

INSTRUCTOR'S SOLUTIONS MANUAL

# REINFORCED CONCRETE

A FUNDAMENTAL APPROACH  
SIXTH EDITION

EDWARD G. NAWY



Upper Saddle River, New Jersey 07458

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**About the Cover:** Shown is the Milwaukee Art Museum, Milwaukee, Wisconsin. Construction in reinforced and prestressed concrete in various shapes that include cantilevered canopies and a unique cable-stayed bridge. Rows of exposed situ-cast concrete arches form a galleria that overlooks Lake Michigan. Designed by Architect Santiago Calatrava and opened in 2002. Photo courtesy Professor Tarun Naik, University of Wisconsin at Milwaukee.

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5.1. For the beam cross-section shown in Fig. 5.33 determine whether the failure of the beam will be initiated by crushing of concrete or yielding of steel. Given:

$$f'_c = 4000 \text{ psi (27.6 MPa) for case (a), } A_s = 10 \text{ in.}^2$$

$$f'_c = 7000 \text{ psi (48.3 MPa) for case (b), } A_s = 5 \text{ in.}^2$$

$$f_y = 60,000 \text{ psi (414 MPa)}$$

Also determine whether the section satisfies ACI Code requirements.

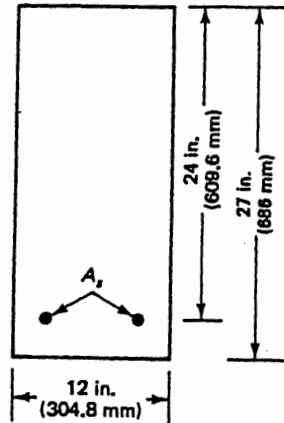


Figure 5.33

Solution:

a)  $\beta_1 = 0.85$

$$A_s = 10 \text{ in.}^2$$

$$f_y = 60,000 \text{ psi}$$

$$f'_c = 4,000 \text{ psi}$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(10)(60,000)}{0.85(4,000)(12)} = 14.71 \text{ inches}$$

$$c = \frac{a}{\beta_1} = \frac{14.71}{0.85} = 17.31 \text{ inches}$$

$$\frac{c}{d_t} = \frac{17.31}{24} = 0.72 > 0.60$$

$\therefore$  Compression-controlled  
and concrete crushes before tension  
steel yields

$$b) \beta_1 = 0.85 - 0.05 \left( \frac{7,000 - 4,000}{1,000} \right) = 0.70$$

$$f'_c = 7,000 \text{ psi}$$

$$A_s = 5 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(5)(60,000)}{0.85(7,000)(12)} = 4.20 \text{ inches}$$

$$c = \frac{a}{\beta_1} = \frac{4.2}{0.70} = 6.0 \text{ inches}$$

$$\frac{c}{d_t} = \frac{6}{24} = 0.25 < 0.375 \quad \therefore \text{Tension-controlled}$$

and steel yields before concrete crushes

$$\rho = \frac{A_s}{bd} = \frac{5}{(12)(24)} = 0.017 \text{ in/in.}$$

$$\rho_{min} = \max \left\{ \frac{3\sqrt{7,000}}{60,000} = 0.0042, \frac{200}{60,000} = 0.0033 \right\} = 0.0042 \text{ in/in.}$$

$$0.017 > 0.0042 \quad \therefore \underline{O.K.} \quad \text{satisfies ACI CODE}$$



5.2. Calculate the nominal moment strength of the beam sections shown in Fig. 5.34. Given:

$$f'_c = 5000 \text{ psi (20.7 MPa) for case (a)}$$

$$f'_c = 6000 \text{ psi (41.4 MPa) for case (b)}$$

$$f_y = 60,000 \text{ psi (414 MPa)}$$

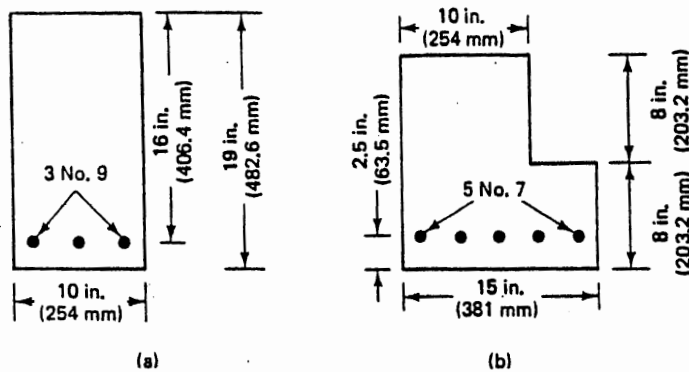


Figure 5.34

Solution:

