

**STRUCTURAL ANALYSIS OF
EIGHT FOOT HIGH
PRECAST CONCRETE FENCE**

**PREPARED FOR
O-WELL PRECAST LLC.**

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**PREPARED BY
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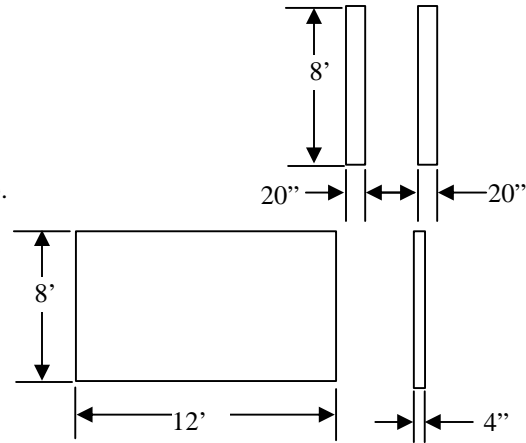
Eight Foot High Precast Concrete Fence

Posts

Height: 8 ft.
 Breadth: 20 in.
 Width: 20 in.
 Weight = $8 \times 20/12 \times 20/12 \times 150 = 3,333$ lb.
 Spacing: 13' - 0"

Panels

Height: 8 ft.
 Breadth: 12 ft.
 Thickness: 4 in.
 Weight = $8 \times 12 \times 4/12 \times 150 = 4,800$ lb.



Lateral Forces (2003 IBC) and Anchor Loads

Wind:

$V = 90$ mph, Exposure C
 $Z = 8$ ft
 Structure Category = I
 $K_z = 2.01(15/z_g)^{2.7} = 0.85$
 Where, $\rho = 9.5$ and $z_g = 900$ ft.
 $K_{zt} = 1$, flat terrain
 $K_d = 0.85$
 $I = 0.87$
 $q_z = 0.00256 K_z K_{zt} K_d V^2 I = 13$ psf
 $F = q_z GC A$
 $C = 1.2, G = 0.85$
 $F = 13 \times 0.85 \times 1.2 \times 13 \times 8 = 1,383$ lb.
 Overturning Moment = $1383 \times 4 = 5,531$ ft-lb.
 Resisting Moment = $0.67(4800) 2/12 + 0.67(3333) 10/12 = 2397$ ft-lb.
 Required hold down force, F_h
 $5531 - 2397 = F_h (10/12)$
 $F_h = 3,761$ lb
 Apply safety factors:
 $V_u = 1,383 \times 1.6 = 2,213$ lb.
 $N_u = 3,761 \times 1.6 = 6,017$ lb.

Seismic:

Short period spectral acceleration, $S_s = 1.5$; 1-Second spectral acceleration, $S_1 = 0.50$
 Site Class D assumed. $F_a = 1.0, F_v = 1.5$,
 $F_p = 0.4a_p S_{DS} W_p / (R_p / I_p) (1 + 2(z/h)) = 0.4W_p$
 $a_p = 2.5$
 $S_{DS} = 2/3 F_a S_s = 1.0$
 $R_p = 2.5$
 $I_p = 1.0$
 $z = 0$ ft., $h = 8$ ft.
 $W_p = 1/8$ panel weight + post weight = $600 + 3333 = 3933$ lb.
 This assumes that the fence panel is supported by the soil between posts and remains within 1 ft. of vertical. Then the force applied at the top of the panel by the post would be: $F = WX/(H)$, W is the panel weight, X is the horizontal distance, measured from vertical to the top edge of the fence panel, and H is the fence height.
 $F_p = 240 + 1333 = 1573$ lb.
 Overturning Moment = $1573 \times 4 = 6292$ ft-lb.
 Resisting Moment = $0.85(4800) 2/12 + 0.85(3333) 10/12 = 3041$ ft-lb.
 Required hold down force, F_h
 $6292 - 3041 = F_h (10/12)$
 $F_h = 3,901$ lb.

Apply safety factors:

$$V_u = 1,573 \times 1.3 = 2,045 \text{ lb.}$$

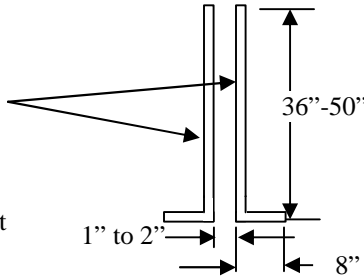
$$N_u = 3,901 \times 1.3 = 5,072 \text{ lb.}$$

Post Hold Down

Description:

(2) #4 bars embedded into footing and post.

