May 25, 2004

ERRATA (Rev. 1)

PCA Notes on ACI 318-02 Building Code Requirements for Structural Concrete with Design Calculations (Publication EB702)

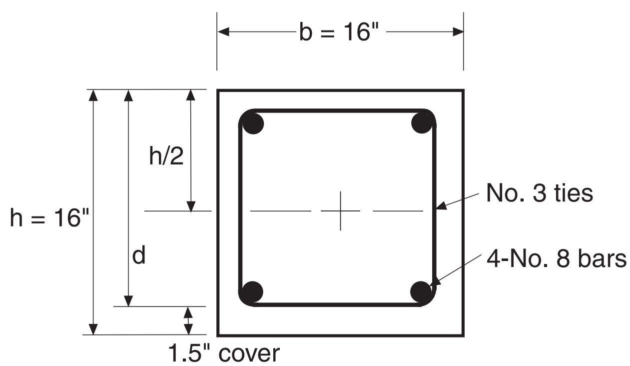
1. Page 3-7, Figure 3-1. Add a bottom, straight bar (positive reinforcement) to the end span, below the bent-up bar. The bar extends between the locations showing captions "End of bar at discontinuous end, ± 1 in." and "End of bar, ±2 in.". These locations represent the left and right ends of the missing bar, respectively.
2. Page 3-17, Figure 3-12. Change the caption for the negative (top) reinforcement at the interior support from "$-A_{s1}$" to "$-A_{s2}$". Also, change the caption for the positive (bottom) reinforcement of the interior span from "$+A_{s1}$" to "$+A_{s2}$".
3. Page 5-5, fifth line from bottom of page. Insert "ϕ" at beginning of expression so as to read: $\phi[A_s f_y(d-a/2)] \geq 1.2M_d + 1.6\ M_\ell \geq 1.4\ M_d$
4. Page 6-30. Add a new, missing line at the bottom of the page:
   $f_s' = E_s \times \varepsilon_s = 29{,}000 \times 0.00202 = 58.7$ ksi
5. Pages 6-34 to 6-39. Some parts of the calculations and a figure are missing from Example 6.4. Replace these pages with the attached ones.
6. Page 7-34, last expression under Step 4. In the denominator, change "30" to "10". The answer becomes 0.0158 > 0.0033 O.K..
7. Page 10-23. At the end of the heading of Item 4, change "Table 8-2" to "Table 10-2." Also, at the end of the heading of Item 5, change "Eq. (9-7)" to "Eq. (9-8)."
8. Page 17-12, Step 6, Line 5. Revise in part to read: "Nodal Zones A and B are…"
9. Page 24-14, Table 24-5. In the heading of the second column from the right, change "$f_c' = 7000$" to "$f_c' = 8000$". In the heading of the first column from the right, change "$f_c' = 8000$" to "$f_c' = 10{,}000$".
10. Page 24-29, Step 5, Line 2. Change expression to read:
    $c/d_p = 5.8/30.0 = 0.19 < 0.375$
    (*By definition, dimension* "d_p" *should be measured to the bottom strand*.)
11. Page 24-29, Example No. 24.5.2, Step 3, Line 3. Change expression to read:
    $c/d_p = 3.1/30 = 0.10 < 0.375$

Example 6.4—Load-Moment Strength, P_n and M_n, for Given Strain Conditions

For the column section shown, calculate the load-moment strength, P_n and M_n, for four strain conditions:

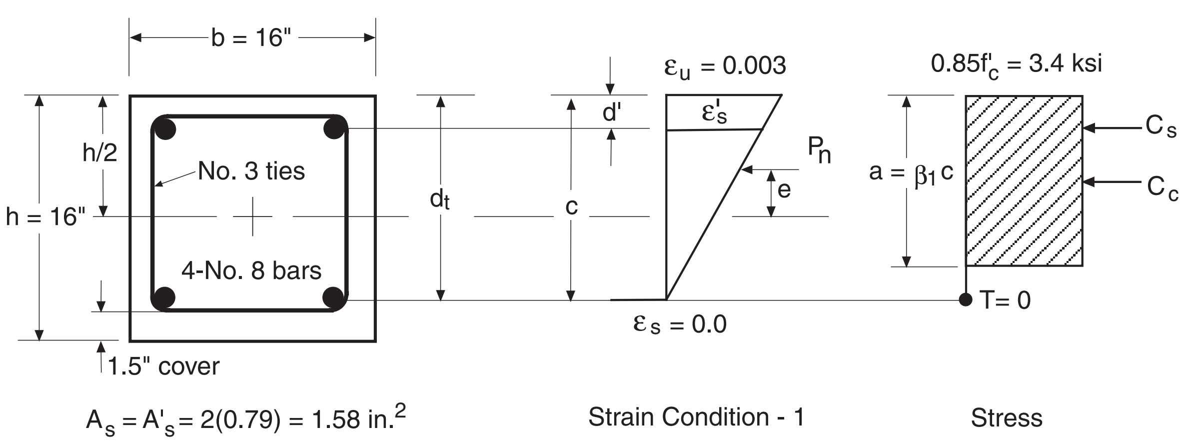
1. Bar stress near tension face of member equal to zero, $f_s = 0$
2. Bar stress near tension face of member equal to $0.5f_y$ ($f_s = 0.5f_y$)
3. At limit for compression-controlled section ($\varepsilon_t = 0.002$)
4. At limit for tension-controlled sections ($\varepsilon_t = 0.005$).