a)  $f'_c = 5,000 \text{ psi}$

$$\beta_1 = 0.80$$

$$A_s = 3 \times 0.9 = 2.7 \text{ in}^2$$

$$b = 10 \text{ in.}$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(3)(60,000)}{0.85 (5,000)(10)} = 4.24 \text{ inches}$$

$$c = \frac{a}{\beta_1} = \frac{4.24}{0.80} = 5.29 \text{ in.}$$

$$\frac{c}{d_t} = \frac{5.29}{16} = 0.33 < 0.375 \quad \therefore \text{Tension-Controlled}$$

$$\phi = 0.90$$

$$\rho = \frac{A_s}{bd} = \frac{3}{(10)(16)} = 0.019$$

$$\rho_{min} = \max \left\{ \frac{3\sqrt{f'_c}}{f_y}, \frac{200}{f_y} \right\} = 0.0035 < 0.019 \quad \underline{\text{O.K.}}$$

$$M_n = A_s f_y (d - a/2) = (3)(60,000) \left( 16 - \frac{4.24}{2} \right) = 2,498,824 \text{ in-lb}$$

$$M_u = \phi M_n = 0.90 (2,498,824) = 2,248,941 \text{ in-lb.}$$

b)  $f'_c = 6,000 \text{ psi}$

$$\beta_1 = 0.75$$

$$A_s = 510.7 = 3 \text{ in}^2$$

$$b = 10 \text{ in (assuming neutral axis is within top 8 inches)}$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(3)(60,000)}{0.85(6,000)(10)} = 3.53 \text{ in.}$$

$$c = a/\beta_1 = 4.71 \text{ in} < 8 \text{ in.} \quad \therefore b = 10 \text{ in.} \quad \underline{\text{O.K.}}$$

$$\frac{c}{d_t} = \frac{4.71}{13.5} = 0.35 < 0.375 \quad \therefore \text{Tension-controlled} \quad \phi = 0.90$$

$$\rho = \frac{A_s}{bd} = 0.022 \quad \rho_{min} = \max \left\{ \frac{3\sqrt{f'_c}}{f_y}, \frac{200}{f_y} \right\} = 0.0039 < 0.022 \quad \underline{\text{O.K.}}$$

$$M_n = A_s f_y (d - a/2) = (3)(60,000) \left( 13.5 - \frac{3.53}{2} \right) = 2,112,353 \text{ in-lb}$$

$$M_u = \phi M_n = 0.9 M_n = 1,901,118 \text{ in-lb.}$$

5.3. Calculate the safe distributed load intensity that the beam shown in Fig. 5.35 can carry. Given:

$$f'_c = 4000 \text{ psi (27.6 MPa), normal-weight concrete}$$

$$f_y = 60,000 \text{ psi (414 MPa)}$$

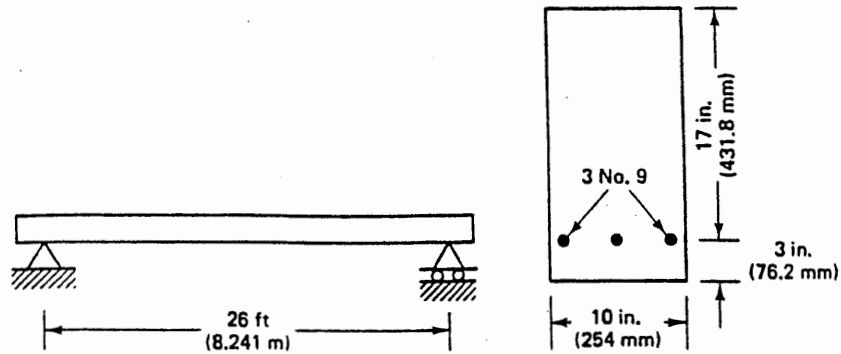


Figure 5.35

Solution:

Given

$$b = 10 \text{ in.}$$

$$f'_c = 4,000 \text{ psi}$$

$$h = 20 \text{ in.}$$

$$f_y = 60,000 \text{ psi}$$

$$d_t = 17 \text{ in.}$$

$$\beta_1 = 0.85$$

$$A_s = 3 \times 0.9 = 3.0 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(3)(60,000)}{(0.85)(4,000)(10)} = 5.29 \text{ in.}$$

$$c = \frac{a}{\beta_1} = \frac{5.29}{0.85} = 6.23 \text{ in.}$$

$$\frac{c}{d_t} = \frac{6.23}{17} = 0.37 < 0.375 \quad \therefore \text{Tension-controlled} \quad \phi = 0.90$$

$$\rho = \frac{A_s}{bd} = \frac{(3)}{(10)(17)} = 0.018$$

$$\rho_{\min} = \max \left\{ \frac{3 \sqrt{f'_c}}{f_y}, \frac{200}{f_y} \right\} = 0.0033 < 0.018$$

$\therefore$  Satisfies ACI  
CODE Requirement

$$M_n = A_s f_y (d - a/2) = (3)(60,000)(17 - \frac{5.29}{2}) = 2,583,529 \text{ in.-lb.}$$

$$\phi M_n = (0.9)(2,583,529) = 2,325,176 \text{ in.-lb.}$$

maximum applied moment

$$M_u = \frac{w_u l^2}{8} = 2,325,176 \text{ in.-lb}$$

$$w_u = \frac{(2,325,176)(8)}{(28 \times 12)^2} = 191.1 \text{ lb/in} = 2293 \text{ lb/ft.}$$

$$w_u = 1.2 \text{ DL} + 1.6 \text{ LL}$$

$$\text{DL} = \frac{(150 \text{ lb/ft}^3)(10 \times 20)}{144} = 208.3 \text{ lb/ft.}$$

$\therefore$

$$2293 = 1.2(208.3) + 1.6 \text{ LL} \Rightarrow \text{LL} = 1277 \text{ lb/ft.}$$

5.4. Design a one-way slab to carry a live load of 100 psf and an external dead load of 50 psf. The slab is simply supported over a span of 12 ft. Given:

$$f'_c = 4000 \text{ psi (27.6 MPa), normal-weight concrete}$$

$$f_y = 60,000 \text{ psi (414 MPa)}$$

Solution:

Design as a 1 ft. wide singly reinforced section.

$$\text{Try, } \min h = \frac{L}{20} = \frac{(12)(12)}{20} = 7.2 \text{ in.}$$

$$\text{Try } h = 8 \text{ in.}, d_t = 7 \text{ in.}; b = 12 \text{ in.}$$

$$\text{Self-weight} = (150) \frac{(8)(12)}{144} = 100 \text{ lb/ft.}$$

$$DL = (50 \frac{\text{lb}}{\text{ft}^2})(1 \text{ ft}) = 50 \text{ lb/ft}$$

$$LL = (100 \frac{\text{lb}}{\text{ft}^2})(1 \text{ ft}) = 100 \text{ lb/ft.}$$

$$\therefore w_u = 1.2(100 + 50) + 1.6(100) = 340 \text{ lb/ft.}$$

$$M_u = \frac{w_u l^2}{8} = \frac{(340 \text{ lb/ft})(12 \text{ ft})^2}{8} = 6,120 \text{ ft-lb} = 73,440 \text{ in.-lb.}$$

Required nominal moment strength:

$$M_n = \frac{73,440}{0.90} = 81,600 \text{ in.-lb.}$$

$$\text{Assume } (d - a/2) \approx 0.9 d = 0.9(7) = 6.3 \text{ in.}$$

$$M_n = A_s f_y (d - a/2)$$

$$81,600 = A_s (60,000)(6.3)$$

$$A_s = 0.22 \text{ in}^2 / 12\text{-in strip}$$

$$P_{\min} = \max \left\{ \frac{3\sqrt{f'_c}}{f_y}, \frac{200}{f_y} \right\} = 0.0033 \quad \therefore \min A_s = (0.0033)(12)(7) = 0.27 \text{ in}^2 / 12\text{-in strip}$$

$$\therefore \text{try } A_s = 0.28 \text{ in}^2 / 12\text{-in strip} \quad (\#4 \text{ bars at } 8.5 \text{ in c-c})$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(0.28)(60,000)}{0.85(4000)(12)} = 0.41 \text{ in.}$$

$$c = \frac{a}{\beta_1} = \frac{0.41}{0.85} = 0.48 \text{ in.}$$

$$\frac{c}{d_t} = \frac{0.48}{7} = 0.069 < 0.375 \quad \therefore \text{Tension-controlled} \quad \phi = 0.90$$

