Example 1 Perforated Shear Wall

Problem Description: The perforated shear wall illustrated in Figure C12.4-4 is sheathed with 15/32" wood structural panel with 10d common nails with 4 in. perimeter spacing. All full-height sheathed sections are 4 ft wide. The window opening is 4 ft high by 8 ft wide. The door opening is 6.67 ft high by 4 ft wide. Sheathing is provided above and below the window and above the door. The wall length and height are 24 ft and 8 ft, respectively. Tie-downs provide overturning restraint at the ends of the perforated shear wall and anchor bolts are used to restrain the wall against shear and uplift between perforated shear wall ends. Determine the shear resistance adjustment factor for this wall.

Solution: The wall defined in the problem description meets the application criteria outlined for the perforated shear wall design method. Tie-downs provide overturning restraint at perforated shear wall ends, and anchor bolts provide shear and uplift resistance between perforated shear wall ends. Perforated shear wall height, factored shear resistances for the wood structural panel shear wall, and aspect ratio of full height sheathing at perforated shear wall ends meet requirements of the perforated shear wall method.

The process of determining the shear resistance adjustment factor involves determining percent full-height sheathing and maximum opening height ratio. Once these are known, a shear resistance adjustment factor can be determined from tabulated reduction factors.

From the problem description and Figure C12.3.-4:

Percent full-height sheathing

$$= \frac{\text{Sum of perforated shear wall segment widths, } \Sigma L}{\text{Length of perforated shear wall, } L}$$

$$= \frac{4\text{ ft} + 4\text{ ft} + 4\text{ ft}}{24\text{ ft}} \times 100 = 50\%$$

Maximum opening height ratio

$$= \frac{\text{Maximum opening height}}{\text{Wall height, } h}$$

$$= \frac{6.67\text{ ft}}{8\text{ ft}} = \frac{5}{6}$$

For a maximum opening height ratio of 5/6 (or maximum opening height of 6.67 ft when wall height, h, equals 8 ft) and percent full-height sheathing equal to 50 percent, a shear resistance adjustment factor of $C_O = 0.57$ is obtained.

Note that if wood structural panel sheathing were not provided above and below the window or above the door the maximum opening height would equal the wall height, h.

Example 2 Perforated Shear Wall

Problem description. Figure C12.4-6 illustrates one face of a 2-story building with the first and second floor walls designed as perforated shear walls. Window heights are 4 ft and door height is 6.67 ft. A trial design is performed in this example based on applied loads, V. For simplification, dead load contribution to overturning and uplift restraint is ignored and the effective width for shear in each perforated shear wall segment is assumed to be the sheathed width. Framing is Douglas fir. After basic perforated shear wall resistance and force requirements are calculated, detailing options to provide for adequate unit shear, v, and unit uplift, t, transfer between perforated shear wall ends are covered. Figure C12.3-7 illustrates possible methods for achieving the required unit shear and uplift transfer. Configuration A considers the condition where a continuous rim joist is present at the second floor. Configuration B considers the case where a continuous rim joist is not provided, as when floor framing runs perpendicular to the perforated shear wall with blocking between floor framing members.

Perforated shear wall resistance and force requirements:

Second floor wall. Determine wood structural panel sheathing thickness and fastener schedule needed to resist applied load, $V = 2.25$ kips, from the roof diaphragm such that the shear resistance of the perforated shear wall is greater than the applied force. Also determine anchorage and load path requirements for uplift force at ends, in plane shear, uplift between wall ends, and compression.

$$\text{Percent full-height sheathing} = \frac{4\text{ ft} + 4\text{ ft}}{16\text{ ft}} \times 100 = 50\%$$

$$\text{Maximum opening height ratio} = \frac{4\text{ ft}}{8\text{ ft}} = \frac{1}{2}$$

Shear resistance adjustment factor, $C_0 = 0.80$

Try 15/32 in. rated sheathing with 8d common nails (0.131 by 2-1/2 in.) at 6 in. perimeter spacing.

