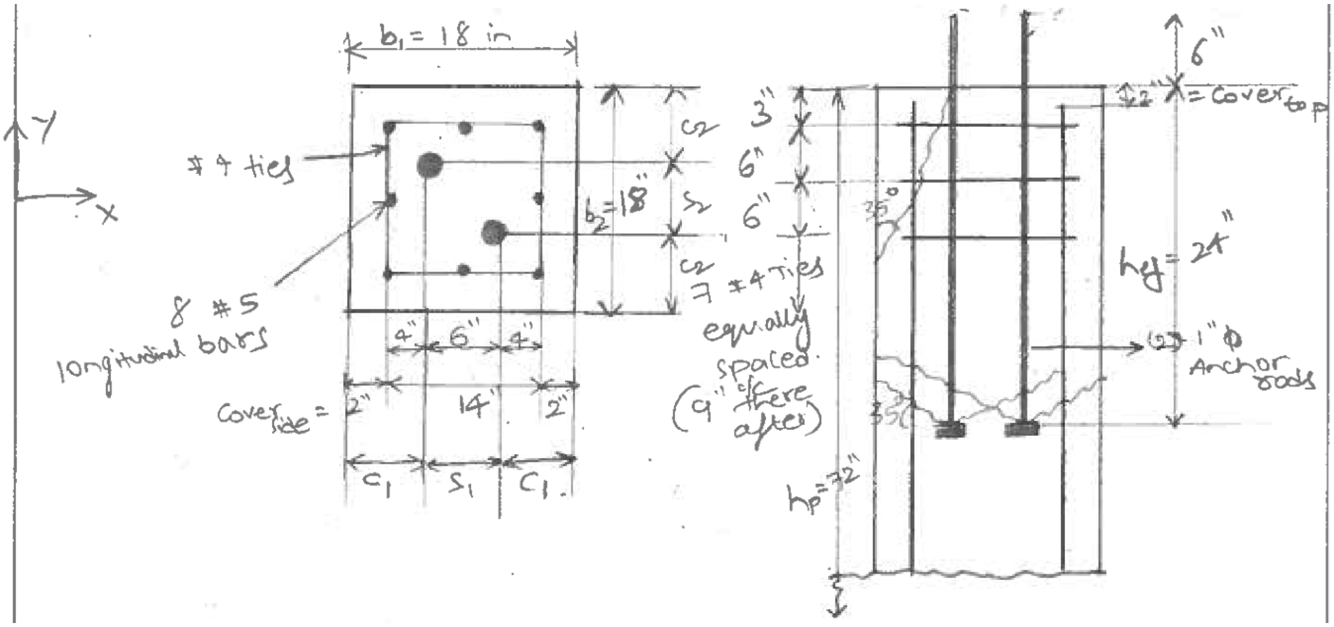
Anchor Bolt Design (Per ACI 318-08 and "Design of Reinforcement in Concrete Pedestals" CSA Today, Vol III, No. 12)



Design Assumptions:

1. Tension is equally distributed among all anchors.
2. Shear force is assumed to be carried by only 1 bolt.
3. No sleeve is used for anchor bolts.
4. The tension and shear forces are transferred to the longitudinal rebars and shear reinforcement respectively, which will restrain the concrete failure prism. Therefore, concrete breakout strength in tension and shear (per sections D5.2 and D 6.2) is not checked.
5. The concrete pryout strength (per section D6.3) is usually critical for short and stiff anchors and hence is assumed OK in this case.

