

Limitations on Reinforcement for Flange Beams

- Lower Limits
 - Flange in compression

$$\rho_{\min} = \frac{A_s}{b_w d} = \text{larger of } \left\{ \begin{array}{l} \frac{3\sqrt{f'_c}}{f_y} \\ \frac{200}{f_y} \end{array} \right.$$

Limitations on Reinforcement for Flange Beams

- Lower Limits

- Flange in tension

$$A_{s(\min)} = \text{smaller of } \left\{ \begin{array}{l} \frac{6\sqrt{f'_c}}{f_y} b_w d \\ \text{larger of } \left\{ \begin{array}{l} \frac{3\sqrt{f'_c}}{f_y} b_{\text{eff}} d \\ \frac{200}{f_y} b_{\text{eff}} d \end{array} \right. \end{array} \right.$$

Limitations on Reinforcement for Flange Beams

- Lower Limits

- If $A_{s(\text{provided})} \geq 4/3 A_{s(\text{req'd})}$ based on analysis

then $A_{s(\text{min})}$ is not required (i.e.)

$$\phi M_n \geq 4/3 M_u \text{ for } A_{s(\text{provided})}$$

See ACI 10.5.3

Example - T-Beam

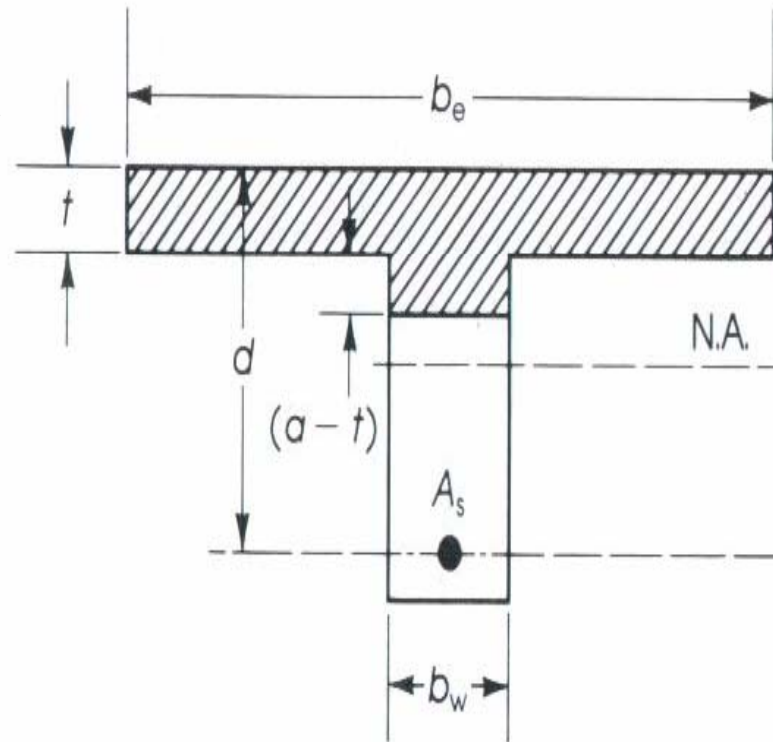
Find M_n and M_u for T-Beam.

$b_{\text{eff}} = 54 \text{ in.}$ $h_f = 3 \text{ in.}$ $b = 7 \text{ ft.}$

$d = 16.5 \text{ in.}$ $A_s = 8.5 \text{ in}^2$

$f_y = 50 \text{ ksi}$ $f_c = 3 \text{ ksi}$

$b_w = 12 \text{ in}$ $L = 18 \text{ ft}$



Example of L-Beam

Confirm b_{eff}

$$\begin{aligned} b_{\text{eff}} &\leq \frac{L}{4} = \frac{18 \text{ ft} \left(\frac{12 \text{ in.}}{\text{ft.}} \right)}{4} = 54 \text{ in.} \\ &\leq 16h_f + b_w = 16(3 \text{ in.}) + 12 \text{ in.} = 60 \text{ in.} \\ &\leq b = 7 \text{ ft.} \left(\frac{12 \text{ in.}}{\text{ft.}} \right) = 84 \text{ in.} \end{aligned}$$

Example - T-Beam

Compute the equivalent c value and check the strain in the steel, ε_s

$$a = \frac{A_s f_y}{0.85 f'_c b_{\text{eff}}} = \frac{(8.5 \text{ in}^2)(50 \text{ ksi})}{0.85(3 \text{ ksi})(54 \text{ in.})} = 3.09 \text{ in.}$$

$$c = \frac{a}{\beta_1} = \frac{3.09 \text{ in}}{0.85} = 3.63 \text{ in.}$$

$$\varepsilon_s = \left(\frac{d}{c} - 1 \right) 0.003 = \left(\frac{16.5 \text{ in.}}{3.63 \text{ in.}} - 1 \right) 0.003 = 0.0106 > 0.005$$

Steel will yield in the tension zone.

