Walls

The following example illustrate the design methods presented in the PCA book "Simplified Design - Reinforced Concrete Buildings of Moderate Size and Height" third edition. Unless otherwise noted, all referenced table, figure, and equation numbers are from that book. The example presented here is for Walls.

Examples for columns are available on our Web page: www.cement.org/buildings.

Design Data

In this example, the 8-in. thick wall below, which is part of a 5-story building, is designed and detailed for gravity loads and the wind forces shown.

Materials

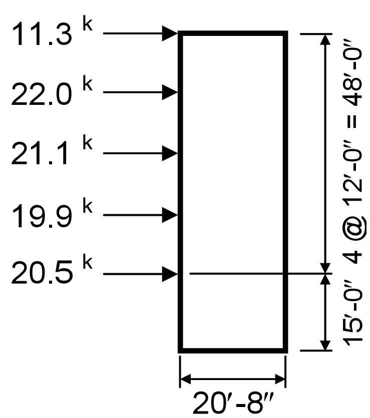
- Concrete: normal weight (150 pcf), 3/4-in. maximum aggregate, f'_c = 4,000 psi
- Mild reinforcing steel: Grade 60 (f_y = 60,000 psi)

Loads

- Total roof dead load = 122 psf
- Total floor dead load = 142 psf
- Live load = 100 psf (floor), 20 psf (roof)
- Wind loads: per ASCE 7-02

Building Data

- Tributary floor area to wall = 300 ft^2



Design for Shear

• Check shear strength in 1st story

Total shear = 11.3 + 22.0 + 21.1 + 19.9 + 20.5 = 94.8 kips

Per ACI 318-05 Sect. 9.2, V_u = 1.6 x 94.8 = 151.7 kips

From Table 6-5, for an 8-in. thick wall, ϕV_c = 7.3 x 20.67 = 150.9 kips

Since $V_u > \phi V_c$, provide horizontal shear reinforcement from Table 6-4.

From Table 6-5.
ϕV_n = 36.4 x 20.67 = 752.3 kips > V_u = 151.7 kips

Therefore, Wall cross-section is adequate.

Determine required horizontal shear reinforcement:
$\phi V_s = V_u - \phi V_c$ = 151.7 - 150.9 = 0.8 kips

ϕV_s = 0.8 / 20.67 = 0.04 kips/ft length of wall

Select horizontal bars from Table 6-4:

For No. 4 bars @ 18", ϕV_s = 4.8 kips/ft > 0.04 kips/ft
However, minimum wall reinforcement per Table 6-3 for an 8 in. wall is No. 4 @ 10"

Use No. 4 @ 10" horizontal reinforcement.

Determine required vertical shear reinforcement:

$\rho_\ell = 0.0025 + 0.5 (2.5 - h_w/\ell_w) (\rho_t - 0.0025)$ where h_w/l_w = 63/20.67 = 3.1

$\rho_t = A_{vh}/s_2h$ = 0.20/(10 x 8) = 0.0025

ρ_ℓ = 0.0025 + 0.5 (2.5 - 3.1) (0.0025 - 0.0025) = 0.0025

Use No. 4 @ 10" vertical reinforcement.

• Check shear strength in 2nd story

V_u = 1.6(11.3 + 22.0 + 21.1 + 19.9) = 118.9 kips

Since ϕV_c /2 = 150.9/2 = 75.4 kips < V_u = 118.9 kips < ϕV_c = 150.9 kips,
use No. 4 @ 10" for the horizontal and vertical reinforcement in the 2nd story.

• Check shear strength for the 3rd story

V_u at 3rd story = 1.6(11.3 + 22.0 + 21.1) = 87.0 kips

Since ϕV_c /2 = 75.4 kips < V_u = 87.0 < V_c = 150.9 kips use No. 4 @ 10" for the horizontal and vertical reinforcement in the 3rd story.

• Check shear strength for the 4th story and above

V_u at 4th story= 1.6(11.3 + 22.0) = 53.3 kips < ϕV_c / 2 = 75.4 kips

Provide minimum reinforcement per Table 6-2.

For 8″ wall, use No. 3 @ 11″ vertical reinforcement and No. 4 @ 12″ horizontial reinforcement.

