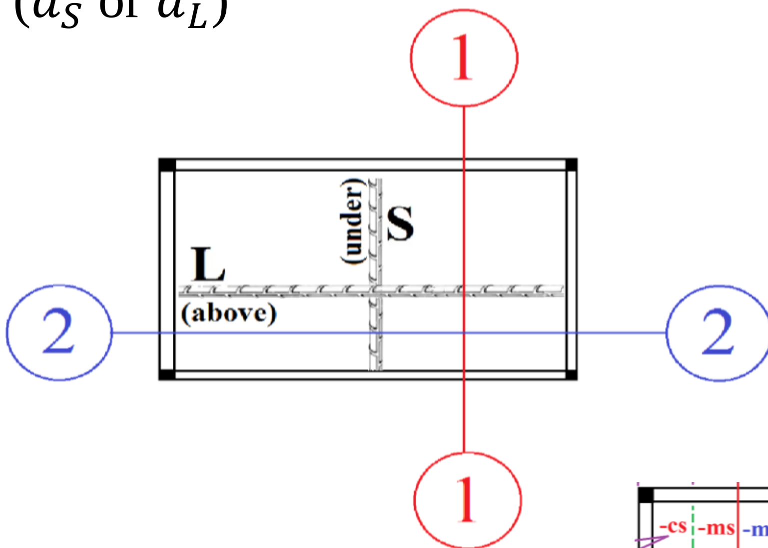
Calculate the effective depth (d_S or d_L)

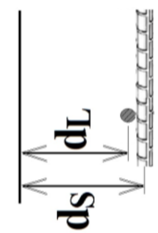
$$d_S = h_f - 20mm - \frac{\emptyset_s}{2}$$

