

SOLUTION - ANCHOR DESIGN PROBLEM 2009

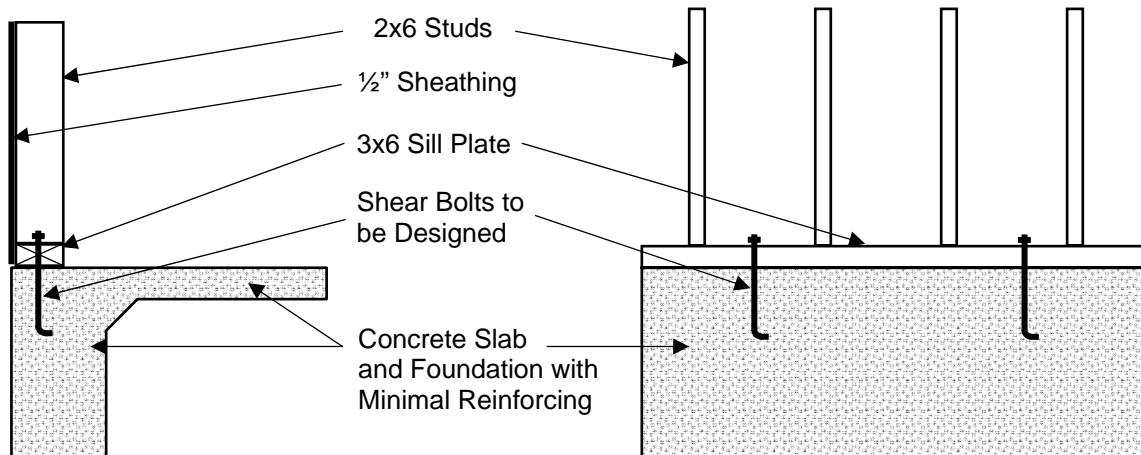
Problem

You are designing a new wood framed residence located in San Diego, California. You have already determined the lateral forces on the wood shear walls and that the house is classified as Seismic Design Category D. You have also determined that you will be using a 3x sill plate of pressure treated Hem Fir lumber and 2,500 psi normal weight concrete for the slab and foundation. The maximum in-plane shear force on the wood shear walls is as follows:

$$v_{\text{wind}} = 600 \text{ plf ultimate} / 420 \text{ plf allowable}$$

$$v_{\text{earthquake}} = 500 \text{ plf ultimate} / 350 \text{ plf allowable}$$

Design the shear anchor bolts connecting the 3x wood sill plate of the shear wall to the cast-in-place reinforced concrete foundation.



Section View

Elevation View

Answer Summary

Time to Complete: **Way, way too much time.**

Bolt Type: **Cast-in-Place 'J' Bolt**
(e.g. cast-in-place 'J' bolt, post-installed expansion anchor, etc.)

Bolt Grade / Material: **A307**
(e.g. A307, etc.)

Bolt Capacity Sources: **ACI Appendix D, NDS**
(e.g. IBC Bolt Capacity Tables, ACI Appendix D, NDS, Bolt Vendor Information, etc.)

Bolt Diameter: **5/8" diameter**

Bolt Embedment: **7"**

Bolt Spacing: **32"**

Solution

Anchor Selection

- Use 5/8" diameter A307 Hooked Anchor Bolts with 7" embedment

ACI Shear Anchor Design (ACI D.4.1)

- $\phi V_n \geq V_{ua}$ (Eq. D-1)
- ϕV_n equals lesser of ϕV_{sa} or ϕV_{cb} or ϕV_{cp}

Edge Distance (ACI D.8.2)

- Untorqued cast-in anchors
- Edge distance per cover requirements of ACI 7.7
- Concrete exposed to earth or weather = 1.5" < 2.5"

Steel Strength of Anchor in Shear (ACI D.6.1)

- $V_{sa} = n0.6A_{se,v}f_{uta}$ (ACI Eq. D-20)
 - $A_{se} = 0.226in^2$ (Threads considered)
 - $f_{uta} = 58,000 psi$ (A307)
- $V_{sa} = (1)(0.6)(0.226in^2)(58,000 psi) = 7,860lbs$
- $\phi V_{sa} = (0.65)(7,860lbs) = 5,110lbs$
 - $\phi = 0.65$ (ACI D.4.4)

Concrete Breakout Strength in Shear (ACI D6.2)