Example - T-Beam

Compute the reinforcement ρ and check to make sure it is greater than $\rho_{\min}$

$$\rho = \frac{A_s}{b_w d} = \frac{(8.5 \text{ in}^2)}{(12 \text{ in.})(16.5 \text{ in.})} = 0.0429$$

$$\rho_{\min} = \begin{cases} \frac{200}{f_y} = \frac{200}{50000} = 0.004 \\ \frac{3\sqrt{f_c}}{f_y} = \frac{3\sqrt{3000}}{50000} = 0.00329 \end{cases} \Rightarrow \rho_{\min} = 0.004$$

$0.0429 > 0.004$

Section works for minimum reinforcement.

Example - T-Beam

Compute ω and check that the c value is greater than h_f

$$\omega = \rho \frac{f_y}{f'_c} = 0.0429 \left(\frac{50 \text{ ksi}}{3 \text{ ksi}} \right) = 0.7155$$

$$h_f \leq \frac{1.18\omega d}{\beta_1} \Rightarrow 3 \text{ in.} \leq \frac{1.18(0.7155)(16.5 \text{ in.})}{0.85} = 16.388$$

$$h_f \leq a \Rightarrow 3 \text{ in.} \leq 3.09 \text{ in.}$$

Analysis the beam as a T-beam.

Example - T-Beam

Compute ω and check that the c value is greater than h_f

$$A_{sf} = \frac{0.85 f'_c (b_{\text{eff}} - b_w) h_f}{f_y} = \frac{0.85(3 \text{ ksi})(54 \text{ in.} - 12 \text{ in.})(3 \text{ in.})}{(50 \text{ ksi})}$$
$$= 6.426 \text{ in}^2$$

Compute a

$$a = \frac{(A_s - A_{sf}) f_y}{0.85 f'_c b_w} = \frac{(8.5 \text{ in}^2 - 6.426 \text{ in}^2)(50 \text{ ksi})}{0.85(3 \text{ ksi})(12 \text{ in.})}$$
$$= 3.889 \text{ in.}$$

Example - T-Beam

Compute nominal moment components

$$\begin{aligned} M_{n1} &= (A_s - A_{sf}) f_y \left(d - \frac{a}{2} \right) \\ &= (8.5 \text{ in}^2 - 6.426 \text{ in}^2)(50 \text{ ksi}) \left(16.5 \text{ in.} - \frac{3.889 \text{ in.}}{2} \right) \\ &= 1535.34 \text{ k-in.} \end{aligned}$$

$$\begin{aligned} M_{n2} &= A_{sf} f_y \left(d - \frac{h_f}{2} \right) = (6.426 \text{ in}^2)(50 \text{ ksi}) \left(16.5 \text{ in.} - \frac{3 \text{ in.}}{2} \right) \\ &= 4819.5 \text{ k-in.} \end{aligned}$$

Example - T-Beam

Compute nominal moment

$$\begin{aligned}M_n &= M_{n1} + M_{n2} \\&= 1535.34 \text{ k-in.} + 4819.5 \text{ k-in.} \\&= 6354.84 \text{ k-in.} \Rightarrow 529.57 \text{ k-ft.}\end{aligned}$$