Unadjusted shear resistance (LRFD) = 0.36 klf

Adjusted shear resistance

= (unadjusted shear resistance)(C_0)

= (0.36 klf)(0.80) = 0.288 klf

Perforated shear wall resistance

= (Adjusted Shear Resistance)(ΣL_i)

= (0.288 klf)(4 ft + 4 ft) = 2.304 kips

2.304 kips > 2.25 kips ✔ OK

Required resistance due to story shear forces, V:

Overturning at shear wall ends, T:

$$T = \frac{Vh}{C_0 \Sigma L_i} = \frac{2.250\text{ kips (8 ft)}}{0.80\text{ (4 ft + 4 ft)}} = 2.813\text{ kips}$$

In-plane shear, v:

$$v = \frac{V}{C_0 \Sigma L_i} = \frac{2.250\text{ kips}}{0.80\text{ (4 ft + 4 ft)}} = 0.352\text{ klf}$$

Uplift, t, between wall ends: $t = v = 0.352$ klf

Compression chord force, C, at each end of each perforated shear wall segment:

$C = T = 2.813$ kips

First floor wall. Determine wood structural panel sheathing thickness and fastener schedule needed to resist applied load, $V = 2.60$ kips, at the second floor diaphragm such that the shear resistance of the perforated shear wall is greater than the applied force. Also determine anchorage and load path requirements for uplift force at ends, in-plane shear, uplift between wall ends, and compression.

$$\text{Percent full-height sheathing} = \frac{4\text{ ft} + 4\text{ ft}}{12\text{ ft}} \times 100 = 67\%$$

Shear resistance adjustment factor, C_0=0.67

Unadjusted shear resistance (LRFD) = 0.49 klf

Adjusted shear resistance

= (Unadjusted Shear Resistance)(C_o)

= (0.49 klf)(0.67) = 0.328 klf

Perforated shear wall resistance

= (Adjusted Shear Resistance)(ΣL_i)

= (0.328 klf)(4 ft + 4 ft) = 2.626 kips

2.626 kips > 2.600 kips ✔ OK

Required resistance due to story shear forces, V:

Overturning at shear wall ends, T:

$$T = \frac{Vh}{C_0 \Sigma L_i} = \frac{2.600 \text{ kips (8 ft)}}{0.67 \text{ (4 ft + 4 ft)}} = 3.880 \text{ kips}$$

When maintaining load path from story above,

T = T from second floor + T from first floor

= 2.813 kips + 3.880 kips = 6.693 kips

In-plane shear, v:

$$v = \frac{V}{C_0 \Sigma L_i} = \frac{2.600 \text{ kips}}{0.67 \text{ (4 ft + 4 ft)}} = 0.485 \text{ klf}$$

Uplift, t, between wall ends:

$t = v = 0.485$ klf

Uplift, t, can be cumulative with 0.352 klf from story above to maintain load path. Whether this occurs depends on detailing for transfer of uplift forces between end walls.

Compression chord force, C, at each end of each perforated shear wall segment:

$C = T = 3.880$ kips

When maintaining load path from story above, C = 3.880 kips + 2.813 kips = 6.693 kips.

Tie-downs and posts and the ends of perforated shear wall are sized using calculated force, T. The compressive force, C, is used to size compression chords as columns and ensure adequate bearing.

Configuration A – Continuous Rim Joist (see Figure C12.3-7)

Second floor. Determine fastener schedule for shear and uplift attachment between perforated shear wall ends. Recall that $v = t = 0.352$ klf.

Wall bottom plate (1 ½ in. thickness) to rim joist. Use 20d box nail (0.148 by 4 in.). Lateral resistance $\phi\lambda Z'$ = 0.254 kips per nail and withdrawal resistance $\phi\lambda W'$ = 0.155 kips per nail.

Nails for shear transfer

= (shear force, v)/$\phi\lambda Z'$

= 0.352 klf/0.254 kips per nail

= 1.39 nails per foot

Nails for uplift transfer

= (uplift force, t)/$\phi\lambda W'$

= 0.352 klf/0.155 kips per nail

= 2.27 nails per foot

Net spacing for shear and uplift

= 3.3 inches on center

Rim joist to wall top plate. Use 8d box nails (0.113 by 2-1/2 in.) toe-nailed to provide shear transfer. Lateral resistance $\phi\lambda Z'$ = 0.129 kips per nail.

Nails for shear transfer

= (shear force, v)/$\phi\lambda Z'$

= 0.352 klf/0.129 kips per nail

= 2.73 nails per foot

Net spacing for shear

= 4.4 inches on center

See detail in Figure C12.3-7 for alternate means a shear transfer (such as a metal angle or plate connector).

Transfer of uplift, t, from second floor in this example is accomplished through attachment of second floor wall to the continuous rim joist which has been designed to provide sufficient strength to resist the induced moments and shears. Continuity of load path is provided by tie-downs at the ends of the perforated shear wall.