- $V_{cb} = 2 \frac{A_{Vc}}{A_{Vco}} \psi_{ed,v} \psi_{c,v} \psi_{h,v} V_b$ (ACI Eq. D-21 & D.6.2.1.c)
 - $A_{Vc} = A_{Vco} = 4.5(c_{a1})^2 = 4.5(2.5")^2 = 28.1in^2$
 - $c_{a1} = 2.5"$
 - $\psi_{ed,v} = 1.0$ (ACI D.6.2.1.c)
 - $\psi_{c,v} = 1.0$ (ACI D.6.2.7)
 - $\psi_{h,v} = 1.0$ (ACI D.6.2.8)
 - $V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda \sqrt{f'_c} (c_{a1})^{1.5}$ (ACI Eq. D-24)
 - $d_a = 0.625"$
 - $l_e = h_{ef} = 7"$ or $l_e = 8d_a = 5"$ (Gov.)
 - $\lambda = 1.0$
 - $V_b = \left(7 \left(\frac{5"}{0.625"} \right)^{0.2} \sqrt{0.625"} \right) 1.0 \sqrt{2,500 psi} (2.5")^{1.5} = 1,658lbs$

- $V_{cb} = (2) \left(\frac{28.1 \text{ in}^2}{28.1 \text{ in}^2} \right) (1.0)(1.0)(1.0)(1,658 \text{ lbs}) = 3,316 \text{ lbs}$
- $\phi V_{cb} = (0.70)(3,316 \text{ lbs}) = 2,320 \text{ lbs}$
 - $\phi = 0.70$ (ACI D.4.4)

Concrete Pryout Strength (ACI D.6.3)

- $V_{cp} = k_{cp} N_{cb}$ (ACI Eq. D-30)
 - $k_{cp} = 2.0$
 - $h_{ef} = 6.38" > 2.5"$
 - $N_{cb} = \frac{A_{Nc}}{A_{Nco}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$ (ACI Eq. D-5)
 - $A_{Nc} = (c_{a1} + 1.5h_{ef})(2 \times 1.5h_{ef})$ (ACI Fig. Rd.5.2.1)
 - $A_{Nc} = (2.5" + 1.5(6.38"))((2)(1.5)(6.38")) = 231 \text{ in}^2$
 - $A_{Nco} = 9h_{ef}^2 = (9)(6.38")^2 = 366 \text{ in}^2$
 - $\psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,\min}}{1.5h_{ef}}$ (ACI Eq. D-11 for $c_{a,\min} < 1.5h_{ef}$)
 - $\psi_{ed,N} = 0.7 + 0.3 \frac{2.5"}{1.5(6.38")} = 0.778$
 - $\psi_{c,N} = 1.0$ (ACI D.5.2.6)
 - $\psi_{cp,N} = 1.0$ (ACI D.5.2.7)
 - $N_b = k_c \lambda \sqrt{f'_c} h_{ef}^{1.5} = (24)(1.0)(\sqrt{2500 \text{ psi}})(6.38)^{1.5} = 19,338 \text{ lbs}$
 - $N_{cb} = \frac{231 \text{ in}^2}{366 \text{ in}^2} (0.778)(1.0)(1.0)(19,338 \text{ lbs}) = 9,495 \text{ lbs}$
- $V_{cp} = (2.0)(9,495 \text{ lbs}) = 18,990 \text{ lbs}$
- $\phi V_{cp} = (0.70)(18,990 \text{ lbs}) = 13,293 \text{ lbs}$
 - $\phi = 0.70$ (ACI D.4.4)

Wood Sill Plate (NDS)

- $Z' = Z C_D C_M C_t C_g C_{\Delta} C_{eg} C_{di} C_m$
 - $Z = 1,170 \text{ lbs}$ (NDS Table 11E)
 - $C_D = 1.6$, $C_M = 1.0$, $C_t = 1.0$, $C_g = 1.0$, $C_{\Delta} = 1.0$, $C_{eg} = 1.0$, $C_{di} = 1.0$,
 $C_m = 1.0$
- $Z' = (1,170 \text{ lbs})(1.6) = 1,870 \text{ lbs}$

Wind Design

- Concrete
 - $\phi V_n = \phi V_{cb} = 2,320\text{lbs}$
 - $V_u = 600\text{plf}$
 - $\text{Spacing} = \frac{2,320\text{lbs}}{600\text{plf}} = 3.8\text{ft}$
- Wood
 - $Z' = 1,870\text{lbs}$
 - $V = 420\text{plf}$
 - $\text{Spacing} = \frac{1,870\text{lbs}}{420\text{plf}} = 4.5\text{ft}$

Earthquake Design

- Concrete
 - $0.75\phi V_n = 0.75(2,320\text{lbs}) = 1,740\text{lbs}$
 - $V_u = 500\text{plf}$
 - $\text{Spacing} = \frac{1,740\text{lbs}}{500\text{plf}} = 3.5\text{ft}$ (Governs Design, Use 32" o.c.)
- Wood
 - $Z' = 1,870\text{lbs}$
 - $V = 350\text{plf}$
 - $\text{Spacing} = \frac{1,870\text{lbs}}{350\text{plf}} = 5.3\text{ft}$

Final Selection

- Use 5/8" diameter cast-in-place hooked anchor bolts with 7" embedment spaced at 32" on center.