$$d_L = h_f - 20mm - 1.5\ \emptyset_L$$

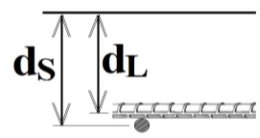
$$R_u = \frac{Mu * 10^6}{0.9\ b\ d^2}$$

$$m = \frac{fy}{0.85\ f'c}$$

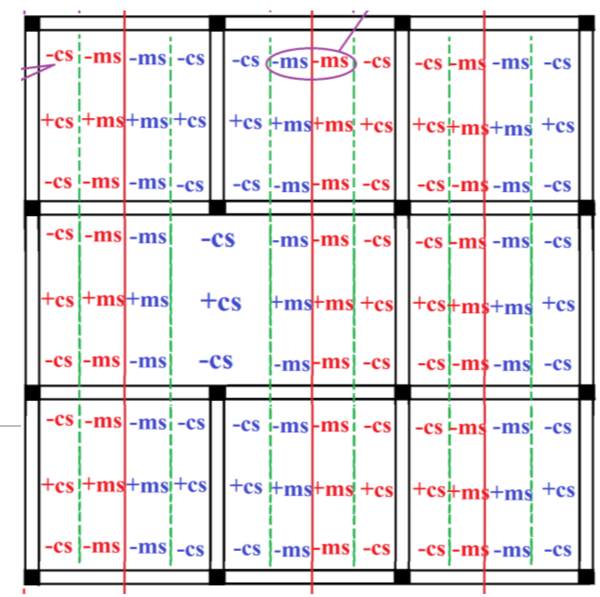




sec. 1-1
(main is long reinf.)
use d_L



sec. 2-2
(main is short reinf.)
use d_S



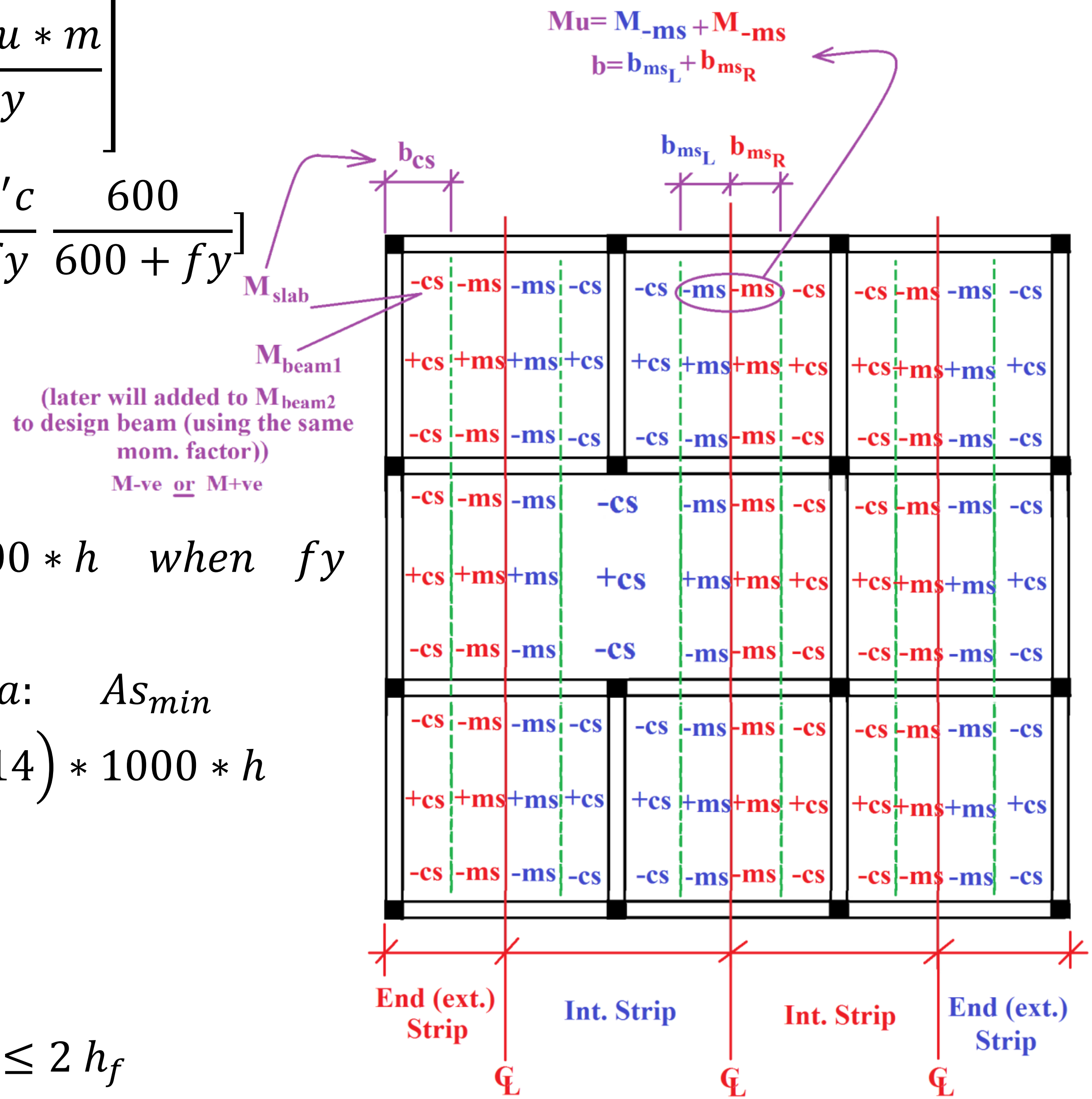
Notes:

- Mu = M_{slab} <u>or</u> Mu=($M_{ms-right}$ +$M_{ms-left}$)
- b = b_{cs} when Mu=M_{slab}
- b = ($b_{ms-right}$ +$b_{ms-left}$) when Mu =($M_{ms-right}$ +$M_{ms-left}$)
- d either d_S <u>or</u> d_L

$$\rho = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 * Ru * m}{fy}}\right]$$

$$\rho_{max} = 0.75\ [0.85\ \beta_1 \frac{f'c}{fy} \frac{600}{600 + fy}]$$

$$\rho_{min} \le \rho \le \rho_{max}$$



- $As_{min} = 0.002 * 1000 * h \quad when \quad fy < 420\ MPa$
- $when\ \ fy \ge 420\ MPa: \quad As_{min} = \left(\frac{0.018*420}{fy} \ge 0.0014\right) * 1000 * h$

$$As = \rho * d * 1000$$

$$S = \frac{\frac{\pi}{4} * \text{Ø}^2 * 1000}{As} \qquad \le 2\ h_f$$

ا.د.خطاب / ديالى

2- Internal strip

2-1 Internal strip / middle span (M+ve=0.35Mo & M-ve=0.65Mo)

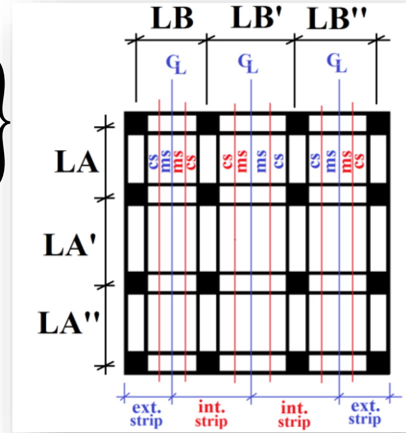
Internal strip width = between the centrelines

