pcaStructurePoint
CONCRETE SOFTWARE SOLUTIONS

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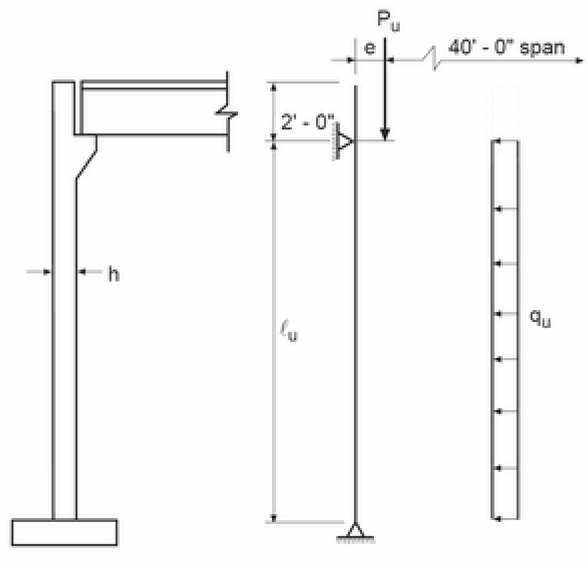
Slender Wall Design

Alternative Design Method (ACI 318-05, 14.8)

Design of the wall shown is required. The wall is restrained at the top edge, and the roof load is supported through 4 in. tee stems spaced at 4 ft on center.

Design Data



Loads:

Roof dead load $q_D := 60psf$

Roof live load $q_L := 30psf$

Wind $q_W := 20psf$

Steel

$f_y := 60ksi$ $E_s := 29000ksi$

$\rho_{minh} := 0.0020$ $\rho_{minv} := 0.0012$

Concrete

$f'_c := 4ksi$ $w_c := 150\frac{lbf}{ft^3}$ $\phi := 0.9$

$E_c := 57000\cdot\sqrt{f'_c\cdot\frac{1}{psi}}\cdot psi$ $E_c = 3605\,ksi$ $f_r := 7.5\cdot\sqrt{f'_c\cdot\frac{1}{psi}}\cdot psi$ $f_r = 474.341\,psi$

$\beta_1 := if\left[f'_c \le 4000psi, 0.85, max\left[0.65, 0.85 - 0.05\cdot\frac{(f'_c - 4000psi)}{1000psi}\right]\right]$ $\beta_1 = 0.85$

Geometry

Wall height	$l_c := 16ft$	Stem width	$w := 4in$
Parapet length	$l_p := 2ft$	Tee beam spacing	$s := 4ft$
Roof load eccentiricity	$e := 6.75in$		
Roof span	$l_r := 40ft$		
Effective length factor	$k := 1.0$		
Wall thickness	$h := 6.50in$		
Slenderness	$\frac{k\cdot l_c}{0.3\cdot h} = 98.462$		
Reinforcement location	$d := 0.5\cdot h$	$d = 3.25\,in$	

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Calculations

1. Trial wall section

Minimum reinforcement area $A_{sminv} := \rho_{minv} \cdot h$ $\quad A_{sminv} = 0.094 \frac{in^2}{ft}$

Trial area of vertical reinforcement $A_s := 0.175 \frac{in^2}{ft}$

2. Effective wall length for roof reaction $l_{eff} := \min(w + 4 \cdot h, s)$ $\quad l_{eff} = 2.5\,ft$

3. Roof loading per foot width of wall $b := 1ft$

Roof dead load $P_{D1} := q_D \frac{s}{l_{eff}} \cdot \frac{l_r}{2}$ $\quad P_{D1} = 1920\,plf$

Wall dead load at midheight $P_{D2} := h \cdot \left(l_p + \frac{l_c}{2}\right) \cdot w_c$ $\quad P_{D2} = 812.5\,plf$

Roof live load $P_L := q_L \frac{s}{l_{eff}} \cdot \frac{l_r}{2}$ $\quad P_L = 960\,plf$

4. Factored load combinations (1.2D + 0.5Lr + 1.6W)

$P_u := b \cdot \left[1.2 \cdot \left(P_{D1} + P_{D2}\right) + 0.5 \cdot P_L\right]$ $\quad P_u = 3.759\,kips$

Factored axial load at mid-height

Moment (not-magnified) at mid-height

$$M_{ua} := b \cdot \left(1.2 \cdot P_{D1} \cdot \frac{e}{2} + 0.5 \cdot P_L \cdot \frac{e}{2} + 1.6 \cdot \frac{q_W \cdot l_c^{\,2}}{8}\right)$$

$M_{ua} = 21.684\,in \cdot kips$

5. Check axial stress at mid-height $A_g := b \cdot h$ $\quad A_g = 78\,in^2$

Gross area of concrete $0.06f'_c = 240\,psi$

Allowable axial stress $\frac{P_u}{A_g} = 48.192\,psi$

Axial stress check

$$\text{if}\left(\frac{P_u}{A_g} \le 0.06 \cdot f'_c, \text{"OK"}, \text{"NG"}\right) = \text{"OK"}$$

