Appendix A Example 2: Column Guying

This appendix covers the topic of column guying. The wind load on a typical rebar cage/ column form is calculated, and the guying system checked for adequacy.

Given Information

- 3'-0" diameter column
- Column reinforcement cover 3 inches
- Pile cutoff 3'-6" below finish grade
- Assume column form is pinned at top of pile
- Deadman dimensions are 4 ft x 4 ft x 4 ft
- For cable attachments to deadman see Figure A-2-5

Required

1. Review guying submittal and verify conformance with *Contract Specifications* Section 52-1.01C(2).
2. Verify deadman capacity to resist loads.
3. Verify cable loads are less than allowable.
4. Check cable connection at deadman.

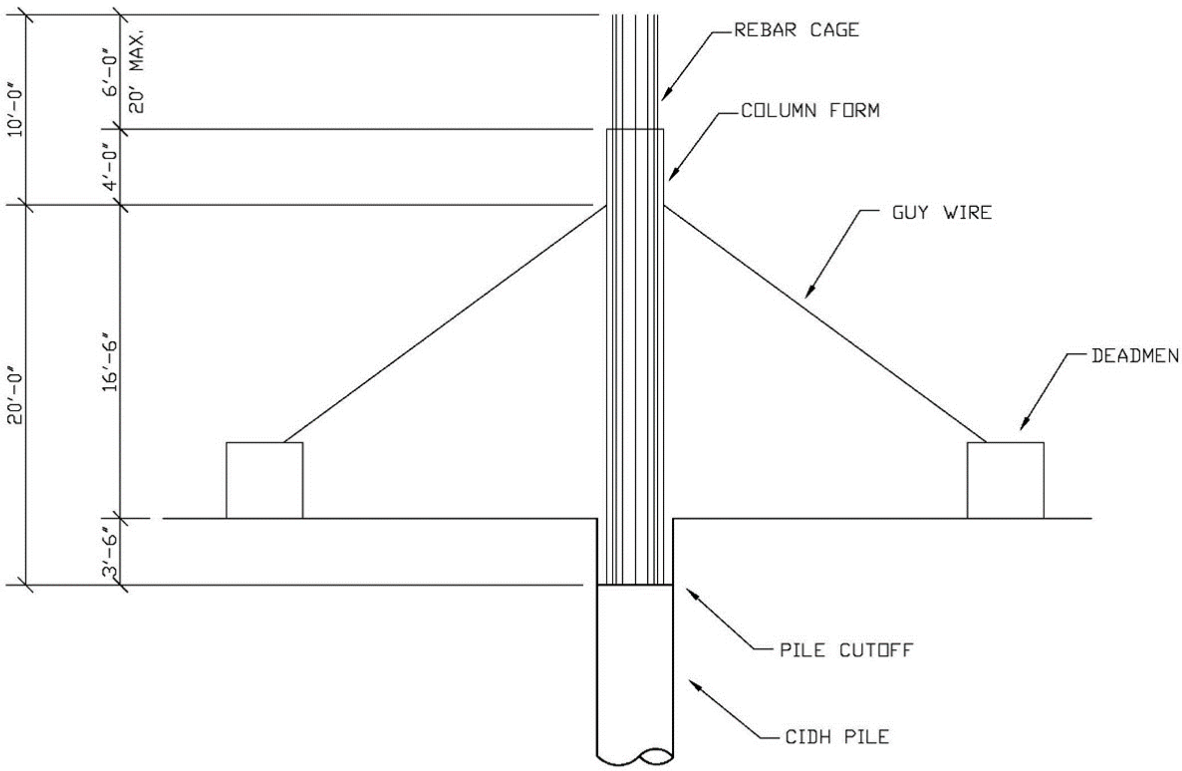

Figure A-2-1. Elevation Column Support

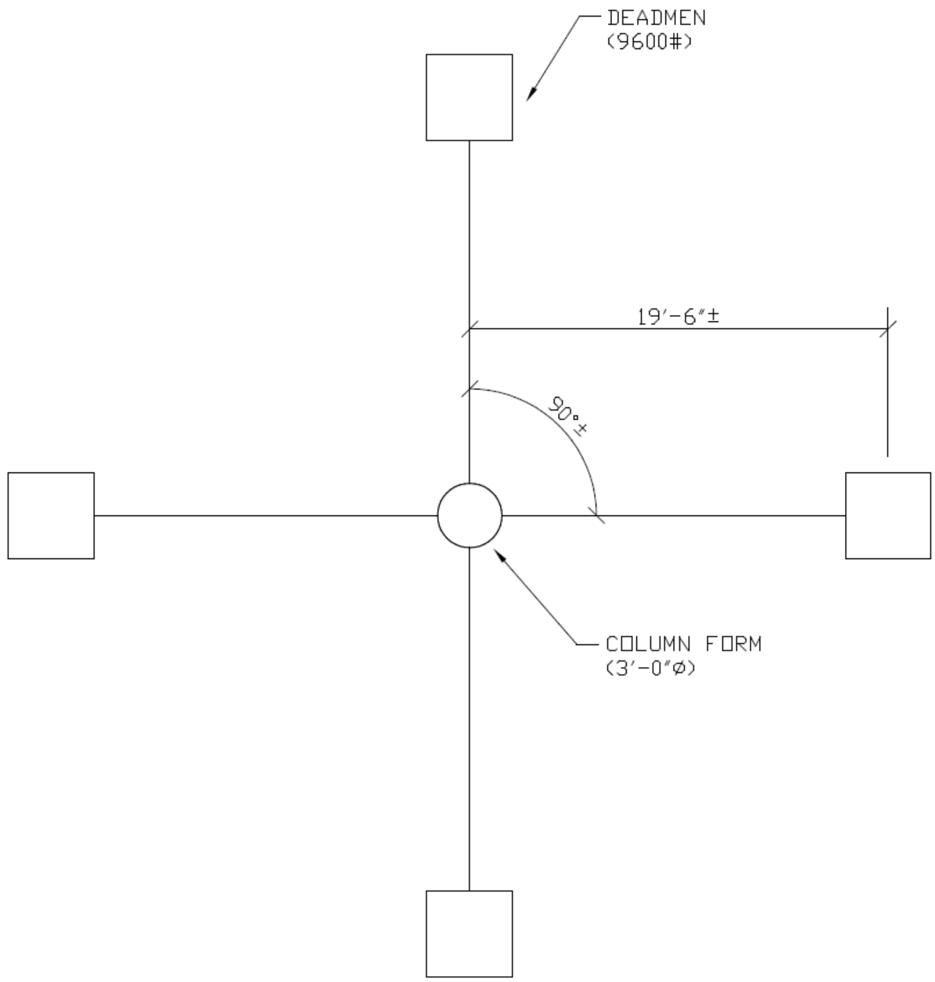

Figure A-2-2. Plan View Column Support

Loading

Wind pressures from *Contract Specifications* Section 52-1.01C(2), *Reinforcement — Shop Drawings*, taken from table below for the associated height zone:

Wind Pressure

Height zone, H (feet above ground)	Wind pressure value (psf)
0 ≤ 30	20
30 < H ≤ 50	25
50 < H ≤ 100	30
H > 100	35