#4 L-Bars, ASTM A615 Grade 60, L-ends or standard hook embedded 12" min. into footing or deformed bars embedded a minimum of 25" into footing and center of post core. The core is 8" diameter at the top and 6" diameter at the bottom. The grout shall have an f'_c 4,000 psi.



Anchors shall have edge reinforcement of a No. 4 bar or greater between anchor and edge and with the edge reinforcement enclosed within stirrups spaced at not more than 4 inches.

Anchor Strength in Post

1. Steel Strength of Anchor in Tension

$$N_s = nA_{se}f_y = 2 \times 0.196 \times 60\text{ksi} = 23.52\text{k per two bars}$$

2. Steel Strength of Anchor in Shear

$$V_s = nA_{se}f_y = 2 \times 0.196 \times 60\text{ksi} = 23.52\text{k per two bars}$$

3. Concrete Breakout Strength of Anchor in Tension

$$N_b = k'f'_c h_{ef}^{1.5} = 24 \times 4000 \times 15.2^{1.5} = 90 \text{ k}$$

$$N_{cbg} = A_v/A_v_o \cdot \gamma_1 \cdot \gamma_2 \cdot \gamma_3 N_b = 400/2079 \times 1 \times 0.82 \times 1 \times 90 = \underline{14.16 \text{ k}}$$

4. Concrete Breakout Strength of Anchor in Shear

$$V_b = 7(1/d_o)^{0.2} \cdot d_o \cdot f'_c \cdot c_1^{1.5} = 7(4/0.5)^{0.2} \times 0.5 \times 4000 \times 9^{1.5} = 14.716 \text{ k}$$

$$V_{cbg} = A_v/A_v_o \cdot \gamma_5 \cdot \gamma_6 \cdot \gamma_7 V_b = 270/365 \times 1 \times 0.9 \times 1.4 \times 14.716 = \underline{13.735 \text{ k}}$$

5. Pullout Strength of Anchor in Tension

Rebar embedded minimum of 15.2 inches to develop full strength.

$$N_{pn} = 2 \times 0.196 \times 60\text{ksi} = 23.52\text{k per two bars}$$

6. Concrete Pryout Strength of Anchor in Shear

$$V_{cp} = k_{cp} N_{cb} = 2 \times 14.16 = 28.3 \text{ k}$$

Allowable Loads

Wind

$$? N_n = N_u: \underline{0.75 \times 14,160 = 10,620 > 6,017 \text{ OK}}$$

$$? V_n = V_u: \underline{0.75 \times 13,735 = 10,301 > 2,213 \text{ OK}}$$

$$\text{If, } V_u > 0.2V_n \text{ and } N_u > 0.2N_n, \text{ then: } N_u/?N_n + V_u/?V_n = 1.2 \cdot 6017/10620 + 2213/10301 = \underline{0.567 + 0.215 = 0.78 \text{ OK}}$$

Seismic

$$0.75? N_n = N_u: \underline{0.75 \times 0.75 \times 14,160 = 7,965 > 5,072 \text{ OK}}$$

$$0.75? V_n = V_u: \underline{0.75 \times 0.75 \times 13,735 = 7,726 > 2,045 \text{ OK}}$$

$$\text{If, } V_u > 0.2? V_n \text{ and } N_u > 0.2? N_n, \text{ then: } N_u/? N_n + V_u/? V_n = 1.2 \\ 5,072 / 7965 + 2045 / 7726 = \underline{0.637 + 0.265 = 0.90 \text{ OK}}$$

Anchor Strength in Footing

1. Steel Strength of Anchor in Tension

$$N_s = nA_{se}f_y = 2 \times 0.196 \times 60\text{ksi} = 23.52\text{k per two bars}$$

2. Steel Strength of Anchor in Shear

$$V_s = nA_{se}f_y = 2 \times 0.196 \times 60\text{ksi} = 23.52\text{k per two bars}$$