First floor. Determine anchorage for shear and uplift attachment between perforated shear wall ends. Recall that $v = t = 0.485$ klf.

Wall bottom plate (1 ½ in. thickness) to concrete. Use ½ in. anchor bolt with lateral resistance $\varphi\lambda Z'$ = 1.34 kips.

Bolts for shear transfer

= (shear force, v)/$\phi\lambda Z'$

= 0.485 klf/1.34 kips per bolt

= 0.36 bolts per ft

Net spacing for shear

= 33 in. on center

Bolts for uplift transfer. Check axial capacity of bolts for $t = v = 0.485$ klf and size plate washers accordingly. No interaction between axial and lateral load on anchor bolt is assumed (that is, the presence of axial tension is assumed not to affect lateral strength).

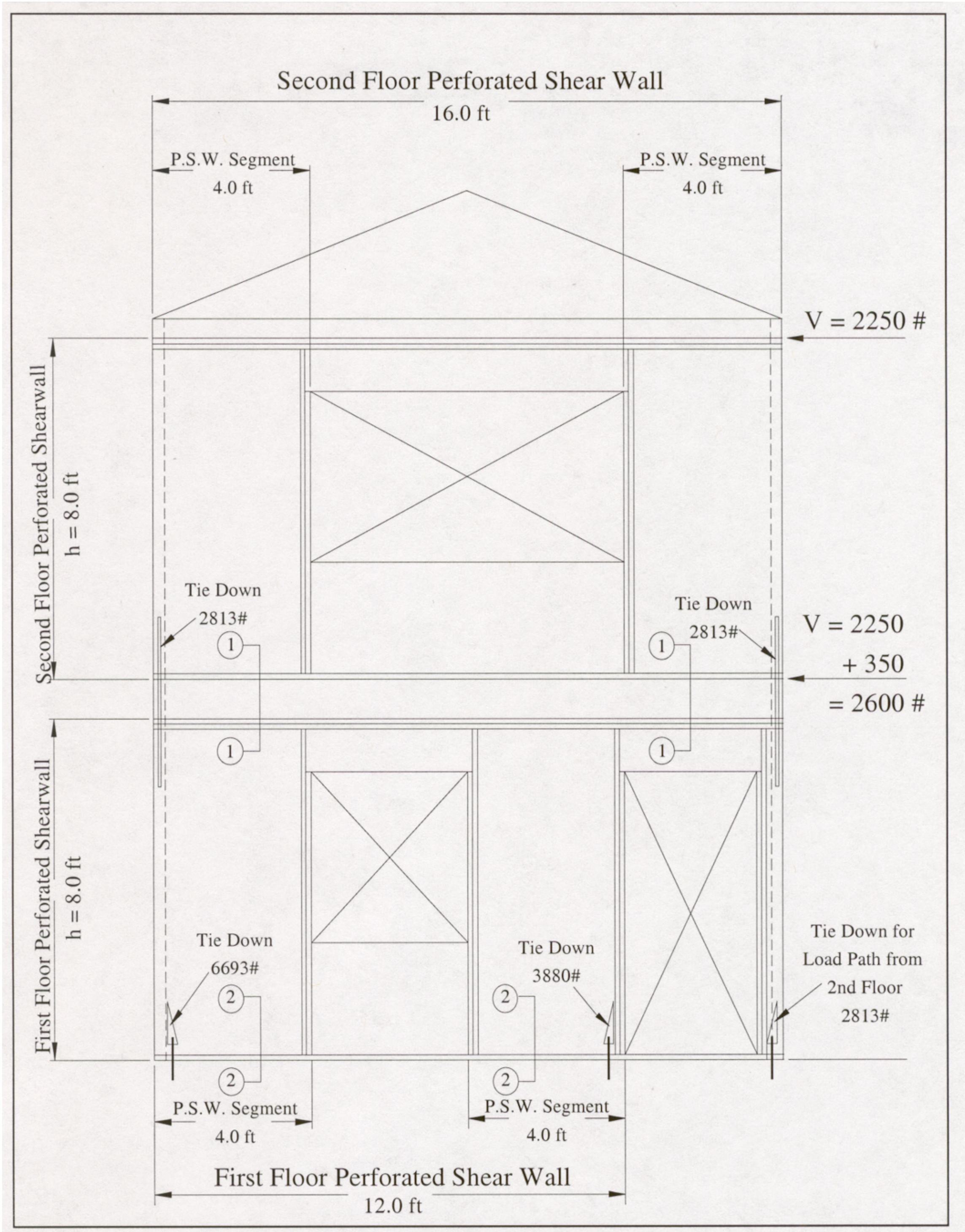

Figure C12.3-6 Elevation for perforated shear wall Example 2.

