

Walls

The following example illustrates the design methods presented in the article "Timesaving Design Aids for Reinforced Concrete, Part 3: Columns and Walls," by David A. Fanella, which appeared in the November 2001 edition of Structural Engineer magazine. Unless otherwise noted, all referenced table, figure, and equation numbers are from that article. The example presented here is for walls.

Examples for columns are available on our Web page: www.portcement.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

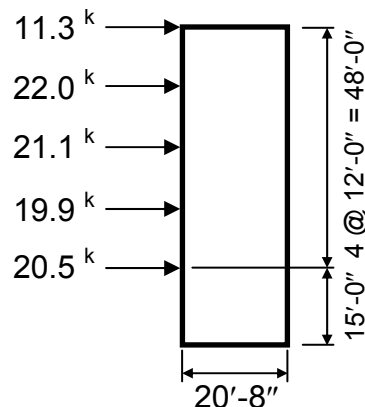
- Concrete: normal weight (150 pcf), $\frac{3}{4}$ -in. maximum aggregate, $f'_c = 4,000$ psi
- Mild reinforcing steel: Grade 60 ($f_y = 60,000$ psi)

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 7-98

Building Data

- Tributary floor area to wall = 300 ft²



Design for Shear

- Check shear strength in 1st story

$$\text{Total shear} = 11.3 + 22.0 + 21.1 + 19.9 + 20.5 = 94.8 \text{ kips}$$

Per ACI 318-99 Sect. 9.2,
 $V_u = 1.3 \times 94.8 = 123.2 \text{ kips}$

From Table 6, for an 8-in. thick wall,
 $\phi V_c = 8.3 \times 20.67 = 171.6 \text{ kips}$

Since $\phi V_c / 2 = 171.6 / 2 = 85.8 \text{ kips}$
 $< V_u = 123.2 \text{ kips} < \phi V_c = 171.6 \text{ kips}$,
 provide minimum shear reinforcement
 from Table 4.

Use No. 5 @ 15" (or No. 4 @ 10") for both
 horizontal and vertical reinforcement in
 the 1st story.

- Check shear strength in 2nd story

$$V_u = 1.3(11.3 + 22.0 + 21.1 + 19.9) = 96.6 \text{ kips}$$

Since $\phi V_c / 2 = 171.6 / 2 = 85.8 \text{ kips}$
 $< V_u = 96.6 \text{ kips} < \phi V_c = 171.6 \text{ kips}$,

use No. 5 @ 15" (or No. 4 @ 10") for the
 horizontal and vertical reinforcement in
 the 2nd story.

- Check shear strength for the 3rd story
 and above

$$V_u \text{ at } 3^{\text{rd}} \text{ story} = 1.3(11.3 + 22.0 + 21.1) = 70.7 \text{ kips}$$

$$< \phi V_c / 2 = 85.8 \text{ kips}$$

Provide minimum reinforcement from
 Table 3.

Use No. 3 @ 11" vertical reinforcement and
 No. 4 @ 12" horizontal reinforcement.

Summary of reinforcement

- Vertical bars

1st and 2nd stories: No. 4 @ 10"

3rd through 5th stories*: No. 3 @ 10"

- Horizontal bars

1st and 2nd stories: No. 4 @ 10"

3rd through 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
 2nd story.

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Design for Flexure

When evaluating moment strength, the load combination given in ACI Eq. (9-3) will usually govern:

$$U = 0.9D + 1.3W$$

- Dead load and wind moment in 1st story

$$\text{Tributary floor area} = 300 \text{ ft}^2$$

$$\begin{aligned} \text{Wall dead load} &= [0.150(8 \times 248)]/144 \\ &= 2.1 \text{ kips/ft wall height} \end{aligned}$$

$$\begin{aligned} P_u &= 0.9[(0.122 \times 300) \\ &\quad + (0.142 \times 300 \times 4) \\ &\quad + (2.1 \times 63)] \\ &= 305 \text{ kips} \end{aligned}$$

$$\begin{aligned} M_u &= 1.3[(11.3 \times 63) + (22.0 \times 51) \\ &\quad + (21.1 \times 39) + (19.9 \times 27) \\ &\quad + (20.5 \times 15)] \\ &= 4,552 \text{ ft-kips} \end{aligned}$$

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

$$\begin{aligned} \text{In 2}^{\text{nd}} \text{ story: } P_u &= 239 \text{ kips} \\ M_u &= 2,704 \text{ ft-kips} \end{aligned}$$

$$\begin{aligned} \text{In 3}^{\text{rd}} \text{ story: } P_u &= 178 \text{ kips} \\ M_u &= 1,544 \text{ ft-kips} \end{aligned}$$

Check moment strength based on required vertical reinforcement for shear. Use Fig. 5 to compute moment strength.

- Moment strength in 1st story (No. 4 @ 10")

$$A_{st} = 0.24 \times 20.67 = 4.96 \text{ in.}^2$$

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

$$\alpha = \frac{P_u}{l_w h f'_c} = \frac{305}{248 \times 8 \times 4} = 0.0384$$

$$\frac{c}{l_w} = \frac{\omega + \alpha}{2\omega + 0.85\beta_1}$$

$$= \frac{0.0375 + 0.0384}{(2 \times 0.0375) + (0.85 \times 0.85)}$$

$$= 0.0952$$

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$$\begin{aligned}\phi M_n &= \phi \left[0.5 A_{st} f_y l_w \left(1 + \frac{P_u}{A_{st} f_y} \right) \left(1 - \frac{c}{l_w} \right) \right] \\ &= 0.9 [(0.5 \times 4.96 \times 60 \times 248) \\ &\quad \times \left(1 + \frac{305}{4.96 \times 60} \right) (1 - 0.0952)] \\ &= 60,848 \text{ in. - kips} \\ &= 5,070 \text{ ft - kips} > M_u = 4,552 \text{ ft - kips}\end{aligned}$$

- Moment strength in 3rd story
(No. 3 @ 10")

$$A_{st} = 0.13 \times 20.67 = 2.69 \text{ in.}^2$$

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

$$\alpha = \frac{178}{248 \times 8 \times 4} = 0.0224$$

$$\begin{aligned}\frac{c}{l_w} &= \frac{0.0203 + 0.0224}{(2 \times 0.0203) + (0.85 \times 0.85)} \\ &= 0.0560\end{aligned}$$

$$\begin{aligned}\phi M_n &= 0.9 [(0.5 \times 2.69 \times 60 \times 248) \\ &\quad \times \left(1 + \frac{178}{2.69 \times 60} \right) (1 - 0.0560)] \\ &= 35,756 \text{ in. - kips} \\ &= 2,980 \text{ ft - kips} > M_u = 1,544 \text{ ft - kips}\end{aligned}$$

The required shear reinforcement is adequate for moment strength for full height of wall.

For comparison purposes, the PCA computer program PCACOL was utilized to determine the adequacy of the wall in the 1st story. As can be seen from the figure that is on the next page, the wall is adequate with No. 4 @ 10". Note that points 1, 2, and 3 on the figure refer to the load combinations corresponding to ACI Eqs. (9-1), (9-2), and (9-3), respectively. Similar results are obtained in the 3rd story.

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