3. Concrete Breakout Strength of Anchor in Tension

$$N_b = k? f_c h_{ef}^{1.5} = 16 \times ? 3000 \times 12^{1.5} = 36.4 \text{ k}$$

$$N_{cbg} = A_v / A_v_o? ?_1? ?_2? ?_3 N_b = 576 / 1296 \times 1 \times 0.88 \times 1.25 \times 36 = \underline{17.88 \text{ k}}$$

4. Concrete Breakout Strength of Anchor in Shear

$$V_b = 7(1/d_o)^{0.2} ? d_o ? f_c c_1^{1.5} = 7(4/0.5)^{0.2} \times ? 0.5 \times ? 3000 \times 11^{1.5} = 17.220 \text{ k}$$

$$V_{cbg} = A_v / A_v_o? ?_5? ?_6? ?_7 V_b = 396 / 545 \times 1 \times 0.9 \times 1.4 \times 19.622 = \underline{15.78 \text{ k}}$$

5. Pullout Strength of Anchor in Tension

Rebar embedded minimum of 11 inches hooked to develop full strength.

$$N_{pn} = 2 \times 0.196 \times 60\text{ksi} = 23.52\text{k per two bars}$$

6. Concrete Pryout Strength of Anchor in Shear

$$V_{cp} = k_{cp} N_{cb} = 2 \times 17.88 = 35.8 \text{ k}$$

Allowable Loads

Wind

$$? N_n = N_u: \underline{0.75 \times 17,880 = 13,410 > 6,017 \text{ OK}}$$

$$? V_n = V_u: \underline{0.75 \times 15,780 = 11,830 > 2,213 \text{ OK}}$$

$$\text{If, } V_u > 0.2? V_n \text{ and } N_u > 0.2? N_n, \text{ then: } N_u/? N_n + V_u/? V_n = 1.2 \\ 6017 / 13410 + 2213 / 11830 = \underline{0.449 + 0.187 = 0.64 \text{ OK}}$$

Seismic

$$0.75? N_n = N_u: \underline{0.75 \times 0.75 \times 17,880 = 10,000 > 5,072 \text{ OK}}$$

$$0.75? V_n = V_u: \underline{0.75 \times 0.75 \times 15,780 = 8,870 > 2,045 \text{ OK}}$$

$$\text{If, } V_u > 0.2? V_n \text{ and } N_u > 0.2? N_n, \text{ then: } N_u/? N_n + V_u/? V_n = 1.2 \\ 5072 / 10000 + 2045 / 8870 = \underline{0.507 + 0.231 = 0.74 \text{ OK}}$$

Post Footings

Wind Overturning Moment = $1383 \times 4 = 5,531$ ft-lb.

Gravity Load Resisting Moment = $0.67(4800) \frac{2}{12} + 0.67(3333) \frac{10}{12} = 2397$ ft-lb.

Resultant wind load on fence panel, F_w

$$5531 - 2397 = F_w (4)$$

$$F_w = 784 \text{ lb.}$$

Seismic Overturning Moment = $1573 \times 4 = 6292$ ft-lb.

Gravity Load Resisting Moment = $0.85(4800) \frac{2}{12} + 0.85(3333) \frac{10}{12} = 3041$ ft-lb.

Required hold down force, F_E

$$6292 - 3041 = F_E (4)$$

$$F_E = 813 \text{ lb.}$$

For footing design use 1.3W or E:

$$1.3W = 1.3 \times 784 = \underline{1019 \text{ lb.}}$$

$$E = 813 \text{ lb.}$$

For lateral bearing allowable use two times the tabular values per Section 1804.3.1

Footings are 24" in diameter for soil bearing allowable greater than or equal to 2,000 psf and 28" in diameter for soil bearing allowable of 1500 psf, with $f'_c = 3,000$ psi min. The depth for soil types GW and GP (sandy gravel and/or gravel) is 46 inches; for soil types SW, SP, SM, SC, GM and GC (sand, silty sand, clayey sand, silty gravel and clayey gravel) is 51 inches; and, for soil types CL, ML, MH, and CH (clay sandy clay, silty clay, clayey silt, silt and sandy silt) is 57 inches.