Figure A-2-3. Wind Pressure Values

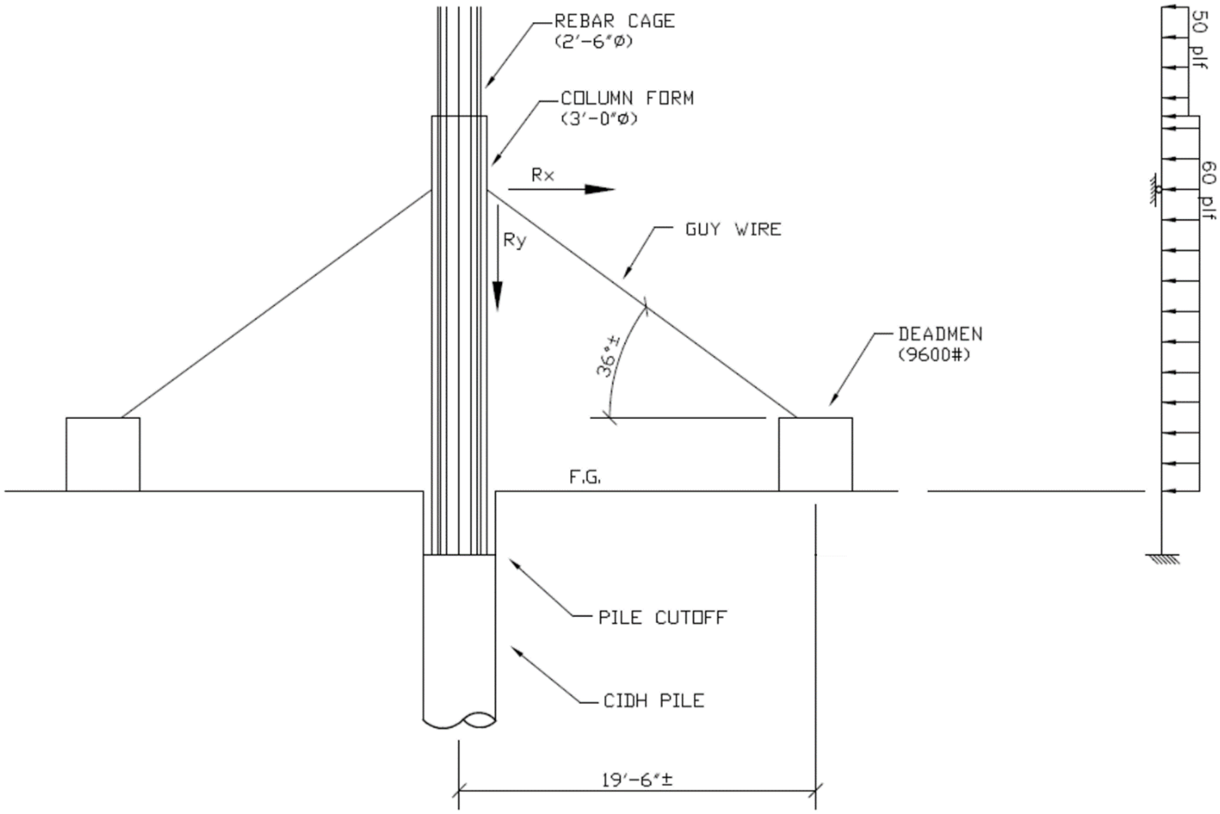

Figure A-2-4. Guying System Loading

Cable forces

Determine cable support reaction using beam theory by summing moments about the base. Conservatively assume the column is pinned at the base to simplify the calculations. A more detailed analysis using beam software could be used.

Cable reaction (**Rx**):

$$\mathrm{R_x} = \frac{(60\ \text{plf})(20.5\ \text{ft})\left(\frac{20.5\ \text{ft}}{2} + 3.5\ \text{ft}\right) + (50\ \text{plf})(6\ \text{ft})\left(\frac{6\ \text{ft}}{2} + 24\ \text{ft}\right)}{20\ \text{ft}} \approx\ 1250\ \text{lbs} \qquad \text{(A-2-1)}$$

Cable reaction (**Ry**):

$$\mathrm{R_y} = 1250\ \text{lbs}\ (\tan 36°)\ =\ 908\ \text{lbs} \qquad \text{(A-2-2)}$$

Resultant (cable tension):

$$\sqrt{\mathrm{R_x}^2 + \mathrm{R_y}^2} = \sqrt{1250^2 + 908^2} = 1545\ \mathrm{lbs} \quad \text{(A-2-3)}$$