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6. Panel properties

Gross moment of inertia

$$I_g := \frac{b \cdot h^3}{12} \qquad I_g = 274.625\ in^4$$

Depth of equivalent concrete stress block

$$a := \frac{\frac{P_u}{\phi} + A_s \cdot b \cdot f_y}{0.85 \cdot f'_c \cdot b} \qquad a = 0.36\ in$$

Neutral axis depth

$$c := \frac{a}{\beta_1} \qquad c = 0.423\ in$$

Net tensile steel strain (Check if section is tension-controlled)

$$\varepsilon_t := \frac{0.003}{c} \cdot (d - c) \qquad \varepsilon_t = 0.02$$

$$\text{if}\left(\varepsilon_t > 0.005, \text{"OK"}, \text{"NG"}\right) = \text{"OK"}$$

Cracked moment of inertia

$$I_{cr} := \frac{b \cdot (c)^3}{3} + \frac{E_s}{E_c} \cdot \left(A_s \cdot b + \frac{P_u}{f_y}\right) \cdot (d - c)^2$$

$$\frac{I_{cr}}{I_g} = 0.057 \qquad I_{cr} = 15.58\ in^4$$

Cracking moment

$$M_{cr} := \frac{f_r \cdot I_g}{\frac{h}{2}} \qquad M_{cr} = 40.082\ in \cdot kips$$

Moment capacity

$$M_n := f_y \cdot \left(A_s \cdot b + \frac{P_u}{\phi \cdot f_y}\right) \cdot \left(d - \frac{a}{2}\right)$$

$$M_n = 45.059\ in \cdot kips \qquad \phi \cdot M_n = 40.553\ in \cdot kips$$

$$\text{if}\left(\phi \cdot M_n \ge M_{cr}, \text{"OK"}, \text{"NG"}\right) = \text{"OK"}$$

7. Check design strength vs. required strength

Magnified moment

$$M_u := \frac{M_{ua}}{1 - \frac{5P_u \cdot l_c^2}{0.75 \cdot 48 \cdot E_c \cdot I_{cr}}} \qquad M_u = 32.988\ in \cdot kips$$

$$\frac{M_u}{\phi \cdot M_n} = 0.813 \quad \text{if}\left(\frac{M_u}{\phi \cdot M_n} \le 1, \text{"OK"}, \text{"NG"}\right) = \text{"OK"}$$

Ultimate load deflections

$$\Delta_u := \frac{5M_u \cdot l_c^2}{0.75 \cdot 48 \cdot E_c \cdot I_{cr}} \qquad \Delta_u = 3.007\ in$$

Double-check magnified moments (Should be equal to M_{ui})

$$M_{ua} + P_u \cdot \Delta_u = 32.988\ in \cdot kips$$

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8. Check service load deflections
(1.0*D + 1.0*Lr + 1.0W)
(For seismic devide by 1.4 to reduce to service level)

Service load (not magnified) moment

$$M_{sa} := b\cdot\left(1.0\cdot P_{D1}\cdot\frac{e}{2} + 1.0\cdot P_L\cdot\frac{e}{2} + 1.0\cdot\frac{q_W\cdot l_c^{\,2}}{8}\right)$$

$$M_{sa} = 17.4\,\text{in}\cdot\text{kips}$$

Service load axial load

$$P_s := b\cdot\left[1.0\cdot\left(P_{D1} + P_{D2}\right) + 1.0\cdot P_L\right] \qquad P_s = 3.693\,\text{kips}$$

Allowable service load displacement

$$\Delta_{s.allowable} := \frac{l_c}{150} \qquad \Delta_{s.allowable} = 1.28\,\text{in}$$

Find magnified moment and effective moment of inertia

$$\delta := 1 \qquad \eta := 1$$

Let the service magnified moment
$M_s = \delta\, M_{sa}$
where

Given

$$\delta = \max\left[1, \frac{1}{1 - \frac{5\cdot P_s\cdot l_c^{\,2}}{48E_c\cdot\left(\eta\cdot I_g\right)}}\right]$$

Let the effective moment of inertia
$I_e = \eta\, I_g$
where

$$\eta = \min\left[1, \left(\frac{M_{cr}}{\delta\cdot M_{sa}}\right)^3 + \left[1 - \left(\frac{M_{cr}}{\delta\cdot M_{sa}}\right)^3\right]\cdot\frac{I_{cr}}{I_g}\right]$$

Solve for δ and η

$$\begin{pmatrix}\delta\\ \eta\end{pmatrix} := \text{Find}(\delta,\eta)$$

$$\delta = 1.015 \qquad \eta = 1.000$$

Magnified service moment

$$M_s := \delta\cdot M_{sa} \qquad M_s = 17.653\,\text{in}\cdot\text{kips}$$

Effective moment of inertia

$$I_e := \eta\cdot I_g \qquad I_e = 274.625\,\text{in}^4$$

Service load displacement

$$\Delta_s := \frac{5M_s\cdot l_c^{\,2}}{48\cdot E_c\cdot I_e} \qquad \Delta_s = 0.068\,\text{in}$$

Sevice load displacement check

$$\frac{\Delta_s}{\Delta_{s.allowable}} = 0.053$$

$$\text{if}\left(\Delta_s \le \Delta_{s.allowable}, \text{"OK"}, \text{"NG"}\right) = \text{"OK"}$$