Use $f'_c = 4000$ psi, and $f_y = 60{,}000$ psi.



Calculations and Discussion	Code Reference

1. Load-moment strength, P_n and M_n, for Strain Condition 1: $\varepsilon_s = 0$



a. Define stress distribution and determine force values. *10.2.7*

$$d' = \text{Cover} + \text{No. 3 tie dia.} + \frac{d_b}{2} = 1.5 + 0.375 + 0.5 = 2.38 \text{ in.}$$

$d_t = 16 - 2.38 = 13.62$ in.

Since $\varepsilon_s = 0$, $c = d_t = 13.62$ in. *10.2.7.2*

$a = \beta_1 c = 0.85\,(13.62) = 11.58$ in. *10.2.7.1*

where $\beta_1 = 0.85$ for $f'_c = 4000$ psi *10.2.7.3*

$C_c = 0.85 f'_c ba = 0.85 \times 4 \times 16 \times 11.58 = 630.0$ kips *10.2.7*

$$\varepsilon_y = \frac{f_y}{E_s} = \frac{60}{29{,}000} = 0.00207$$ *10.2.4*

From strain compatibility:

$$\varepsilon'_s = \varepsilon_u \left(\frac{c - d'}{c}\right) = 0.003\left(\frac{13.62 - 2.38}{13.62}\right) = 0.00248 > \varepsilon_y = 0.00207$$ *10.2.2*

Compression steel has yielded.

$C_s = A'_s f_y = 1.58\,(60) = 94.8$ kips

b. Determine P_n and M_n from static equilibrium.

$P_n = C_c + C_s = 630.0 + 94.8 = 724.8$ kips *Eq. (16)*

$$M_n = P_n e = C_c\left(\frac{h}{2} - \frac{a}{2}\right) + C_s\left(\frac{h}{2} - d'\right)$$ *Eq. (17)*

$$= 630\,(8.0 - 5.79) + 94.8\,(8.0 - 2.38) = 1925.1 \text{ in.-kips} = 160.4 \text{ ft-kips}$$

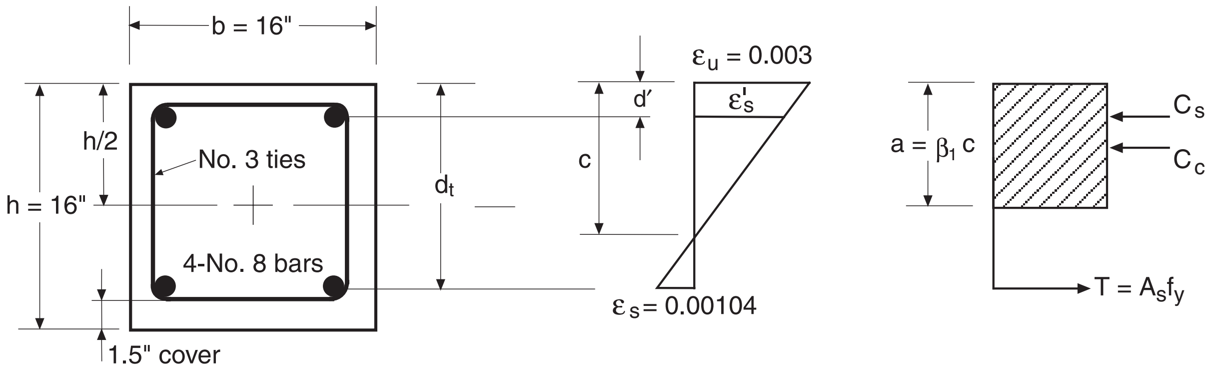
$$e = \frac{M_n}{P_n} = \frac{1925.1}{724.8} = 2.66 \text{ in.}$$

Therefore, for strain condition $\varepsilon_s = 0$:

Design axial load strength, $\phi P_n = 0.65\,(724.8) = 471.1$ kips *9.3.2.2*

Design moment strength, $\phi M_n = 0.65\,(160.4) = 104.3$ ft-kips

2. Load-moment strength, P_n and M_n, for Strain Condition 2: $\varepsilon_s = 0.5\varepsilon_y$



Strain Condition - 2

Stress

a. Define stress distribution and determine force values. *10.2.7*

$d' = 2.38$ in., $d_t = 13.62$ in.