Support Cables

Cable reaction = 1545 lbs (previously calculated)

For 1/2" 6x19 IWRC cable:

Minimum breaking strength (**MBF**)	=	13.30 tons = 26,600 lbs (Contractor to provide manufacturer's data in submittal)
Factor of safety (**FS**)	=	2 (guying not required to adhere to FS found in the *Falsework Manual*)

Connection: 3 wire rope clips (Crosby)

Connection efficiency (**CE**)	=	80 % (*Falsework Manual,* Table 5-2, Wire Rope Connections)

Allowable cable load:

$$\frac{\mathrm{MBF(CE)}}{\mathrm{FS}} = \frac{26{,}600(0.80)}{2} = 10640\ \mathrm{lbs} > 1545\ \mathrm{lbs} \Longleftarrow \mathrm{OK} \quad \text{(A-2-4)}$$

Cable Attachment at Deadmen

Cable tension	=	1,545 lbs (previously calculated)
Angle to horizontal	=	36°
$\mathbf{R_x}$	=	1,250 lbs
$\mathbf{R_y}$	=	908 lbs

Anchor spacing and edge distance as illustrated below:

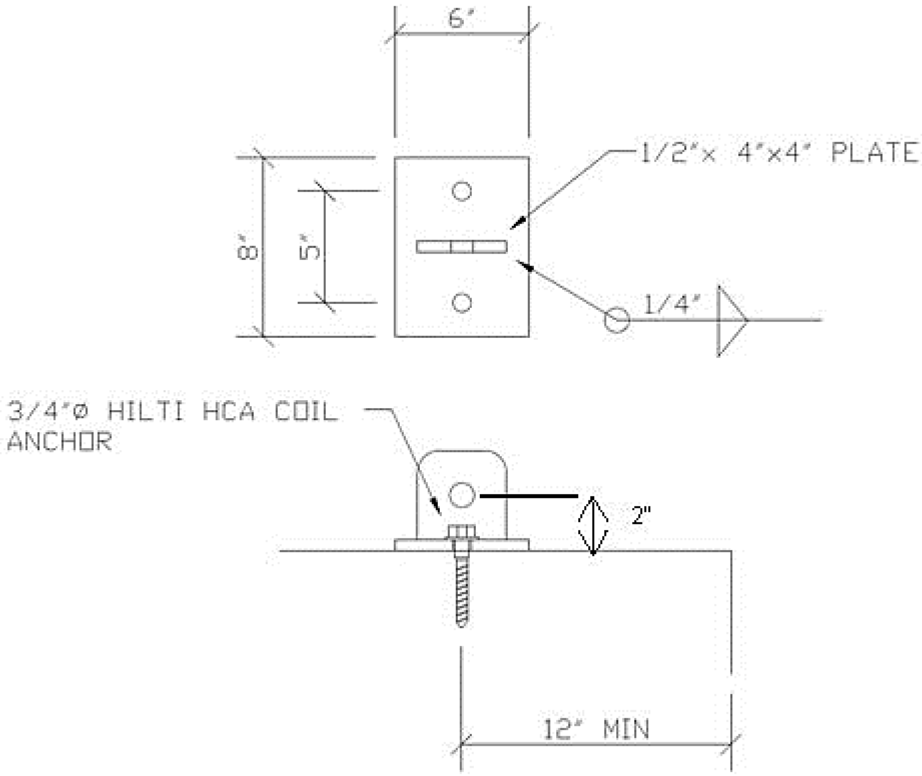

Figure A-2-5. Cable Attachment at Deadmen

Anchor Analysis

For two ¾" Hilti HCA coil anchors:

Nominal embedment	=	4.5" min
Edge distance	=	12" min
Spacing	=	5"
Assume $\mathbf{f'_c}$	=	3000 psi
Vertical load $\mathbf{R_y}$	=	908 lbs (previously calculated)
Horizontal load $\mathbf{R_x}$	=	1250 lbs (previously calculated)

