FRA-71-19.36 under Cleveland Ave. (Pier Bearings Strength Check/Anchor Bolts)

These calculations provide the capacity of a single anchor or an anchor group according to AASHTO LRFD (9th Ed.) and ACI 318 Appendix D.

DEFINE CONSTANTS:

Grade 36 was selected as the material for the structural bolts.

Material

Min. Yield Strength $F_y := 36\text{ksi}$

Min. Tensile Strength $F_u := 58\text{ksi}$

Concrete $F_c := 4\text{ksi}$ $w_{conc} \equiv 0.15 \cdot \frac{\text{kip}}{\text{ft}^3}$

Resistance Factors [AASHTO LRFD Bridge Design 6.5.4.2]

for Flexure (Steel) $\phi_f := 1.0$

For ASTM F1554 bolts in Shear $\phi_s := 0.75$

GEOMETRY AND PROPERTIES

Nominal Anchor Bolt Diameter $d_{bolt} := 1.25\text{in}$

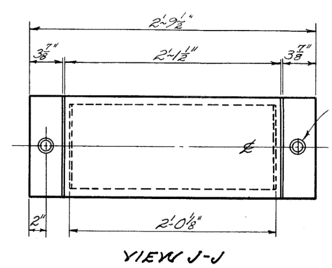
Nominal Anchor Bolt Area $A_{bolt} := \frac{\pi \, d_{bolt}^2}{4} = 1.23 \cdot \text{in}^2$

Anchor bolt bearing area $A_{bolt\_brg} := 1.817\text{in}^2$ Table A.2 (a), smallest bearing area used conservatively (Hex Head Bolt)

Number of Bolts per Bearing $N_{bolt} := 2$

Spacing of Bolts $S_{bolts} := 29.5\text{in}$

Check Minimum Spacing b/w Centers of Bolts (in Standard Holes) $S_{min} := 3 \cdot d_{bolt} = 3.75 \cdot \text{in}$



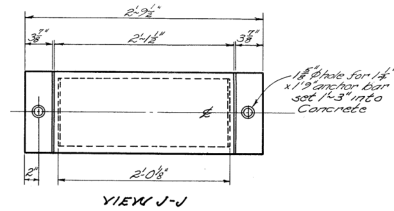
$$Check_{Spacing} := \begin{cases} \text{"OK"} & \text{if } S_{bolts} \geq S_{min} \\ \text{"NG, increase spacing"} & \text{otherwise} \end{cases}$$

$Check_{Spacing} = \text{"OK"}$

Clear Distance b/w Holes $L_c := S_{bolts} - \left(1 \cdot \frac{1}{16} in\right) = 29.44 \cdot in$

Edge Distance $d_{edge} := 5.25in$ As-built plans

Effective Embedment $h_{ef} := 15in$ As-built plans



DESIGN LOADS

Refer to the load calcs above for shear forces under seismic event.

Shear Force on Bolt due to seismic effects:

$Shear\_Load := 75.68kip$ Total shear force (for both bolts)

$V_u := \max(Shear\_Load) = 75.68 \cdot kip$ per bolt group/brg

ANCHOR BOLT CAPACITY

[AASHTO LRFD Bridge Design 14.8.3.1]

The shear resistance of anchor bolts shall be determined as specified in Article 6.13.2.12.

Shear Resistance

[AASHTO LRFD Bridge Design 6.13.2.12]

Calculation below is for shear resistance where threads are included in shear plane.

Factored Shear Resistance $R_r = \phi_s 0.50 \cdot A_{bolt} \cdot F_u \cdot N_s$

Design Shear Force $R_{shear} := V_u$ $R_{shear} = 75.68 \cdot kip$

No. of Shear Planes per Anchor Bolt $N_s := 1N_{bolt}$

Nominal Shear Resistance $R_n := 0.50 \cdot A_{bolt} \cdot F_u \cdot N_s$ $R_n = 71.18 \cdot kip$

Shear Capacity Check

$$Check_s := \begin{cases} \text{"Design is OK"} & \text{if } \phi_s \cdot R_n > R_{shear} \\ \text{"N.G"} & \text{otherwise} \end{cases}$$

$Check_s = \text{"N.G"}$

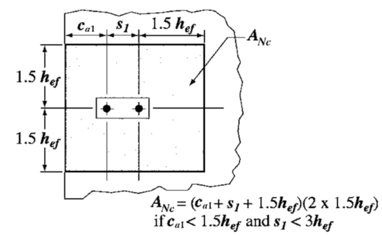
CONCRETE CAPACITY

Concrete Breakout Strength in Tension (Calculated for concrete pryout strength): [ACI D.5.2.1]