From strain compatibility:

$$\frac{c}{0.003} = \frac{d_t - c}{0.5\varepsilon_y}$$

$$c = \frac{0.003d_t}{0.5\varepsilon_y + 0.003} = \frac{0.003 \times 13.62}{0.00104 + 0.003} = 10.13 \text{ in.}$$

Strain in compression reinforcement:

$$\varepsilon'_s = \varepsilon_u \left(\frac{c - d'}{c}\right) = 0.003\left(\frac{10.13 - 2.38}{10.13}\right) = 0.00230 > \varepsilon_y = 0.00207$$

Compression steel has yielded.

$a = \beta_1 c = 0.85\,(10.13) = 8.61$ in. *10.2.7.1*

$C_c = 0.85 f'_c ba = 0.85 \times 4 \times 16 \times 8.61 = 468.4$ kips *10.2.7*

$C_s = A'_s f_y = 1.58\,(60) = 94.8$ kips

$T = A_s f_s = A_s\,(0.5f_y) = 1.58\,(30) = 47.4$ kips

b. Determine P_n and M_n from static equilibrium. *Eq. (16)*

$P_n = C_c + C_s - T = 468.4 + 94.8 - 47.4 = 515.8$ kips *Eq. (17)*

$$M_n = P_n e = C_c\left(\frac{h}{2} - \frac{a}{2}\right) + C_s\left(\frac{h}{2} + d'\right) + T\left(d - \frac{h}{2}\right)$$

$$= 468.4\,(8.0 - 4.31) + 94.8\,(8.0 - 2.38) + 47.4\,(13.62 - 8.0)$$

$$= 2527.6 \text{ in.-kips} = 210.6 \text{ ft-kips}$$

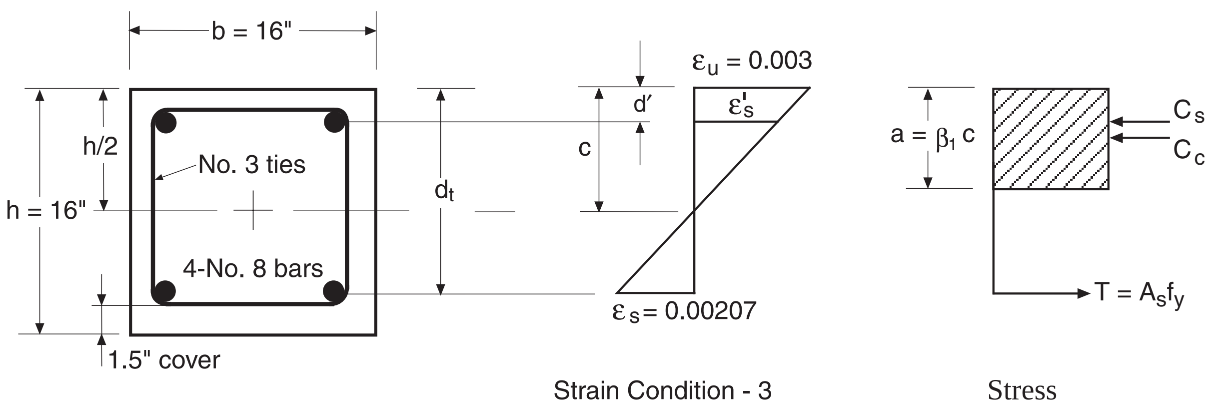
$$e = \frac{M_n}{P_n} = \frac{2527.6}{515.8} = 4.90 \text{ in.}$$

Therefore, for strain condition $\varepsilon_s = 0.5\varepsilon_y$:

Design axial load strength, $\phi P_n = 0.65\,(515.8) = 335.3$ kips *9.3.2.2*

Design moment strength, $\phi M_n = 0.65\,(210.6) = 136.9$ ft-kips

3. Load-moment strength, P_n and M_n, for Strain Condition 3: $\varepsilon_s = \varepsilon_y$



a. Define stress distribution and determine force values. *10.2.7*

$d' = 2.38$ in., $d_t = 13.62$ in.