Base Units and Design Data:

$kip \equiv 1000 \cdot lb$

$psi \equiv \frac{lb}{in^2}$

$ksi \equiv psi \cdot 1000$

Maximum Total Factores Loads Per Anchor:

Tension: $N_u := 70kip$

Maximum Shear in X-Direction: $V_{ux} := 3.7kip$

Maximum Shear in Y-Direction: $V_{uy} := 3.75kip$

Resistance Factors (Section D4.4):

Tension: $\phi_T := 0.75$ Shear: $\phi_V := 0.65$

Pedestal Data:

Concrete Compressive Strength: $f_c := 3000psi$

Height of Pier: $h_p := 72in$ Width of Pier: $b_p := 18in$ Length of Pier: $l_p := 18in$

Embedment Depth of Anchor Rod: $h_{ef} := 24in$

Edge Distances: $C_1 := 6in$ $C_2 := 6in$

Anchor Spacings: $S_1 := 6in$ $S_2 := 6in$

Concrete Cover: $Cover_{top} := 2in$ $Cover_{side} := 2in$

Anchor Data:

Specification: ASTM A615 Grade 60 $f_{ya} := 60ksi$ $f_{uta} := 90ksi$

Diameter: $d_A := 1in$

Threads per inch: $n_T := 8$ No. of Anchors: $n_a := 2$ Width Across Flats: $F := 1.625in$

Reinforcing Bars:

Specification: ASTM A615 Grade 60 $f_{yb} := 60ksi$ $f_{utb} := 90ksi$

Vertical Longitudinal Bars: $bar_{size\_reinf} := 5$ $d_b := \frac{bar_{size\_reinf}}{8} in$ $A_{s\_b} := \frac{\pi}{4} \cdot d_b{}^2 = 0.31 \cdot in^2$

Shear reinforcement: $bar_{size\_tie} := 4$ $d_{tie} := \frac{bar_{size\_tie}}{8} in$ $A_{s\_tie} := \frac{\pi}{4} \cdot d_{tie}{}^2 = 0.20 \cdot in^2$

Check the Size of Anchors:

Anchor Diameter: $d_A = 1.00 \cdot in$

Effective Cross Sectional Area of Anchor Rod: $A_{se} := \frac{\pi}{4} \cdot \left(d_A - \frac{0.9743in}{n_T}\right)^2 = 0.61 \cdot in^2$

The Available Steel Strength of One Anchor in Tension (Per Section D5.1.2):

$$f_{uta} := \min\left(f_{uta}, 1.9 \cdot f_{ya}, 125ksi\right) = 90.00 \cdot ksi$$

$$N_{sa} := A_{se} \cdot f_{uta} = 54.52 \cdot kip \qquad \text{(Eq D-3)}$$

Available Tensile Strength Per Anchor: $\phi N_n := \phi_T \cdot N_{sa} = 40.89 \cdot kip$

Applied Tensile Force Per Anchor: $N_{ua} := \frac{N_u}{n_a} = 35.00 \cdot kip$

$Check\_Tension := if\left(\phi N_n \geq N_{ua}, "OK", "NG"\right)$ $Check\_Tension = "OK"$

The Available Steel Strength of One Anchor in Shear (Per Section D6.1.2b & D6.1.3):

$$V_{sa} := 0.8 \cdot \left(0.6 \cdot A_{se} \cdot f_{uta}\right) = 26.17 \cdot kip \qquad \text{(Eq D-20)}$$

Note: Since grout pad is used, the nominal strength is multiplied by 0.8 per D6.1.3

Available Shear Strength Per Anchor: $\phi V_n := \phi_V \cdot V_{sa} = 17.01 \cdot kip$

Applied Shear Force Per Anchor: $V_{ua} := \max\left(V_{ux}, V_{uy}\right) = 3.75 \cdot kip$

$Check\_Shear := if\left(\phi V_n \geq V_{ua}, "OK", "NG"\right)$ $Check\_Shear = "OK"$

$$\text{Interaction\_Ratio} := \frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} = 1.08$$

$$\text{Check\_Interaction} := \text{if}\left(\text{Interaction\_Ratio} \le 1.2, \text{"OK"}, \text{"NG"}\right) \qquad \text{Check\_Interaction} = \text{"OK"}$$

Check the Pullout Resistance of Anchor in Tension (Section D5.3):