$c_{a1} := d_{edge} = 5.25 \cdot in$ $S_1 := S_{bolts} = 29.50 \cdot in$

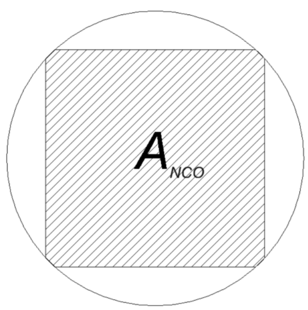
$c_{a2} := c_{a1} = 5.25 \cdot in$

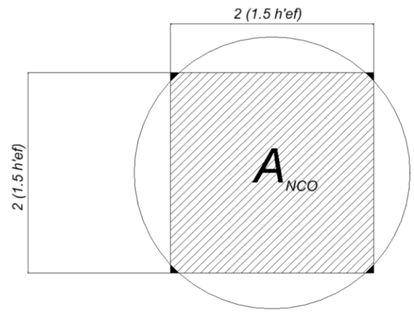
Note (318-14, 17.4.2.3): Since three edge distances (i.e. 5.25 inches) are less than the 1.5 h_{ef} (i.e. 22.5 inches), h'_{ef} shall be calculated. h'_{ef} is taken largest of $c_{a,max}$/1.5 & 1/3 of bolts spacing. Therefore, (Bolts spacing/3 = 9.83") controls.



$$h'_{ef} := \max\left(\frac{c_{a1}}{1.5}, \frac{S_{bolts}}{3}\right) = 9.83 \cdot in$$

For A_{nco} & A_{nc}, use reduced embedment of anchor.

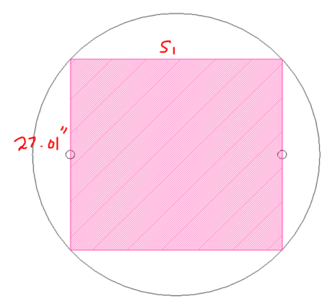




$A_{Nco} := 866.71 in^2$ $N_{bolt} \cdot A_{Nco} = 1.73 \times 10^3 \cdot in^2$

(A_{nco} (for non circular edges) = $9h_{ef}^2$ = 870 in^2. However, due to ciruclar edge constraints, the area is slightly reduced. Reduced (or effective) h'_{ef} shall be used for calculation of area.

$A_{Nc} := (S_1) \cdot (27.01 in)$ (27.01" is taken from CAD for given bolt spacing)



$A_{Nc} = 796.80 \cdot in^2$

$$check := \begin{cases} \text{"ok"} & \text{if } A_{Nc} \le N_{bolt} \cdot A_{Nco} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$check = \text{"ok"}$ $A_{Nc} := \min(A_{Nc}, N_{bolt} \cdot A_{Nco}) = 796.80 \cdot in^2$

modification for eccentric load (D5.2.4)

$e_N := 0 in$ For single corner anchor in tension, e'_N shall be 0

$$\Psi_{ec,N} := \frac{1}{1 + \frac{2e_N}{3h'_{ef}}} = 1.00$$ $\Psi_{ec,N} := \min(\Psi_{ec,N}, 1.0) = 1.0$

modification for edge effects (D5.2.5)

$$\Psi_{ed,N} := \begin{cases} 1 & \text{if } c_{a1} \geq 1.5h'_{ef} \\ 0.7 + 0.3 \cdot \dfrac{c_{a1}}{1.5h'_{ef}} & \text{if } c_{a1} < 1.5h'_{ef} \end{cases} = 0.81$$

Modification for cracked section (D5.2.6)

$\Psi_{c,N} := 1.25$ for cast-in anchors

Modification for post-installed anchors (D5.2.6)

$\Psi_{cp,N} := 1.0$ for cast-in anchors

Basic concrete breakout strength of a single anchor in tension in cracked concrete

$k_c := 24$ for cast-in-anchors

Note:
17 = Post-installed anchors
24 = Cast-in anchors

$$N_b := k_c \cdot \sqrt{\frac{F_c}{(psi)}} \cdot \left[\frac{h'_{ef}}{(in)}\right]^{1.5} \cdot (lbf) = 46.81 \cdot kip$$

Nominal concrete breakout strength (D5.2)

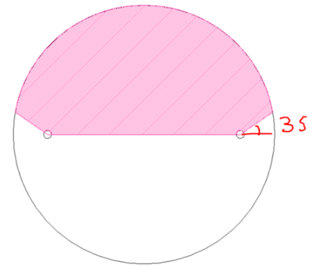
$$N_{cbg} := \frac{A_{Nc}}{A_{Nco}} \cdot \left(\Psi_{ec,N} \cdot \Psi_{ed,N} \cdot \Psi_{c,N} \cdot \Psi_{cp,N} \cdot N_b\right) = 43.39 \cdot kip$$

PROJECT: FRA-71
CALCULATED BY: MAN
DATE: 10/24/2022

CALCULATION SHEET
CHECKED BY: MJR
DATE: 10/14/22
SHEET NO: 6 of 10

Concrete Breakout Strength in Shear:

Assembly 1

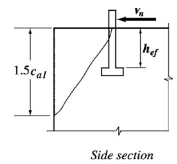


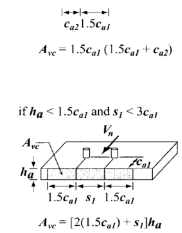
Projected Area for single anchor in a deep member

$$A_{Vco} := 4.5 c_{a1}^{2} = 124.03 \cdot in^{2}$$

Projected Area of Failure Surface (at 35 deg cone) at its edge for a single or group of anchors.)