From strain compatibility:

$$\frac{c}{0.003} = \frac{d_t - c}{\varepsilon_y}$$

$$c = \frac{0.003d_t}{\varepsilon_y + 0.003} = \frac{0.003 \times 13.62}{0.00207 + 0.003} = 8.06 \text{ in.}$$

Note: The code permits the use of 0.002 as the strain limit for compression-controlled sections with Grade 60 steel. It is slightly conservative, and more consistent, to use the yeild strain of 0.00207.

Strain in compression reinforcement:

$$\varepsilon_s' = \varepsilon_u \left(\frac{c - d'}{c}\right) = 0.003\left(\frac{8.06 - 2.38}{8.06}\right) = 0.00211 > \varepsilon_y = 0.00207$$

Compression steel has yielded.

$a = \beta_1 c = 0.85\,(8.06) = 6.85$ in. *10.2.7.1*

$C_c = 0.85 f_c' ba = 0.85 \times 4 \times 16 \times 6.85 = 372.7$ kips *10.2.7*

$C_s = A_s' f_y = 1.58\,(60) = 94.8$ kips

$T = A_s f_s = A_s f_y = 1.58\,(60) = 94.8$ kips

b. Determine P_n and M_n from static equilibrium. *Eq. (16)*

$P_n = C_c + C_s - T = 372.7 + 94.8 - 94.8 = 372.7$ kips *Eq. (17)*

$$M_n = P_n e = C_c\left(\frac{h}{2} - \frac{a}{2}\right) + C_s\left(\frac{h}{2} + d'\right) + T\left(d - \frac{h}{2}\right)$$

$$= 372.7\,(8.0 - 3.43) + 94.8\,(8.0 - 2.38) + 94.8\,(13.62 - 8.0)$$

$$= 2770.5 \text{ in.-kips} = 230.9 \text{ ft-kips}$$

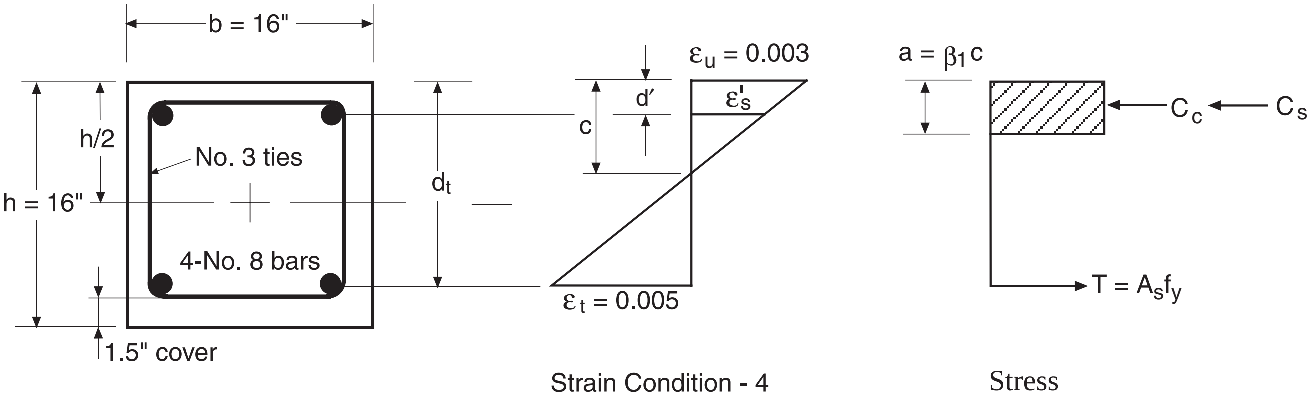
$$e = \frac{M_n}{P_n} = \frac{2770.5}{372.7} = 7.43 \text{ in.}$$

Therefore, for strain condition $\varepsilon_s = \varepsilon_y$:

Design axial load strength, $\phi P_n = 0.65\,(372.7) = 242.3$ kips *9.3.2.2*

Design moment strength, $\phi M_n = 0.65\,(230.9) = 150.1$ ft-kips

4. Load-moment strength, P_n and M_n, for Strain Condition 4: $\varepsilon_s = 0.005$



a. Define stress distribution and determine force values. *10.2.7*

$d' = 2.38$ in., $d_t = 13.62$ in.