Vertical load:

$$[3333 + (150 \times 46/12 \times p1^2)]/ p1^2 = (3333+1806)/3.1416 = 1,636 \text{ psf} < 3,000 \text{ OK}$$

$$[3333 + (150 \times 51/12 \times p1^2)]/ p1^2 = (3333+2003)/3.1416 = 1,698 \text{ psf} < 2,000 \text{ OK}$$

$$[3333 + (150 \times 57/12 \times p1.167^2)]/ p1.167^2 = (3333+3048)/4.275 = 1,492 \text{ psf} < 1,500 \text{ OK}$$

Fence Panels

$$\text{Wind load} = q_z GC = 13 \times 0.85 \times 1.2 = 13.3 \text{ psf} \times 1.6 = \underline{21.3 \text{ psf}}$$

$$\text{Seismic load} = 0.4(150 \times 4/12) = 20.0 \text{ psf}$$

 DESIGN OF FOOTINGS FOR CANTILEVERED POST

DESCRIPTION >> 8' High Fence with Posts at 13' O/C.
 >> CL,ML,MH SW,SP,SM GW & GP

| DESCRIPTION | | CL | ML | MH | SW | SP | SM | GW & GP |
|--|------|-------|-------|-------|----|----|----|---------|
| ALLOW PASSIVE | psf | 200 | 300 | 400 | | | | 0 |
| MAX PASSIVE | psf | 3,000 | 4,500 | 6,000 | | | | 0 |
| LOAD DURATION FACTOR | | 1.33 | 1.33 | 1.33 | | | | 1.33 |
| POINT LOAD | lbs | 1,019 | 1,019 | 1,019 | | | | 0 |
| LOAD Ht. | ft | 4.00 | 4.00 | 4.00 | | | | 0.00 |
| DIST. LOAD | #/ft | 0 | 0 | 0 | | | | 0 |
| START HT. | ft | 0.00 | 0.00 | 0.00 | | | | 0.00 |
| END HT. | ft | 0.00 | 0.00 | 0.00 | | | | 0.00 |
| WIDTH/DIAMETER | in | 28 | 24 | 24 | | | | 0 |
| CIRCULAR ? | y/n | Y | Y | Y | | | | N |
| RESTRAINED ? | y/n | N | N | N | | | | N |
| ----- SUMMARY ----- | | | | | | | | |
| Moments @ Surface: | | | | | | | | |
| Point Load | ft-# | 4,077 | 4,077 | 4,077 | | | | 0 |
| Uniform Load | ft-# | 0 | 0 | 0 | | | | 0 |
| ... Total Moment | ft-# | 4,077 | 4,077 | 4,077 | | | | 0 |
| Total Lateral Load | # | 1,019 | 1,019 | 1,019 | | | | 0 |
| ----- NON-RESTRAINED ----- RESULTS ----- | | | | | | | | |
| Min. Req'd Embedment | | | | | | | | |
| $A(1+(1+4.36h/A)^{.5})/2$ | | | | | | | | |
| A=2.34P/(S 1 b) | ft | 4.71 | 4.26 | 3.80 | | | | 0.00 |
| Press @ 1/3 Embed.: | | | | | | | | |
| Actual | psf | 418 | 566 | 673 | | | | 0 |
| Allowable | psf | 417 | 567 | 675 | | | | 0 |