Actual nominal moment strength.

$$M_n = A_s f_y (d - a/2) = (0.28)(60,000) \left( 7 - \frac{0.41}{2} \right) = 114,156 \text{ in-lb}$$

$$114,156 \text{ in-lb} > \text{Req'd } 81,600 \text{ in-lb} \quad \underline{\text{O.K.}}$$

Shrinkage and Temperature Reinforcement:

$$\text{Req'd steel area} = 0.0018 (12)(8) = 0.17 \text{ in}^2 / 12\text{-in strip}$$

$$\text{maximum spacing} = \min \{ 5(8) = 40 \text{ in}, 18 \text{ in} \} = 18 \text{ in.}$$

$$\therefore \text{use } \#4 \text{ bar @ } 14 \text{ in. c-c} \quad (A_s = 0.17 \text{ in}^2 / 12\text{-in strip})$$

5.5. Design the simply supported beams shown in Fig. 5.36 as rectangular sections. Given:

$$f'_c = 5000 \text{ psi (34.5 MPa), normal-weight concrete}$$

$$f_y = 60,000 \text{ psi (414 MPa)}$$

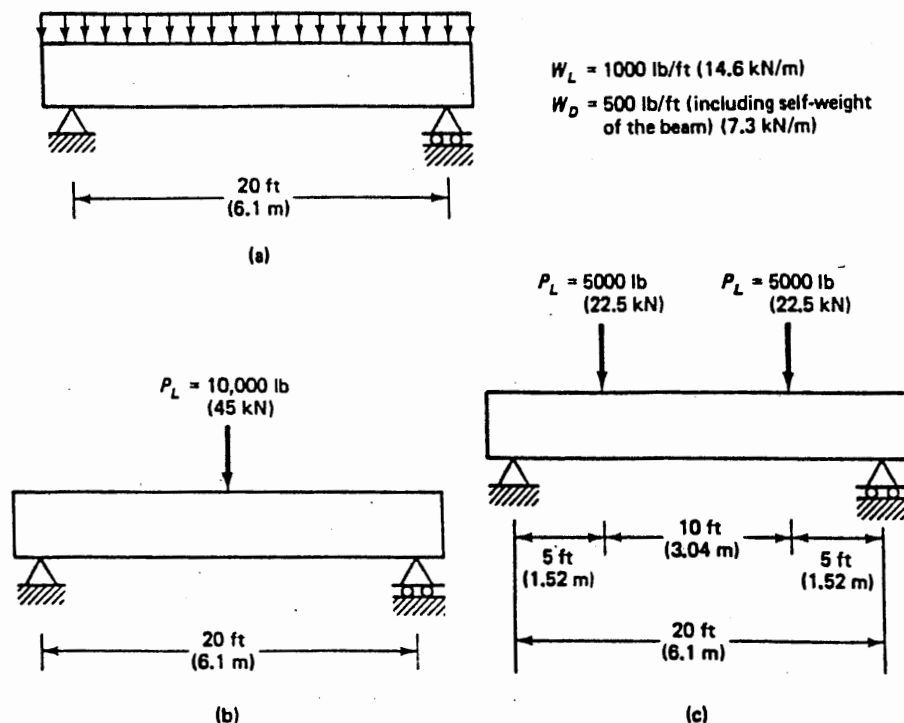


Figure 5.36

Solution:

$$a) \quad w_u = 1.2 DL + 1.6 LL = 1.2(500) + 1.6(1,000) = 2200 \text{ lb/ft.}$$

$$M_u = \frac{w_u l^2}{8} = \frac{(2200)(20)^2}{8} \times 12 = 1,320,000 \text{ in-lb}$$

Required nominal moment strength:

$$M_n = \frac{1,320,000}{0.90} = 1,466,667 \text{ in-lb}$$