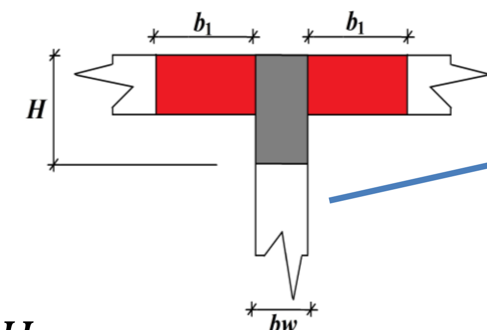
$$width\ of\ cs_1 = min\left\{\frac{LB'}{4}, \frac{LA}{4}, \frac{LA'}{4}, \frac{LA''}{4}\right\}$$

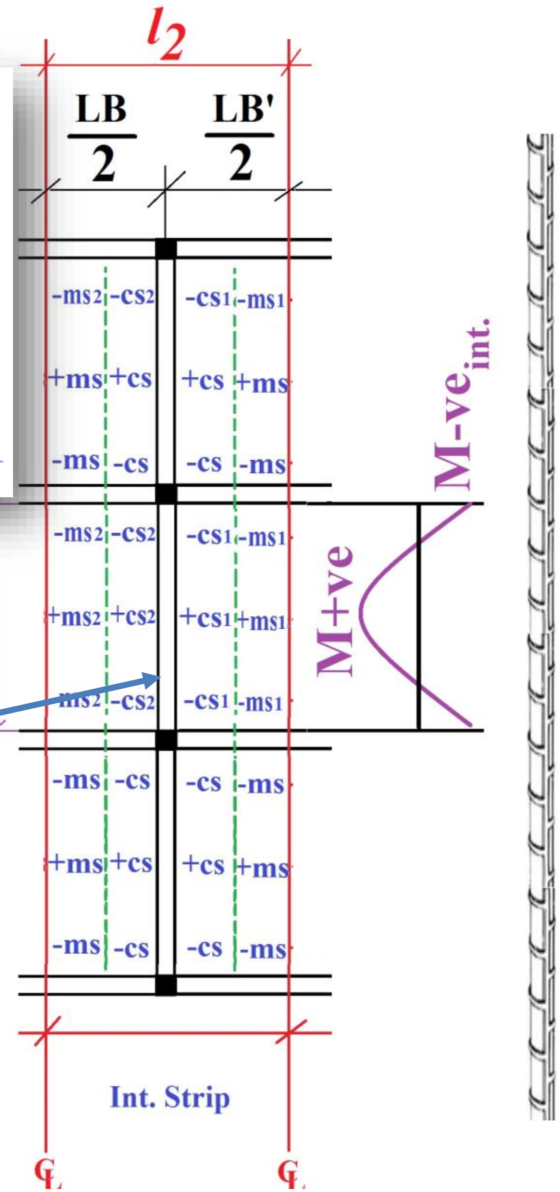
$$width\ of\ cs_2 = min\left\{\frac{LB}{4}, \frac{LA}{4}, \frac{LA'}{4}, \frac{LA''}{4}\right\}$$

$$width\ of\ ms_1 = \frac{LB'}{2} - cs_1$$

$$width\ of\ ms_2 = \frac{LB}{2} - cs_2$$







Note:

$$\bar{y} = \frac{2b_1 * h_f\ \frac{h_f}{2} + H * b_w * \frac{H}{2}}{2b_1 * h + H * b_w}$$

$$I_b = (2b_1 + b_w)\ \frac{(\bar{y})^3}{3} + b_w \frac{(H - \bar{y})^3}{3} - \frac{2b_1\ (\bar{y} - h)^3}{3}$$

Note: if no parallel beam:

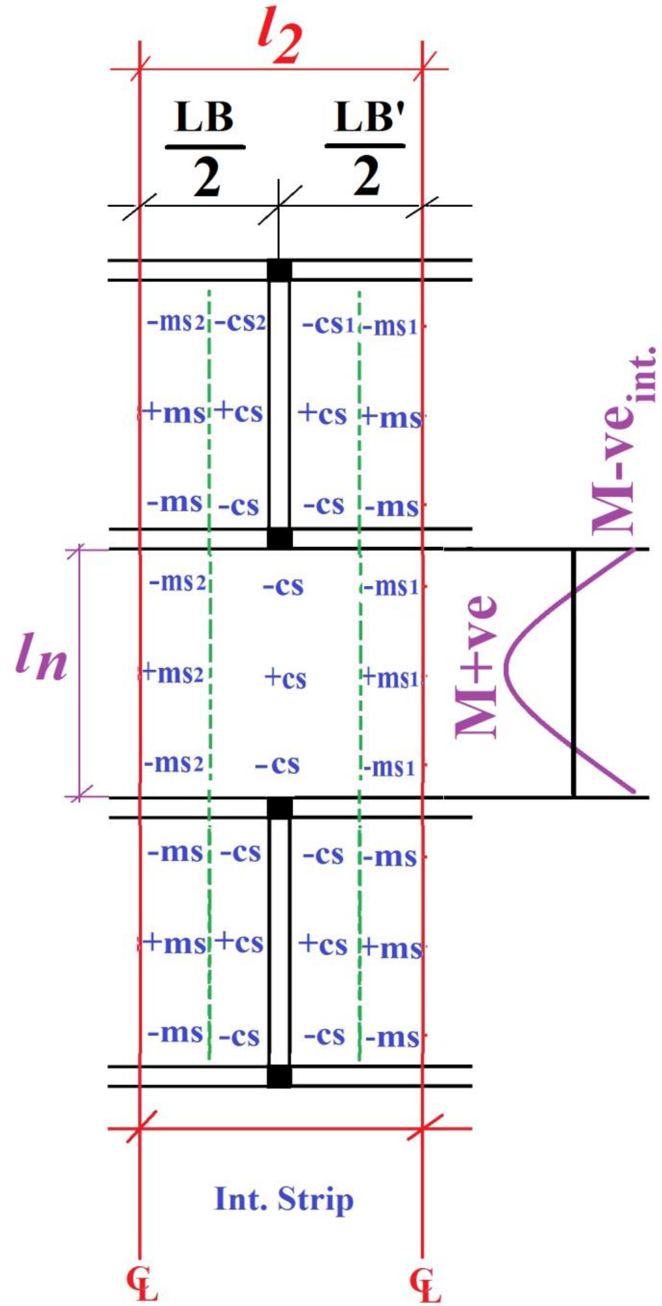
cs = $cs_1 + cs_2$

$$width\ of\ cs_1 = min\left\{\frac{LB'}{4},\frac{LA}{4},\frac{LA'}{4},\frac{LA''}{4}\right\}$$

$$width\ of\ cs_2 = min\left\{\frac{LB}{4},\frac{LA}{4},\frac{LA'}{4},\frac{LA''}{4}\right\}$$

$$width\ of\ ms_1 = \frac{LB'}{2} - cs_1$$

$$width\ of\ ms_2 = \frac{LB}{2} - cs_2$$



- To find Mcs$)_{+ve}$, use Table 8.10.5.5
- To find Mcs$)_{-ve/int.}$, use Table 8.10.5.1

- To find Mcs$)_{beam}$, use Table 8.10.5.7.1

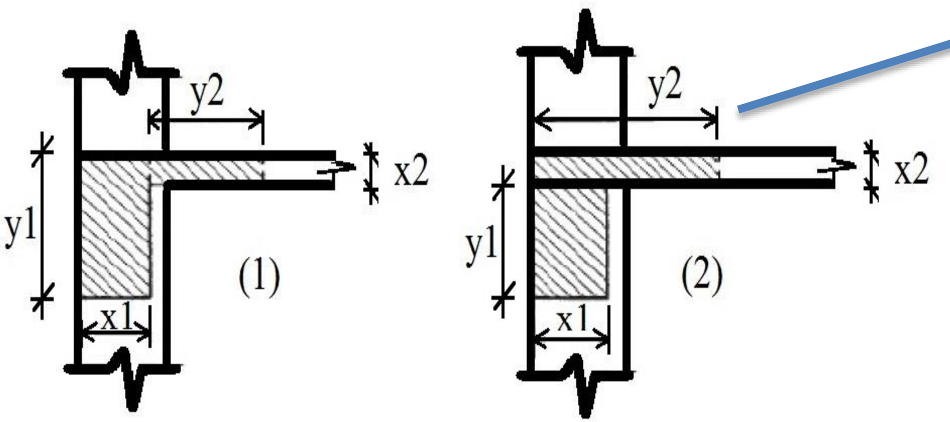
2-2 Int. strip / End span (M+ve & M-ve from Table 8.10.4.2)

$$\beta_t = \frac{\beta_{t-left} + \beta_{t-right}}{2}$$

Torque beam:

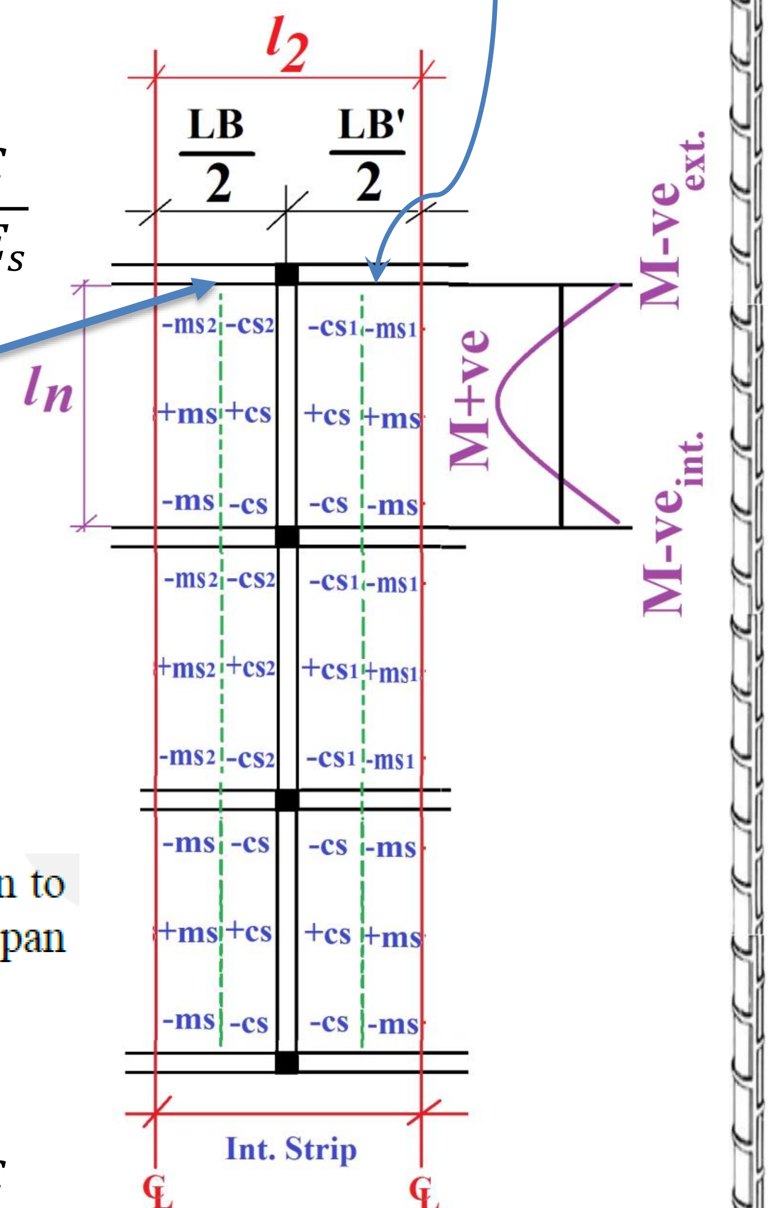
$$C = \sum \left(1 - 0.63\frac{x}{y}\right)\frac{x^3 y}{3}$$

$$\beta_t = \frac{E_b\, C}{2\, I_s\, E_s}$$



Use larger C computed in (1) and (2)

β_t = ratio of torsional stiffness of edge beam section to flexural stiffness of a width of slab equal to span length of beam, center-to-center of supports



$$\beta_{t-left} = \frac{E_b\, C}{2\, I_{s-left}\, E_s} \qquad \beta_{t-right} = \frac{E_b\, C}{2\, I_{s-right}\, E_s}$$

Analysis of beam (Mb_{total}):

$$Mb_{total} = M_{beam1} + M_{beam2}$$

1. M_{beam1} was found from $Mcs)_{beam}$, using Table 8.10.5.7.1
2. To find M_{beam2} for the undashed portion of the beams section:

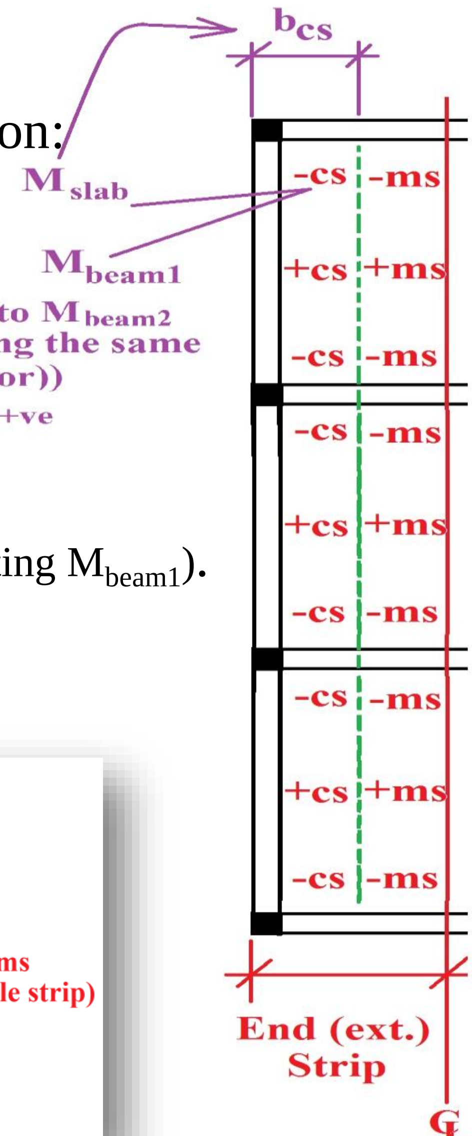
$$D_{beam} = [24 * b_w * (H - h) + D_{wall}] * 1.2$$

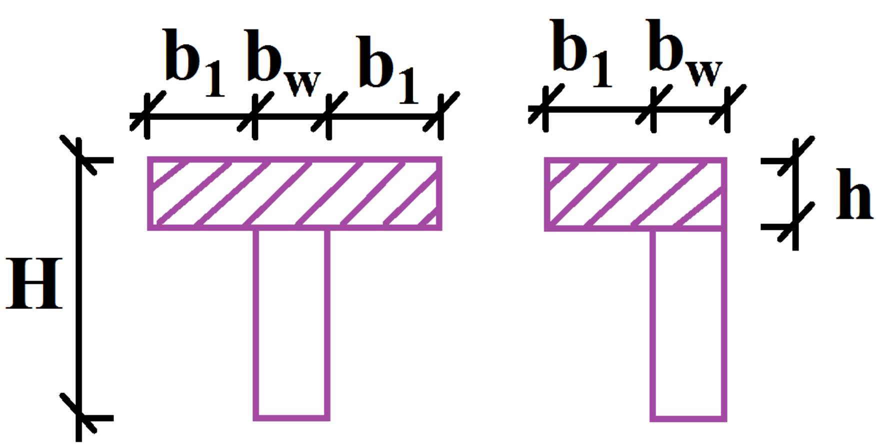
Noting that D_{wall} in kN/m

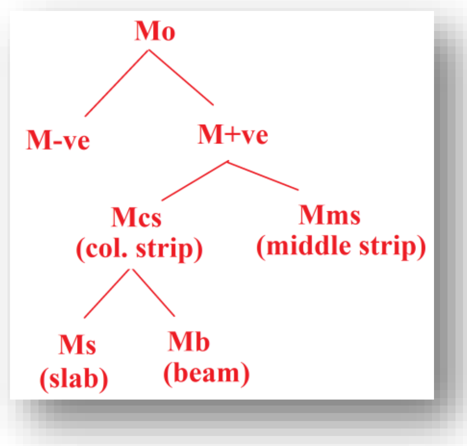
$$Mo_{beam} = \frac{D_{beam} * l_n^2}{8}$$

$M_{beam2} = Mo_{beam}$ * coef. from Table 8.10.4.2 (same one in getting M_{beam1}).

$\therefore Mb_{total} = M_{beam1} + M_{beam2}$





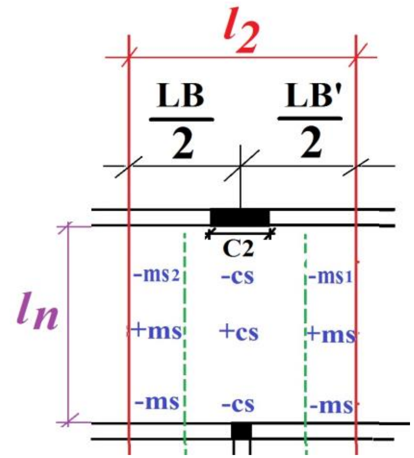


ا.د.خطاب / ديالى

Notes:

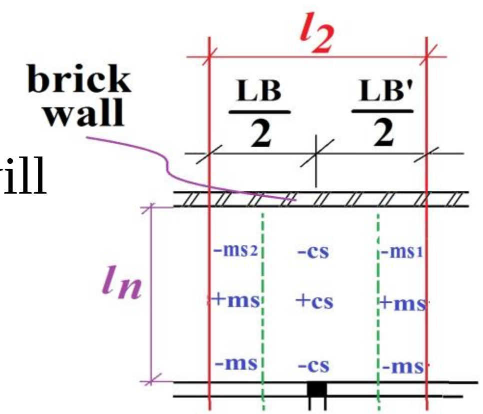
1. In case of wide column ($C2 \geq 0.75 l_2$), $M\text{-}ve_{ext.}$ will not be divide into (Mcs and Mms).

$Mu = M\text{-}ve_{ext.}$ and $b = l_2$



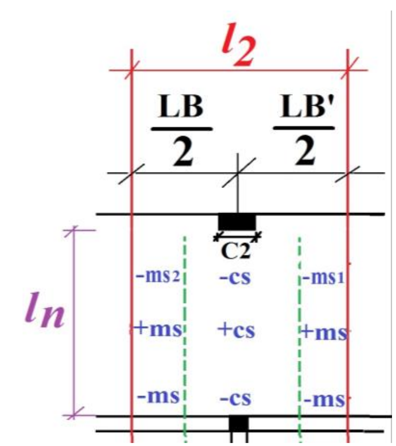
2. In case of no perpendicular beam, $M\text{-}ve_{ext.}$ will not be divide into (Mcs and Mms).

$Mu = M\text{-}ve_{ext.}$ and $b = l_2$.



3. In case of no perpendicular beam, only a column exists, $M\text{-}ve_{ext.}$ will not be divide into (Mcs and Mms).

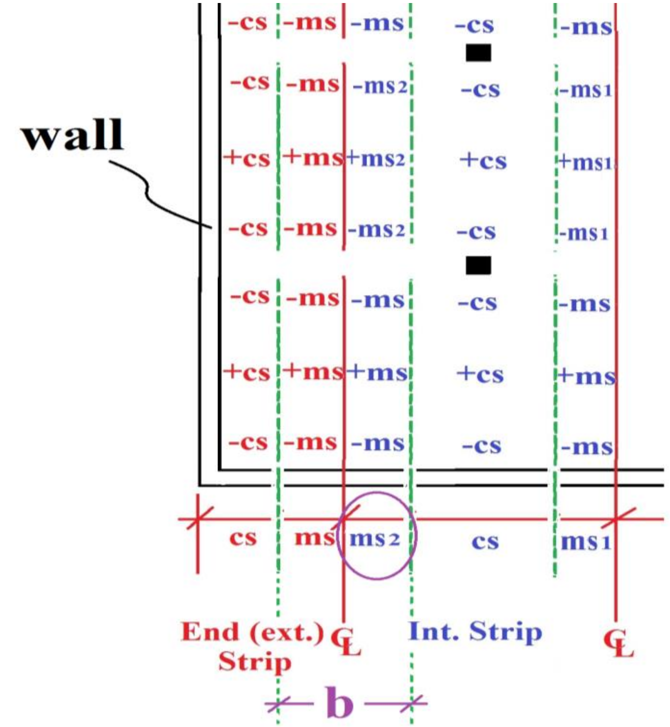
$I_b = 0$, $Mu = M\text{-}ve_{ext.}$ and $b = C2$.



4. To design the end (ext.) strip that has no parallel end beam (wall existence):

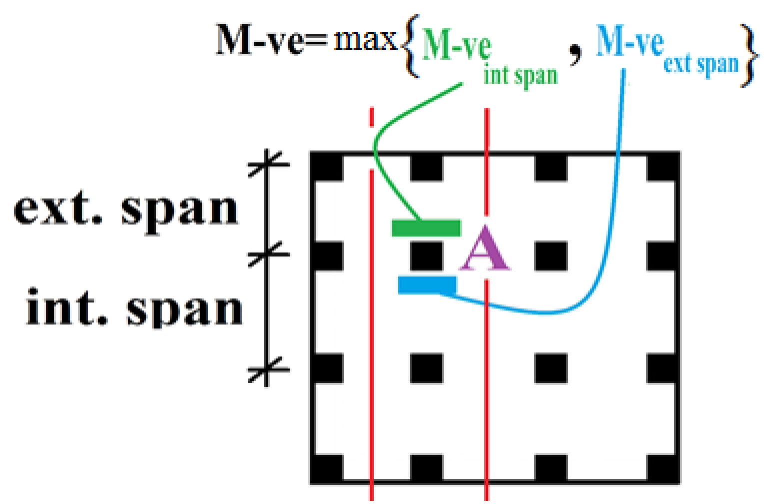
Mu=2 * ms2

b= bms+bms2



5. To design the negative top reinf. @ support A, max M-ve of the two adjacent spans will be taken (ACI 318-14, 8.10.4.5):