 CONCRETE FENCE PANEL DESIGN & ANALYSIS

| DESCRIPTION | | >> Fence Panels--#3 bars @ 12" O/C. | | | |
|------------------------------|------|-------------------------------------|-----------|-----------|-----------|
| | | >> Maximum Design | | | |
| ----- GENERAL ----- | | --Span 1- | --Span 2- | --Span 3- | --Span 4- |
| ALL SPANS SIMPLE SUPPORT ? | y | y/n | | | |
| SPAN LENGTH | ft | 12 | 12 | 0 | 0 |
| END FIXITY..... | Lft | 1 | 1 | 1 | 1 |
| Fix,Pin,Free = 2,1,0 | Rt | 1 | 1 | 1 | 1 |
| BEAM WIDTH | in | 12 | 12 | 0 | 0 |
| BEAM DEPTH | in | 4 | 4 | 0 | 0 |
| ---- CALCULATED VALUES ---- | | | | | |
| Left: Max Mu | ft-k | 0.0 | 0.0 | 0.0 | 0.0 |
| Mn * Phi | ft-k | 1.0 | 1.0 | 0.0 | 0.0 |
| Center: Max Mu | ft-k | 1.0 | 0.6 | 0.0 | 0.0 |
| Mn * Phi | ft-k | 1.0 | 1.0 | 0.0 | 0.0 |
| ..Dist. to Mu | ft | 6.00 | 6.00 | 0.00 | 0.00 |
| Right: Max Mu | ft-k | 0.0 | 0.0 | 0.0 | 0.0 |
| Mn * Phi | ft-k | 1.0 | 1.0 | 0.0 | 0.0 |
| Max Vu: Left | k | 0.34 | 0.20 | 0.00 | 0.00 |
| Rt | k | 0.34 | 0.20 | 0.00 | 0.00 |
| Reactions: Left: Dead | k | 0.00 | 0.00 | 0.00 | 0.00 |
| ..(service) Live | k | 0.21 | 0.13 | 0.00 | 0.00 |
| Total | k | 0.21 | 0.13 | 0.00 | 0.00 |
| Right: Dead | k | 0.00 | 0.00 | 0.00 | 0.00 |
| Live | k | 0.21 | 0.13 | 0.00 | 0.00 |
| Total | k | 0.21 | 0.13 | 0.00 | 0.00 |
| Max. Defl @ Mid Span | in | -0.071 | -0.043 | 0.000 | 0.000 |
| X-Dist | ft | 6.00 | 6.00 | 0.00 | 0.00 |
| ----- BEAM DESIGN DATA ----- | | | | | |
| f'c | psi | 4,000 | 4,000 | 3,000 | 3,000 |
| Fy | psi | 60,000 | 60,000 | 60,000 | 60,000 |
| LEFT: As-TOP | in^2 | 0.12 | 0.12 | 0 | 0 |
| 'd' TO BARS | in | 2 | 2 | 0 | 0 |
| CENTER: As-BOTTOM | in^2 | 0.12 | 0.12 | 0 | 0 |
| 'd' TO BARS | in | 2 | 2 | 0 | 0 |
| RIGHT: As-TOP | in^2 | 0.12 | 0.12 | 0 | 0 |
| 'd' TO BARS | in | 2 | 2 | 0 | 0 |
| ----- APPLIED LOADS ----- | | | | | |
| USE LL THIS SPAN? | Y/N | Y | Y | Y | Y |
| UNIFORM..... DL | klf | 0 | 0 | 0 | 0 |
| LL | klf | 0.035 | 0.02128 | 0 | 0 |

 RECTANGULAR CONCRETE COLUMN DESIGN

DESCRIPTION >> 8' high fence post
 >>

| DESIGN DATA | COLUMN DATA |
|--------------------------------|--------------------------|
| f'c = 4,000 psi | DEPTH = 20 in |
| Fy = 60,000 psi | WIDTH = 20 in |
| SEISMIC ZONE (0=wind): 0 0-4 | COLUMN HEIGHT = 8 ft |
| COMBINE LL & ST ? Y y/n | CALC P:M DIAGRAM ? N y/n |
| EFF. LENGTH FACTOR = 1 | |
| | REBARS: COUNT BAR # "d" |
| IS COLUMN UNBRACED ? y y/n | SET #1 : 2 5 4 in |
| IF UNBRACED, Delta:S = 0 | SET #2 : 2 5 16 in |
| | SET #3 : 0 0 0 in |
| Total Reinf. Area = 1.24 in^2 | SET #4 : 0 0 0 in |
| % Steel = 0.31 % | SET #5 : 0 0 0 in |
| Note: 1% Min < Actual < 8% Max | |

 APPLIED LOADS

| | | MOMENTS: | | |
|---------------------|--------|-----------|----------------|--------|
| | | Top | | Bottom |
| AXIAL: DL = 0.111 k | | DL = 0 | ft-k | 0 |
| LL = 0.111 k | | LL = 0 | ft-k | 0 |
| ST = 0 k | | SHORT = 0 | ft-k | 0 |
| Ecc. = 0 in | | | | |
| | | DEAD | LIVE | SHORT |
| DISTRIBUTED : | #1 = 0 | 0 | 0.286 klf @ x= | 0 8 ft |
| | #2 = 0 | 0 | 0 klf @ x= | 0 0 ft |
| POINT : | #1 = 0 | 0 | 0 k @ x= | 0 ft |
| | #2 = 0 | 0 | 0 k @ x= | 0 ft |