Anchor Manufacturer's Instructions

MATERIAL SPECIFICATIONS

1/4-in. HCA manufactured from case hardened AISI 1038 carbon steel with a minimum tensile strength of 100 ksi (690 MPa).
3/8-, 1/2-, 5/8- and 3/4-in. HCA meet the chemical requirements of AISI 1035 carbon steel and are heat treated for a minimum tensile strength of 120 ksi (830 MPa).
Coil is manufactured from carbon steel.
Anchor and coil are zinc plated in accordance with ASTM B633, SC 1.

Figure 1 - HCA specifications

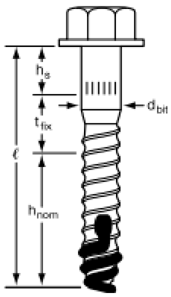

Table 1 - Hilti HCA Coil Anchor specifications

Setting information		Symbol	Units	Nominal anchor diameter				
				1/4	3/8	1/2	5/8	3/4
Nominal bit diameter		d_o	in.	1/4	3/8	1/2	5/8	3/4
Embedment mark[1]		h_s	in.	3/8	5/8	5/8	3/4	1
Anchor Length	min.	ℓ	in.	1-3/4	2-1/4	3	3-1/2	4-1/2
	max.	ℓ	in.	3-1/2	5	7	8	10
Fixture hole diameter		d_h	in.	5/16	7/16	9/16	11/16	13/16
Installation torque		T_{inst}	ft-lb	10	40	80	130	180
Minimum base material thickness		h	in.	the greater of 3 or 1.3 times h_{nom}				

1 Maximum fixture thickness $t = \ell - (h_{nom} + h_s)$

Combined shear and tension loading

$$\left(\frac{N_d}{N_{rec}}\right) + \left(\frac{V_d}{V_{rec}}\right) \leq 1.0$$

Figure A-2-6. Anchor Manufacturer's Instructions

Table 2 - Hilti HCA allowable concrete and steel capacity (lb)[1]

Nominal anchor diameter in.	Nominal embedment in.	f'_c = 2,000 psi		f'_c = 4,000 psi		f'_c = 6,000 psi		Allowable steel strength[2]	
		Tension[3]	Shear	Tension[3]	Shear	Tension[3]	Shear	Tension	Shear
1/4	3/4	230	230	325	330	400	400	1,620	835
	1	355	380	500	535	615	655		
3/8	1-1/2	650	850	920	1,205	990	1,475	4,375	2,255
	2	1,005	1,390	1,420	1,965	1,740	2,410		
1/2	2	1,005	1,515	1,420	2,145	1,740	2,625	7,775	4,005
	3	1,845	3,020	2,605	4,270	3,190	5,230		
5/8	2-3/8	1,300	2,175	1,835	3,075	2,250	3,765	12,150	6,260
	3-7/8	2,705	5,000	3,825	7,070	4,685	8,660		
3/4	3-1/4	2,080	3,915	2,940	5,540	3,600	6,780	17,495	9,010
	4-1/2	3,385	6,810	4,790	9,630	5,865	11,705		

1 Allowable concrete capacities based on a safety factor of 4.
2 Steel strength calculated using 0.33 f_{uta} $A_{nominal}$ for tension and 0.17 f_{uta} $A_{nominal}$ for shear.
3 Reduce tension capacity by 20% for HCA Hex Head Bolts that are reused. Coils may not be reused.