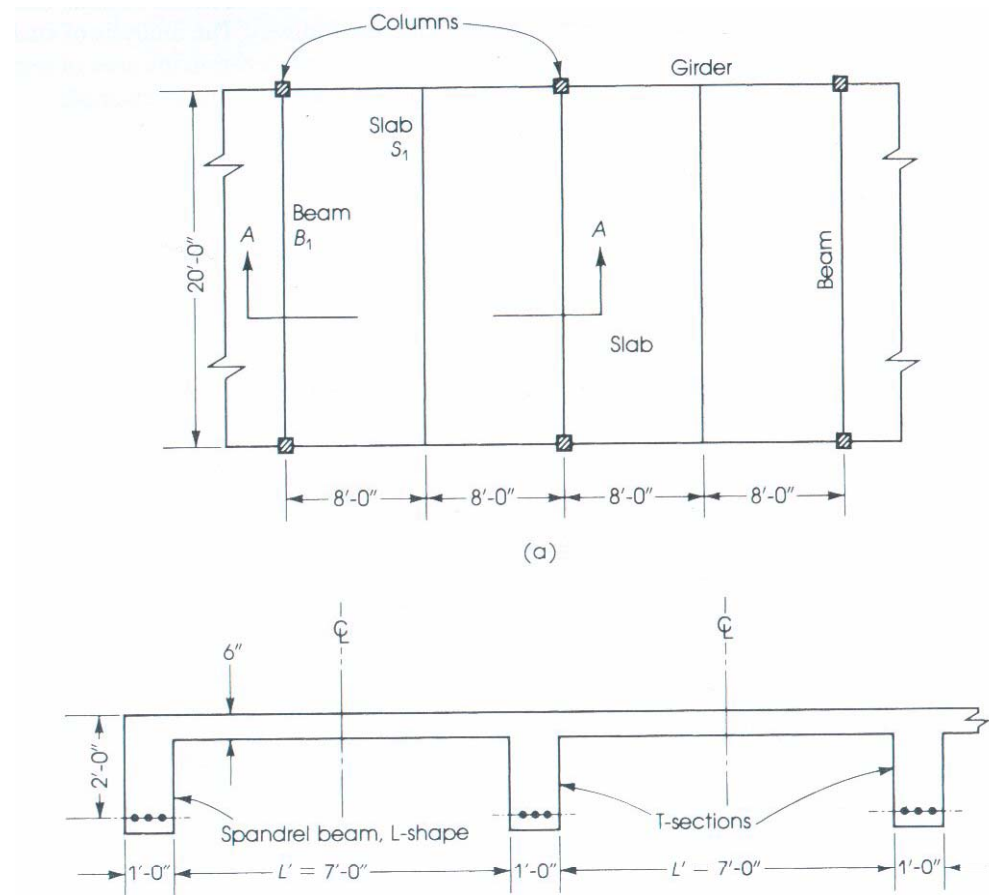
Compute ultimate moment

$$\begin{aligned}M_u &= \phi M_n = 0.9(529.57 \text{ k-ft.}) \\&= 416.6 \text{ k-ft.}\end{aligned}$$

Example of L-Beam

Determine the effective b for the spandrel beam and do the analysis.

Use 4 #9 bars and find the ultimate moment capacity.
 $f_y = 50$ ksi, $f_c = 3$ ksi



Example of L-Beam

Compute b_{eff}

$$b_{\text{eff}} \leq \frac{L}{12} + b_w$$

$$\leq 6h_f + b_w$$

$$\leq b_{\text{actual}} = b_w + 0.5 * (\text{clear distance to next web})$$

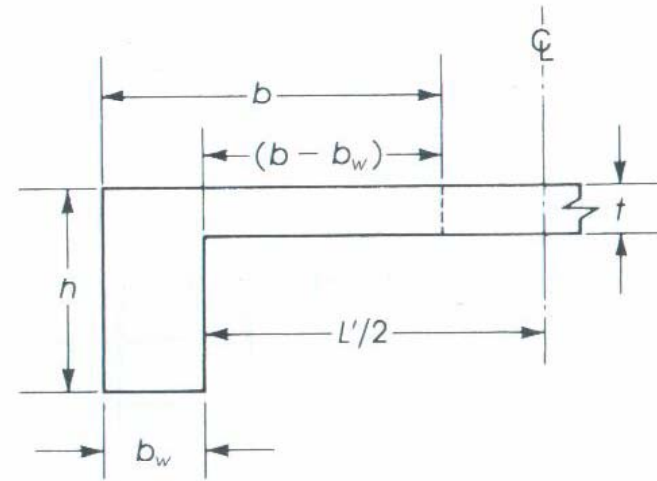


Diagram (a) illustrates a portion of a continuous slab and beam system. The slab is labeled "Slab S_1 " and "Slab". The beam is labeled "Beam B_1 ". The system is supported by "Columns". The height of the slab is 20'-0". The width of the slab is divided into four equal segments of 8'-0" each. The beam is labeled "A" at both ends.