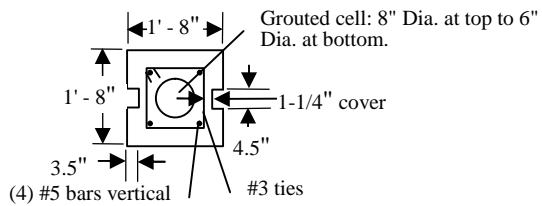
 SUMMARY

| | | ACI Equation | | |
|-----------------------------------|---|--------------|--------|-----------|
| | | 9-1 | 9-2 | 9-3 |
| Pu : Max. Factored | = | 0.3441 | 0.2580 | 0.0999 k |
| Pn * Phi : Capacity @ Design Ecc. | = | 800.903 | 4.1902 | 1.7371 k |
| | | OK | OK | OK |
| Mc = Delta:B*M2b + Delta:S*M2S | = | 0.03 | 2.92 | 2.97 kft |
| Final Ecc.: Axial*Ecc + Moments | = | 1.20 | 135.64 | 357.29 in |
| Magnification Factor | = | 1.000 | 1.000 | 1.000 in |
| Design Eccentricity | = | 1.20 | 135.64 | 357.29 in |
| Po * .80 : (short column) | = | 1144.14 | 1144.1 | 1144.1 k |
| P : Balanced | = | 539.177 | 539.17 | 539.17 k |
| Ecc: Balanced | = | 6.80 | 6.80 | 6.80 in |

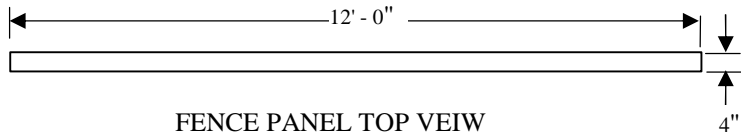
 SLENDERNESS EFFECTS

| | |
|--------------------------------------|-----------------------------|
| Actual kLu/r = 16.00 | Elastic Modulus = 4E+06 psi |
| Beta = 0.85 | |
| | 9-1 9-2 9-3 |
| Neutral Axis Distance from Edge = | 20.90 1.39 1.33 in |
| Phi = | 0.700 0.705 0.702 |
| Max. kLu/r to neglect slenderness = | 22.0 22.0 22.0 |
| Beta = Sustained / Maximum Moments = | 0.452 0.452 1.000 |
| Cm = | 1.000 1.000 1.000 |
| EI = Max[(.2*Ec*Ig+Es*Is)/(1+Beta) | |
| -or- .4 Ec Ig/(1+Beta)]/1000000 = | 0 0 0 |
| Pc : Pi^2 * EI / (kLu)^2 = | 0.0 0.0 0.0 |
| Alpha : Max Pu / (Phi * Pc) = | 0.000 0.000 0.000 |
| Delta:b=Cm/(1-Alpha) = | 1.000 1.000 1.000 |
| Delta:b * M2b = | 0.00 0.00 0.00 ft-k |
| Delta:s * M2s = | 0.00 2.92 2.97 ft-k |

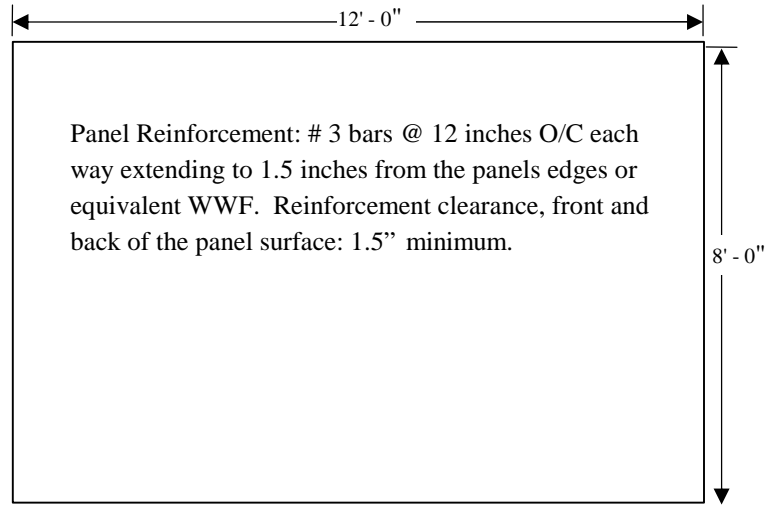
| | | | | | |
|------------------------------------|---|-------------|-------------------------|--------|----|
| Eccentricity: Ecc. Loads + Moments | = | 1.20 | 135.64 | 357.29 | in |
| Design Ecc. = Ecc * Delta | = | 1.20 | 135.64 | 357.29 | in |
| ----- | | | | | |
| | | DEFAULT ACI | LOAD FACTORS | | |
| ACI 9-1 & 9-2 DL = | | 1.40 | ACI 9-2 Group Factor = | 0.75 | |
| ACI 9-1 & 9-2 LL = | | 1.70 | ACI 9-3 Dead Load Fact= | 0.90 | |
| ACI 9-1 & 9-2 ST = | | 1.70 | ACI 9-3 Short Term = | 1.30 | |
| Seismic = ST * | | 1.10 | | | |