Summary of reinforcement

• Vertical bars

1st through 3rd stories: No. 4 @ 10″

4th and 5th stories*: No. 3 @ 10″

• Horizontal bars

1st through 3rd stories: No. 4 @ 10″

4th and 5th stories: No. 4 @ 12″

* *Spacing of vertical bars reduced from 11 in. to 10 in. so that the bars in the 3rd story can be spliced with the bars in the 4th story.*

Design for Flexure

When evaluating moment strength, the load combination given in ACI Eq. (9-6) will usually govern:

U = 0.9D + 1.6W

• Dead load and wind moment in 1st story

Tributary floor area = 300 ft^2

Wall dead load = [0.150(8 x 248)]/144 = 2.1 kips/ft wall height

P_u = 0.9[(0.122 x 300) + (0.142 x 300 x 4) + (2.1 x 63)] = 305 kips

M_u = 1.6[(11.3 x 63) + (22.0 x 51) + (21.1 x 39) + (19.9 x 27) + (20.5 x 15)] = 5,603 ft-kips

• Dead loads and wind moments in 2nd and 3rd stories

In 2nd story: P_u = 239 kips
M_u = 3,327 ft-kips

In 3rd story: P_u = 178 kips
M_u = 1,900 ft-kips

In 4th story: P_u = 117 kips
M_u = 856 ft-kips

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Check moment strength based on required vertical reinforcement for shear.

• Moment strength in 1st story (No. 4 @ 10″)

A_{st} = 0.24 x 20.67 = 4.96 in.^{2}

$$\omega = \left(\frac{A_{st}}{\ell_w h}\right)\frac{f_y}{f'_c} = \left(\frac{4.96}{248 \times 8}\right)\frac{60}{4} = 0.0375$$

$$\alpha = \left(\frac{P_u}{\ell_w h f'_c}\right) = \frac{305}{248 \times 8 \times 4} = 0.0384$$

$$\frac{c}{\ell_w} = \frac{\omega + \alpha}{2\omega + 0.85\beta_1} = \frac{0.0375 + 0.0384}{(2 \times 0.0375) + (0.85 \times 0.85)} = 0.0952$$

$$\phi M_n = \phi \left[0.5 A_{st} f_y \ell_w \left(1 + \frac{P_u}{A_{st} f_y}\right)\left(1 - \frac{c}{\ell_w}\right)\right] =$$

$$= 0.9\Big[(0.5 \times 4.96 \times 60 \times 248)$$

$$\times \left(1 + \frac{305}{4.96 \times 60}\right)(1 - 0.0952)\Big]$$

= 60,848 in. - kips

= 5,070 ft - kips < M_u = 5,603 ft - kips

Therefore, increase amount of vertical reinforcement for moment strength. It can be shown that No. 5 @ 10″ (ϕM_n = 6,307 ft-kips) is adequate.

• Moment strength in 2nd story (No. 4 @ 10″)

A_{st} = 0.24 x 20.67 = 4.96 in.^{2}

ω = 0.0375

$$\alpha = \frac{239}{248 \times 8 \times 4} = 0.0301$$

$$\frac{c}{\ell_w} = \frac{0.0375 + 0.0301}{(2 \times 0.0375) + (0.85 \times 0.85)} = 0.0848$$

$$\phi M_n = 0.9 \left[(0.5 \times 4.96 \times 60 \times 248)\left(1 + \frac{239}{4.96 \times 60}\right)(1 - 0.0848)\right]$$

= 54,806 in. -kips = 4567 ft -kips > M_u = 3,327 ft - kips

• Moment strength in 4th story (No. 3 @ 10")

A_{st} = 0.13 x 20.67 = 2.69 in.^{2}

$$\omega = \left(\frac{2.69}{248 \times 8}\right)\frac{60}{4} = 0.0203$$

$$\alpha = \frac{117}{248 \times 8 \times 4} = 0.0147$$

$$\frac{c}{\ell_w} = \frac{0.0203 + 0.0147}{(2 \times 0.0203) + (0.85 \times 0.85)} = 0.0459$$

$$\phi M_n = 0.9\left[(0.5 \times 2.69 \times 60 \times 248) \times \left(1 + \frac{117}{2.69 \times 60}\right)(1 - 0.0459)\right]$$

= 29,643 in. - kips

= 2,470 ft - kips > M_u = 856 ft - kips

The required shear reinforcement is adequate for moment strength, except in the 1st story.