From strain compatibility:

$$\frac{c}{0.003} = \frac{d - c}{0.005}$$

$$c = \frac{0.003d}{0.005 + 0.003} = \frac{0.003 \times 13.62}{0.005 + 0.003} = 5.11 \text{ in.}$$

Strain in compression reinforcement:

$$\varepsilon'_s = \varepsilon_u \left(\frac{c - d'}{c}\right) = 0.003\left(\frac{5.11 - 2.38}{5.11}\right) = 0.00160 < \varepsilon_y = 0.00207$$

Compression steel has not yielded.

$f'_s = \varepsilon'_s E'_s = 0.00160\,(29{,}000) = 46.5$ ksi

$a = \beta_1 c = 0.85\,(5.11) = 4.34$ in. *10.2.7.1*

$C_c = 0.85 f'_c ba = 0.85 \times 4 \times 16 \times 4.34 = 236.2$ kips *10.2.7*

$C_s = A'_s f_y = 1.58\,(46.5) = 73.5$ kips

$T = A_s f_s = A_s\,(f_y) = 1.58\,(60) = 94.8$ kips

b. Determine P_n and M_n from static equilibrium. *Eq. (16)*

$P_n = C_c + C_s - T = 236.2 + 73.5 - 94.8 = 214.9$ kips *Eq. (17)*

$$M_n = P_n e = C_c\left(\frac{h}{2} - \frac{a}{2}\right) + C_s\left(\frac{h}{2} + d'\right) + T\left(d - \frac{h}{2}\right)$$

$$= 236.2\,(8.0 - 2.17) + 73.5\,(8.0 - 2.38) + 94.8\,(13.62 - 8.0)$$

$$= 2322.9 \text{ in.-kips} = 193.6 \text{ ft-kips}$$

$$e = \frac{M_n}{P_n} = \frac{2322.9}{214.9} = 10.81 \text{ in.}$$

Therefore, for strain condition $\varepsilon_s = 0.005$:

Design axial load strength, $\phi P_n = 0.9\,(214.9) = 193.4$ kips *9.3.2.2*

Design moment strength, $\phi M_n = 0.9\,(193.6) = 174.2$ ft-kips

A complete interaction diagram for this column is shown in Fig. 6-25.

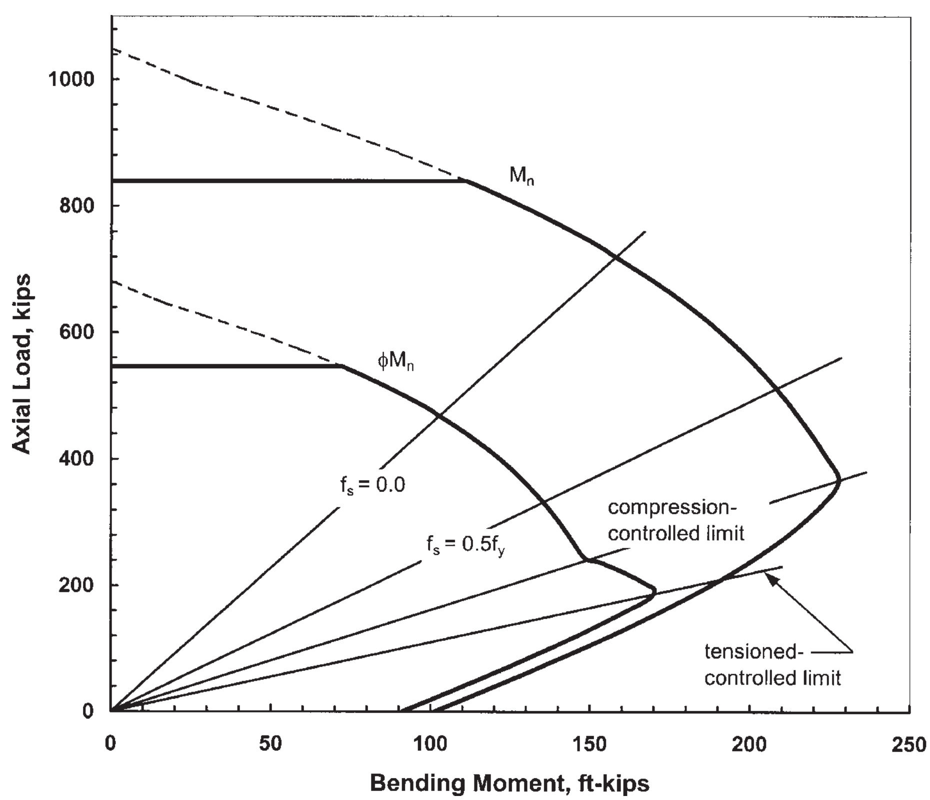


Figure 6-25 Interaction Diagram