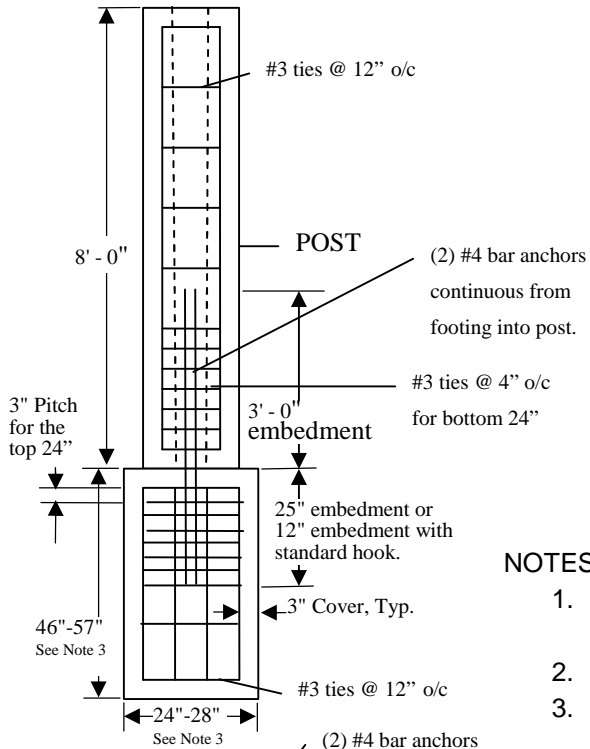
POST TOP VIEW



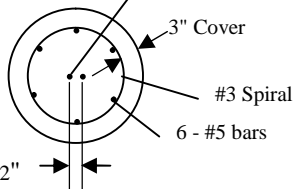
FENCE PANEL TOP VIEW



FENCE PANEL FRONT VIEW



FRONT VIEW



FOOTING TOP VIEW

NOTES:

1. $F'_c = 4,000$ PSI MINIMUM FOR POST AND PANEL CONCRETE INCLUDING CELL GROUT.
2. $F'_c = 3,000$ PSI MINIMUM FOR FOOTINGS.
3. FOOTINGS ARE 24" IN DIAMETER FOR SOIL BEARING ALLOWABLE GREATER THAN OR EQUAL TO 2,000 PSF AND 28" IN DIAMETER FOR MINIMUM SOIL BEARING ALLOWABLE OF 1500. FOOTING DEPTH FOR SOIL TYPES GW AND GP (SANDY GRAVEL AND/OR GRAVEL) IS 46 INCHES; FOR SOIL TYPES SW, SP, SM, SC, GM AND GC (SAND, SILTY SAND, CLAYEY SAND, SILTY GRAVEL AND CLAYEY GRAVEL), 51 INCHES; AND, FOR SOIL TYPES CL, ML, MH, AND CH (CLAY SANDY CLAY, SILTY CLAY, CLAYEY SILT, SILT AND SANDY SILT), 57 INCHES.
4. MINIMUM SOIL BEARING PRESSURE ALLOWABLE: 1500 PSF
5. WIND: $V = 90$ MPH, EXPOSURE C.
6. SEISMIC: SHORT PERIOD SPECTRAL ACCELERATION, $S_s = 1.5$ OR LESS; SITE CLASSES A, B, C, OR D ; IMPORTANCE FACTOR, $I_p = 1.0$