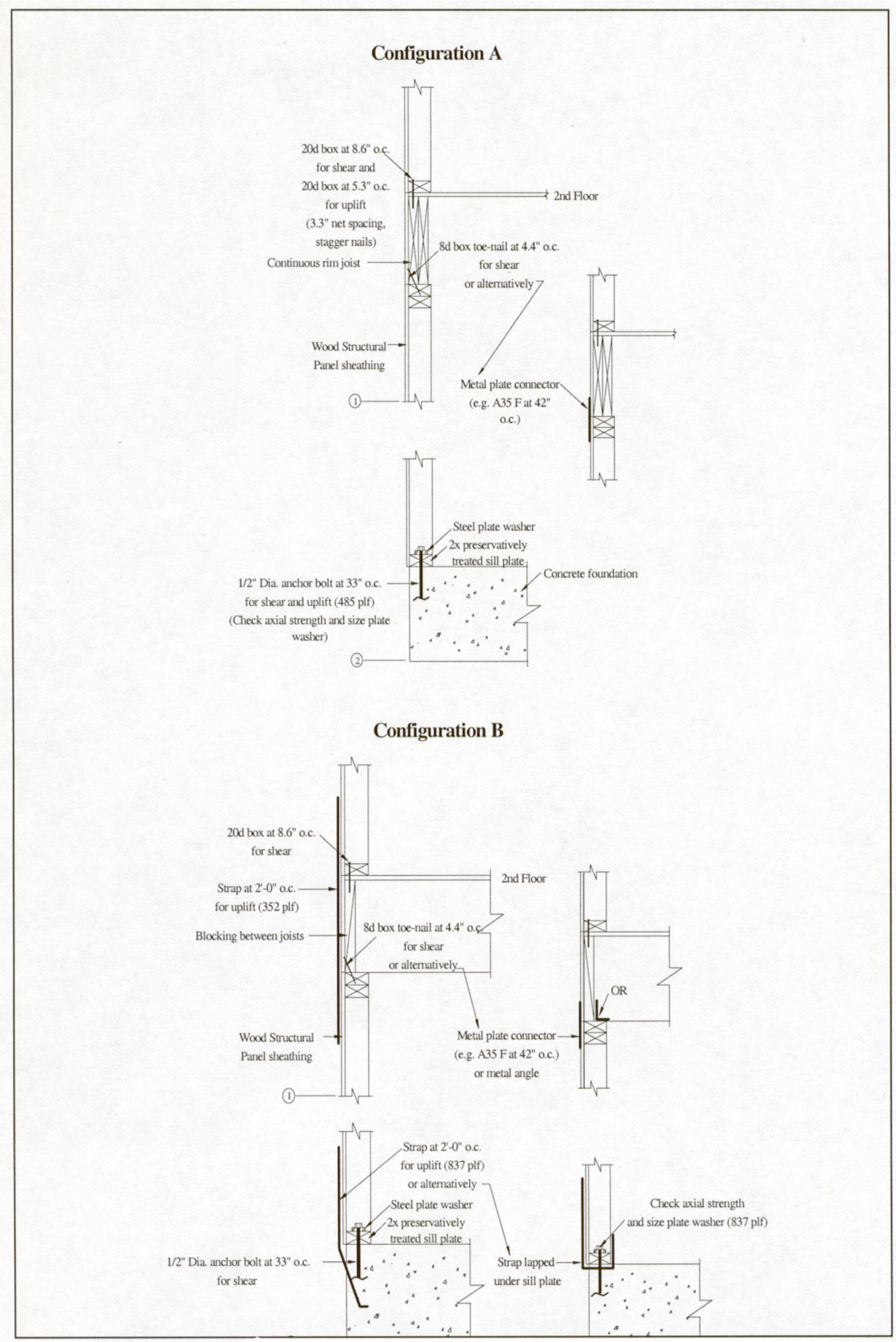

Figure C12.3-7 Details for perforated shear wall Example 2.