Bearing Area of Anchor Head: $A_{brg} := 0.866 \cdot F^2 - \frac{\pi}{4} \cdot {d_A}^2 = 1.50 \cdot in^2$

Assuming the concrete is uncracked, the modification factor for pullout resistance (per D5.3.6):

$$\psi_{c\_p} := 1.4$$

The pullout resistance of anchor in tension for a headed bolt (per D5.3.4):

$$N_p := \psi_{c\_p} \cdot 8 \cdot A_{brg} \cdot f_c = 50.45 \cdot kip \qquad \text{(Eq D-15)}$$

The strength reduction factor for anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength for Condition A (per D4.4C):

$$\phi := 0.75$$

Available Pullout Resistance: $\phi N_{pn} := \phi \cdot N_p = 37.83 \cdot kip$

Applied Tensile Force Per Anchor: $N_{ua} := \frac{N_u}{n_a} = 35.00 \cdot kip$

$$\text{Check\_Pullout} := \text{if}\left(\phi N_{pn} \ge N_{ua}, \text{"OK"}, \text{"NG"}\right) \qquad \text{Check\_Pullout} = \text{"OK"}$$

Check the Side Face Blowout Resistance of Anchor in Tension (Section D5.4):

Bearing Area of Anchor Head: $A_{brg} = 1.50 \cdot in^2$

The side-face blow out of anchor in tension for a headed bolt (per D5.4.1):

$$N_{sb} := 160 \cdot \min\left(C_1, C_2\right) \sqrt{A_{brg}} \cdot \sqrt{f_c \cdot psi} = 64.43 \cdot kip \qquad \text{(Eq D-17)}$$

$$N_{sb\_Modified} := \text{if}\left[1 \le \frac{C_2}{C_1} \le 3, N_{sb} \cdot \frac{\left(1 + \frac{C_2}{C_1}\right)}{4}, N_{sb}\right] = 32.21 \cdot kip \qquad \text{(Per Section D5.4.1)}$$

The strength reduction factor for anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength for Condition A (per D4.4C):

$$\phi := 0.75$$

Available Side-Face Blowout Strength: $\phi N_{sb} := \phi \cdot N_{sb\_Modified} = 24.16 \cdot kip$

Applied Tensile Force Per Anchor: $N_{ua} := \frac{N_u}{n_a} = 35.00 \cdot kip$

$$\text{Check\_SideFace\_Blowout} := \text{if}\left(\phi N_{sb} \ge N_{ua}, \text{"OK"}, \text{"NG"}\right) \qquad \text{Check\_SideFace\_Blowout} = \text{"NG"}$$

Check the Interaction Equation (Section D7):

$$\phi N_n := \min(\phi_T \cdot N_{sa}, \phi N_{pn}, \phi N_{sb}) = 24.16 \cdot kip$$

$$Interaction\_Ratio := \frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} = 1.67$$

$Check\_Interaction := if(Interaction\_Ratio \le 1.2, "OK", "NG")$ $Check\_Interaction = "NG"$

Transfer of Anchor Load to Vertical Rebars (Section D5.2.9):

As per section D5.2.9, If anchor reinforcement is developed in accordance with chapter 12 on either sides of the breakout surface, the design strength of anchor reinforcement can be permitted to be used instead of the concrete breakout strength. Only the reinforcement that is located less than $0.5h_{ef}$ = 0.5*24 = 12 in. from center of anchor rod should be considered effective for resisting anchor tension.