Figure A-2-7. Hilti HCA Allowable Concrete and Steel Capacity

Table 4 - Hilti HCA edge distance and anchor spacing guidelines[1,2]

	Load Direction	Critical	Minimum	Influence factor[3]
Spacing	Tension	3.0 h_{nom}	1.0 h_{nom}	$f_{AN} = 0.70$
Spacing	Shear	2.0 h_{nom}	1.0 h_{nom}	$f_{AV} = 0.70$
Edge distance	Tension	1.5 h_{nom}	0.8 h_{nom}	$f_{RN} = 0.75$
Edge distance	Shear ⊥ toward edge[4]	2.5 h_{nom}	1.0 h_{nom}	$f_{RV1} = 0.25$
Edge distance	Shear ll or ⊥ away from edge[4]	2.5 h_{nom}	1.0 h_{nom}	$f_{RV2} = 0.50$

1 For edge and spacing distances between critical and minimum spacing/edge distances, use linear interpolation.

2 Influence factors are cumulative.

3 Influence factor at minimum spacing/edge distance. Influence factor at critical equals 1.0.

4 For shear loads in between perpendicular toward edge and parallel with edge, use the following equation, $f_{RV3} = 0.25 / (\cos \beta + 0.5 \sin \beta)$ for $55° \le \beta < 90°$. For $0° \le \beta < 55°$, use influence factor for shear perpendicular toward edge. See Figure 2.

Figure A-2-8. Hilti HCA Edge Distance and Anchor Spacing Guidelines

Tension

Maximum anchor plate thickness (t) = l – (H_{nom}+h_s) = 6" – (4.5"+1") = 0.5" max (Figure A-2-6)

Note: Verify anchor plate thickness less than or equal to maximum ½" in field; if larger than ½", a longer anchor is required.

Minimum spacing shear and tension = 1.0(h_{nom}) = 1.0(4.5") = 4.5"

Critical spacing tension = 3(h_{nom}) = 3(4.5") = 13.5"> 5" (Reduction required)
Critical edge Dist. tension = 1.5(h_{nom}) = 1.5(4.5") = 6.75" < 12" (No reduction for edge Dist.)

Critical spacing shear = 2(h_{nom}) = 2(4.5") = 9" > 5" (Reduction required)
Critical edge Dist. shear = 2.5(h_{nom}) = 2.5(4.5") = 11.25" < 12" (No reduction for edge Dist.)

Determine spacing influence factors using linear interpolation between critical and minimum distances.

Spacing influence factor for tension:

$$0.7 + 0.3\left(\frac{5 - 4.5}{13.5 - 4.5}\right) = 0.717 \qquad \text{(A-2-5)}$$

Spacing influence factor for shear:

$$0.7 + 0.3\left(\frac{5-4.5}{9-4.5}\right) = 0.733 \tag{A-2-6}$$

Allowable tension load:

$$2\left(\frac{3385+4790}{2}\right)(0.717) = 5{,}861 \text{ lbs} > 908 \text{ lbs} \quad \Longleftarrow \quad \text{OK} \tag{A-2-7}$$

Allowable shear load:

$$2\left(\frac{6810+9630}{2}\right)(0.733) = 12{,}050 \text{ lbs} > 1250 \text{ lbs} \quad \Longleftarrow \quad \text{OK} \tag{A-2-8}$$

Combined loading:

$$\left(\frac{908}{5861}\right) + \left(\frac{1250}{12050}\right) = 0.26 < 1 \quad \Longleftarrow \quad \text{OK} \tag{A-2-9}$$

<u>Cable Attachment Plate</u>

Load to welds:

R_x = 1,250 lbs (previously calculated)
R_y = 908 lbs (previously calculated)
R = 1,545 lbs

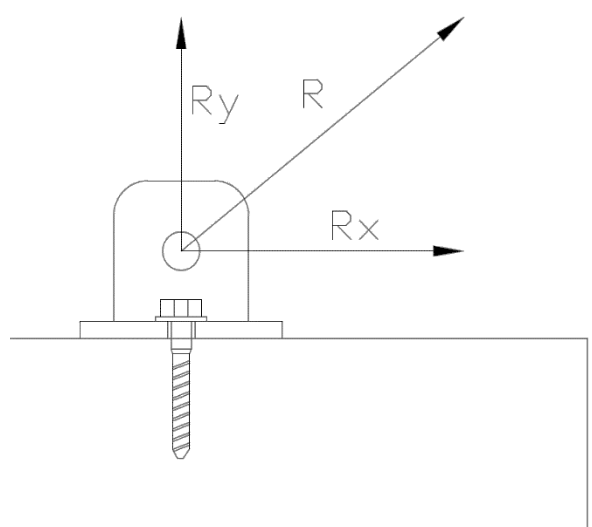

Figure A-2-9. Resultant Forces on Anchor Plate

Weld Capacity per AISC Chapter J:

For ¼" fillet welds:

$$A_w = 0.25"(0.707)(2)(4") = 1.414 \text{ in}^2 \qquad \text{(A-2-10)}$$

$$M_w = R_x(2) = 1250(2) = 2500 \text{ in-lbs} \qquad \text{(A-2-11)}$$

$$I_w = \frac{bd^3}{12} = \frac{2(0.25)(0.707)(4)^3}{12} = 1.885 \text{ in}^4 \qquad \text{(A-2-12)}$$

Determine capacity of weld assuming a uniform shear distribution and combining the shear, bending, and axial stresses vectorially. This is conservative since the maximum bending stress and maximum shear stress occur at different locations.

Loading in the **y** direction:

$$f_t = \frac{P}{A} + \frac{Mc}{I} = \frac{908}{1.414} + \frac{2500(2)}{1.885} = 3295 \text{ psi} \qquad \text{(A-2-13)}$$

Loading in the **x** direction:

$$f_v = \frac{V}{A} = \frac{1250}{1.414} = 884 \text{ psi} \qquad \text{(A-2-14)}$$

Resultant load:

$$f_r = \sqrt{3295^2 + 884^2} = 3412 \text{ psi} \qquad \text{(A-2-15)}$$

For ASD weld capacity:

$$R_n = \frac{F_w A_w}{\Omega} \qquad \text{(A-2-16)}$$

$$\Omega = 2.00$$

$$F_w = 0.60F_{exx}(1 + 0.50(\sin^{1.5}\theta)) \quad \text{from AISC J2-5} \qquad \text{(A-2-17)}$$

$$F_{wy} = 0.60(70 \text{ ksi})(1 + 0.50(\sin^{1.5}90)) = 63 \text{ ksi} = 63{,}000 \text{ psi}$$

$$\frac{F_{wy}}{\Omega} = \frac{63000}{2} = 31{,}500 \text{ psi}$$

$$F_{wx} = 0.60(70 \text{ ksi})(1 + 0.50(\sin^{1.5} 0)) = 42 \text{ ksi} = 42{,}000 \text{ psi}$$

$$\frac{F_{wx}}{\Omega} = \frac{42000}{2} = 21{,}000 \text{ psi}$$

$$F_{wr} = \sqrt{31500^2 + 21000^2} = 37{,}852 \text{ psi} > 3{,}412 \text{ psi} \quad \Longleftarrow \quad \text{OK} \qquad \text{(A-2-18)}$$

Deadmen:

Deadmen weight	=	9,600 lbs
Deadmen dimensions	=	4' x 4' x 4'
R_x	=	1,250 lbs (previously calculated)
R_y	=	908 lbs (previously calculated)
Soil type:	=	Gravel
Coefficient of friction	=	0.60 (dry soil)

Sliding resistance of Deadmen = 0.60(9600 – 908) = 5,215 lbs

$$\frac{1250}{5215} = 0.24 < 1 \quad \Longleftarrow \quad \text{OK} \qquad \text{(A-2-19)}$$

Overturning of Deadmen = 1250(4') + 908(1') = 5908 ft-lbs (moment taken about leading toe)

Deadmen resistance to overturning = 9600(2') = 19,200 ft-lbs

$$\frac{5908}{19200} = 0.31 < 1 \quad \Longleftarrow \quad \text{OK} \qquad \text{(A-2-20)}$$