For comparison purposes, the PCA computer program pcaColumn was utilized to determine the adequacy of the wall in the 1st story. As can be seen from the figure, the wall is adequate with No. 4 @ 10".

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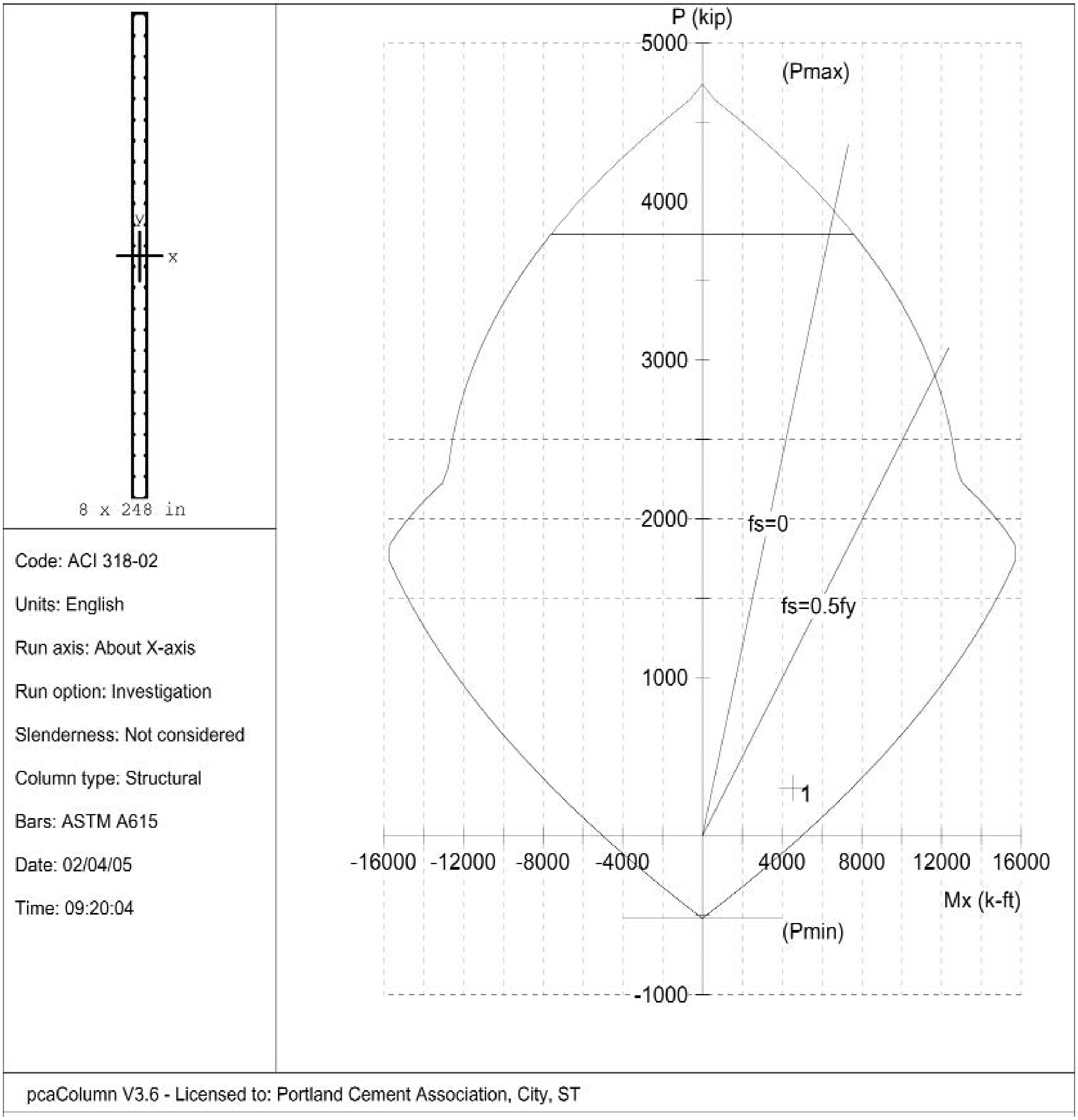
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Run option: Investigation
Slenderness: Not considered
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Bars: ASTM A615
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Time: 09:20:04
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4000
3000
2000
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(Pmax)
(Pmin)
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4000
8000
12000
16000
Mx (k-ft)
pcaColumn V3.6 - Licensed to: Portland Cement Association, City, ST