Rebar Strength Analysis *(as per ACI 318-08, 12.2)*

Number of rebars contributing to each anchor rod and within a distance "g" to the anchor rod: $N := 5$

$\phi := 0.9$ (For capacity that is governed by yielding of rebar)

Nominal strength of the rebars: $Rebar\_Strength := \phi \cdot f_{yb} \cdot N \cdot A_{s\_b}$ $Rebar\_Strength = 82.83 \cdot kip$

Anchor strength: $Anchor\_Strength := \phi N_n$ $Anchor\_Strength = 24.16 \cdot kip$

Check to ensure that rebar strength is sufficient for the anchor rod:

$Rebar\_Strength\_Status := if(Rebar\_Strength \ge Anchor\_Strength, "OK", "NO GOOD")$ $Rebar\_Strength\_Status = "OK"$

$$\frac{Anchor\_Strength}{Rebar\_Strength} = 0.29$$

Embedment Analysis *(as per ACI 318-08, 12.2)*

$\psi_t := 1.0$ Reinforcement Location Factor (Use 1.0 for vertical bars)

$\psi_e := 1.0$ Coating Factor (Use 1.0 for uncoated bars)

$\lambda := 1.0$ Lightweight Aggregate Factor (Use 1.0 for normal weight concrete)

$K_{tr} := 0$ Transverse Reinforcement Index (Conservatively use 0)

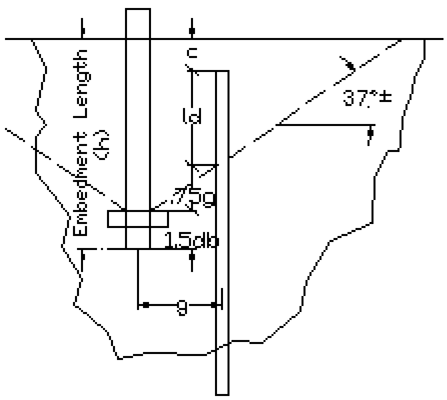
Length required to develop maximum strength of rebar:

$$l_{d\_max} := if\left(d_b \le 0.75 \cdot in, \frac{f_{yb} \cdot \psi_t \cdot \psi_e \cdot \lambda}{25 \cdot \sqrt{f_c \cdot psi}} \cdot d_b, \frac{f_{yb} \cdot \psi_t \cdot \psi_e \cdot \lambda}{20 \cdot \sqrt{f_c \cdot psi}} \cdot d_b\right)$$ $$l_{d\_max} = 27.39 \cdot in$$

Required development length for the rebar group (reduction in the development length is permitted where there are multiple rebars, or where they provide excessive strength, as per ACI 318-08, Chapter 12.2.5):

$$l_{d\_req} := l_{d\_max} \cdot \left(\frac{Anchor\_Strength}{Rebar\_Strength} \right) \qquad l_{d\_req} = 7.99 \cdot in$$

(Per AISC Steel Design 1-"Base Plate and Anchor Rod Design" pg.23)



$g := 3 \cdot in$ Distance between center of anchor rod and center of rebar group

$c := 3 \cdot in$ Concrete cover at top of rebar (Use 3" cover if 2" is shown on dwg.)

Required Minimum Anchor Rod Embedment Length as per AISC Steel Design 1 - "Base plate and Anchor Rod Design" pg.23. ($1.5d_{AR}$ is added to length by inspection, for portion of rod below top of embedded nut):

$$h := l_{d\_req} + c + 0.75g + 1.5d_A \qquad h = 14.74 \cdot in$$

Provided Embedment Length, $h_{ef} = 24.00 \cdot in$

$Embedment\_Depth\_Status := if(h_{ef} \geq h, "OK", "NO GOOD")$ $\qquad Embedment\_Depth\_Status = "OK"$

Check if longitudinal reinforcement is developed on either side of the breakout surface (Section D5.2.9):

Required anchor reinforcement depth: $reinf\_depth\_req := 2 \cdot h = 29.48 \cdot in$

Provided depth of longitudinal reinforcement: $reinf\_depth\_pro := h_p - Cover_{top} = 70.00 \cdot in$

$Embedment\_Reinf\_Depth\_Status := if(reinf\_depth\_pro \geq reinf\_depth\_req, "OK", "NO GOOD")$

$Embedment\_Reinf\_Depth\_Status = "OK"$