$$\text{M-ve}= max\{M - ve_{int.span} , M - ve_{ext.\,span}\}$$

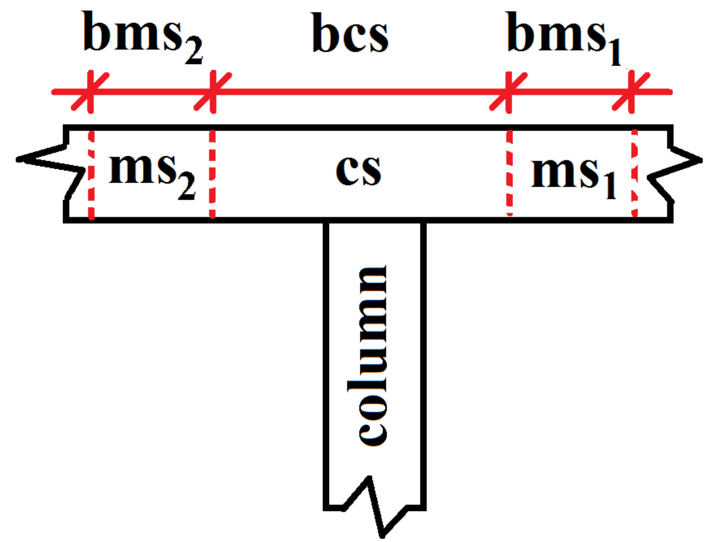


6. In case of no parallel beam:

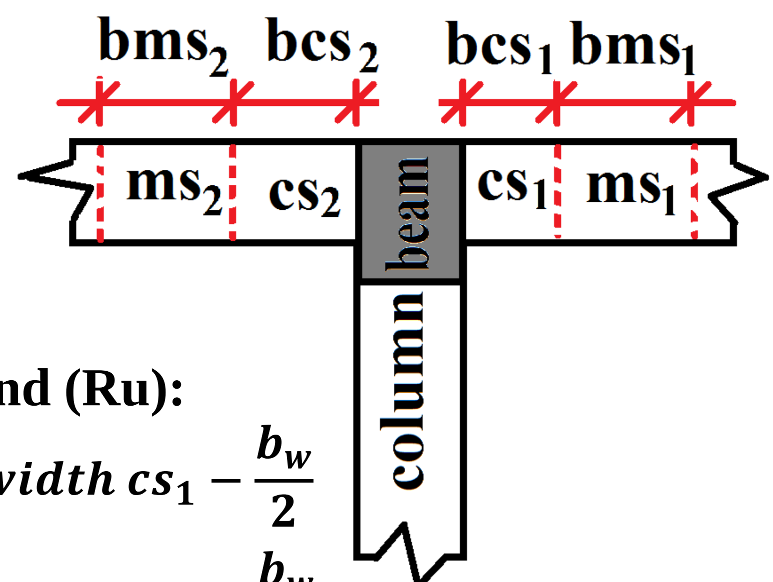
$$M_{cs} = M_{cs}$$

$$M_{ms1} = M_{ms}\frac{bms_1}{bms_1 + bms_2}$$

$$M_{ms2} = M_{ms}\frac{bms_2}{bms_1 + bms_2}$$



7. In case of parallel beam existence:



$$M_{cs1} = M_{cs}\frac{bcs_1}{bcs_1 + bcs_2}$$

$$M_{cs2} = M_{cs}\frac{bcs_2}{bcs_1 + bcs_2}$$

$$M_{ms1} = M_{ms}\frac{bms_1}{bms_1 + bms_2}$$

$$M_{ms2} = M_{ms}\frac{bms_2}{bms_1 + bms_2}$$

(b) to find (Ru):

$$b_{cs1} = width\ cs_1 - \frac{b_w}{2}$$

$$b_{cs2} = width\ cs_2 - \frac{b_w}{2}$$