Diagram showing the elevation view of the wall section. The wall has a total height of 2'-0" and a thickness of 6". The spandrel beam is L-shaped and 1'-0" high. The T-sections are 7'-0" long and 1'-0" high. The wall is supported by a foundation.

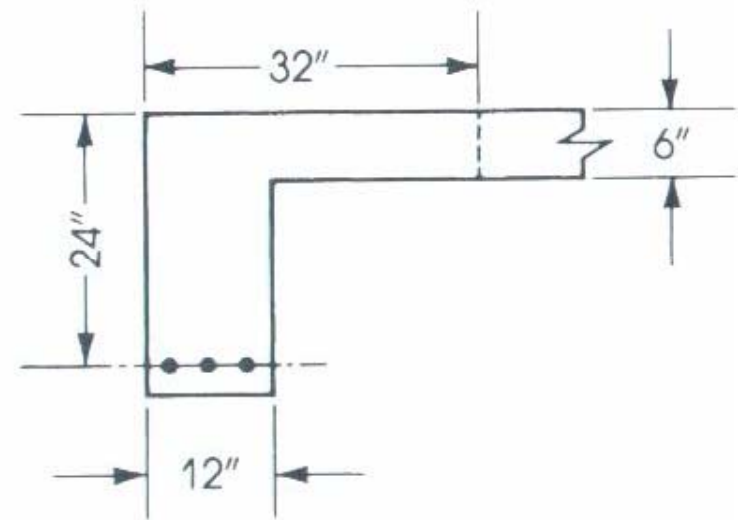
$$= 12 \text{ in.} + 0.5 * \left(7 \text{ ft} \left(\frac{12 \text{ in.}}{\text{ft}} \right) \right) = 54 \text{ in.}$$

Example of L-Beam

The value b_{eff} and A_s

$$b_{\text{eff}} = 32 \text{ in.}$$

$$A_s = 4(1.0 \text{ in}^2) = 4.0 \text{ in}^2$$



Example - L-Beam

Compute the equivalent c value and check the strain in the steel, ε_s

$$a = \frac{A_s f_y}{0.85 f'_c b_{\text{eff}}} = \frac{(4.0 \text{ in}^2)(50 \text{ ksi})}{0.85(3 \text{ ksi})(32 \text{ in.})} = 2.45 \text{ in.}$$

$$c = \frac{a}{\beta_1} = \frac{2.45 \text{ in}}{0.85} = 2.88 \text{ in.}$$

$$\varepsilon_s = \left(\frac{d}{c} - 1 \right) 0.003 = \left(\frac{24 \text{ in.}}{2.88 \text{ in.}} - 1 \right) 0.003 = 0.0220 > 0.005$$

Steel will yield in the tension zone.

Example - L-Beam

Compute the reinforcement ρ and check to make sure it is greater than $\rho_{\min}$

$$\rho = \frac{A_s}{b_w d} = \frac{(4.0 \text{ in}^2)}{(12 \text{ in.})(24 \text{ in.})} = 0.0139$$

$$\rho_{\min} = \begin{cases} \frac{200}{f_y} = \frac{200}{50000} = 0.004 \\ \frac{3\sqrt{f_c}}{f_y} = \frac{3\sqrt{3000}}{50000} = 0.00329 \end{cases} \Rightarrow \rho_{\min} = 0.004$$

$0.0139 > 0.004$

Section works for minimum reinforcement.

Example - T-Beam

Compute ω and check that the c value is greater than h_f

$$\omega = \rho \frac{f_y}{f'_c} = 0.0139 \left(\frac{50 \text{ ksi}}{3 \text{ ksi}} \right) = 0.2315$$

$$h_f \leq \frac{1.18\omega d}{\beta_1} \Rightarrow 6 \text{ in.} \leq \frac{1.18(0.2315)(24 \text{ in.})}{0.85} = 7.71 \text{ in.}$$

$$h_f \leq a \Rightarrow 6 \text{ in.} \leq 2.45 \text{ in.}$$

False!

Analysis the beam as a Singly reinforced beam.