$$A_{Vc} := \left[S_1 + \left(\frac{c_{a1}}{\cos(35deg)} \right) \cdot 2 \right] \cdot 1.5 c_{a1} = 333.26 \cdot in^{2}$$





$$check := \begin{cases} \text{"ok"} & \text{if } A_{Vc} \le N_{bolt} \cdot A_{Vco} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

check = "NG"

$$A_{Vc} := \min\left(A_{Vc}, N_{bolt} \cdot A_{Vco}\right) = 248.06 \cdot in^{2}$$

Basic concrete breakout strength (cracked concrete)

$$V_b = 8 \cdot \left(\frac{l_e}{d_{bolt}} \right)^{0.2} \cdot \sqrt{\frac{d_{bolt}}{in}} \cdot \sqrt{\frac{F_c}{psi}} \cdot \left(\frac{c_{a1}}{in} \right)^{1.5} \cdot (lbf)$$

[ACI D.6.2.3]

$$d_{bolt} = \frac{5}{4} \cdot in \qquad l_e := h_{ef} = 15.00 \cdot in$$

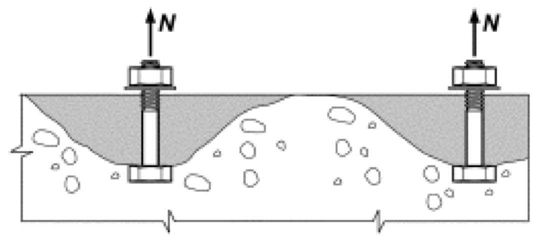
D.6.2.2

$$V_b := 8 \cdot \left(\frac{l_e}{d_{bolt}}\right)^{0.2} \cdot \sqrt{\frac{d_{bolt}}{in}} \cdot \sqrt{\frac{F_c}{psi}} \cdot \left(\frac{c_{a1}}{in}\right)^{1.5} \cdot (lbf) = 11.19 \cdot kip$$

Modification for eccentricity (D6.2.5)

$$e_V := 0in$$

$$\Psi_{ec,V} := \frac{1}{1 + \frac{2 \cdot e_V}{3 \cdot c_{a1}}} = 1.00$$



(iii) Concrete breakout

Modification for edge effect (D6.2.6)

$$\Psi_{ed,V} := \begin{cases} 1 & \text{if } c_{a2} \ge 1.5c_{a1} \\ 0.7 + 0.3 \cdot \frac{c_{a2}}{1.5c_{a1}} & \text{if } c_{a2} < 1.5c_{a1} \end{cases} = 0.90$$

$$\Psi_{ed,V} = 0.90$$

Modification for cracked concrete (D6.2.7)

$\Psi_{c,V} := 1.2$ for anchors in cracked concrete with supplementary reinforcement of a No. 4 bar or greater between the anchor and the edge

Nominal Concrete Breakout Strength

$$V_{cbg} := \frac{A_{Vc}}{A_{Vco}} \cdot \Psi_{ec,V} \cdot \Psi_{ed,V} \cdot \Psi_{c,V} \cdot V_b = 24.16 \cdot kip$$ [ACI D.6.2.1]

Concrete Pryout Strength:

$$h_{ef} = 15.00 \cdot in$$ [ACI D.6.3.1]

$$k_{cp} := \begin{cases} 1.0 & \text{if } h_{ef} < 2.5in \\ 2.0 & \text{if } h_{ef} \ge 2.5in \end{cases} \qquad k_{cp} = 2.0$$

$$N_{cbg} = 4.34 \times 10^4 \cdot lbf$$

$$V_{cpg} := k_{cp} \cdot N_{cbg} = 8.68 \times 10^4 \cdot lbf$$

Factored Strength:

$$\phi V_n \ge V_u$$

$$\phi N_n \ge N_u$$

Note: Condition is determined from ACI 355.2

concrete breakout, side-face blowout, pullout or pryout strength

i) shear loads $\phi_{c,V} := 0.75$

ii) tension loads $\phi_{c,N} := 0.75$

Condition A is applied due to provision of supplemental reinf.

Shear:

Concrete breakout strength $\phi_{c,V} = 0.75$ $V_{cbg} = 24160 \cdot lbf$ $\phi_{c,V} \cdot V_{cbg} = 18 \cdot kip$

Concrete pryout strength $\phi_{c,V} = 0.75$ $V_{cpg} = 86788 \cdot lbf$ $\phi_{c,V} \cdot V_{cpg} = 65 \cdot kip$

FACTORED SHEAR CAPACITY $\phi V_n := \min\left(\phi_{c,V} \cdot V_{cbg}, \phi_{c,V} \cdot V_{cpg}\right) = 18 \cdot kip$

$Check_2 :=$ "OK" if $\phi V_n > V_u$; "Not OK, Modify" otherwise

$Check_2 =$ "Not OK, Modify"

Embedment Length $l_e = 15.00 \cdot in$