Seismic Design Force for Equipment Anchorage

Seismic Design Force, F_p

$F_p = \frac{(0.4 \cdot a_p \cdot S_{DS} \cdot W_p)}{(R_P / I_P)} \cdot (1 + 2(z/h))$ → **F_p** = **0.20 W_p** → 855 lbs — **ASCE 7-16, Equation: 13.3-1**

Max. Seismic Design Force
$F_{p\,max}$ = $1.6 \cdot S_{DS} \cdot I_p \cdot W_p$ — **$F_{p\,max}$** = **2.00 W_p** → 8554 lbs max — **ASCE 7-16, Equation: 13.3-2**

Min. Seismic Design Force
$F_{p\,min}$ = $0.3 \cdot S_{DS} \cdot I_p \cdot W_p$ — **$F_{p\,min}$** = **0.38 W_p** → 1604 lbs min — **ASCE 7-16, Equation: 13.3-3**

Seismic Design Force:
Use → **F_p** = **0.38 W_p**

Seismic Design Forces

Horizontal Seismic Load Effect — **E_h = $\rho \cdot Q_E$** — **E_h** = **1604** lbs ←→ — **ASCE 7-16 Equation (12.14-5)**
Q_E = horizontal application of F_p — **E_h = 0.38 W_p**

Vertical Seismic Load Effect — **E_v = $\pm 0.2 \cdot S_{DS} \cdot W_p$** — **$E_h$** = **1069** lbs ↓↑ — **ASCE 7-16 Section 13.3.1.2**
W_p = dead load of equipment, D — **E_v = 0.25 W_p** ← Upward Force

LRFD Seismic Load Effects

LC 8 $1.2D + E_v + E_h$ (Shear Condition) D = 0, E_v = 0
= 1.0 Q_E
= 1.0 x 0.38 W_p
= **0.38** W_p
= **1604 lbs** ← Shear Force

LC 7 $.9D - E_v + E_h$ (Uplift Condition) E_h = 0
= 0.9 D - E_v
= 0.9 W_p - $0.2 \cdot S_{DS} \cdot W_p$
= 0.9 W_p - **0.25** W_p
= **0.65** W_p → $(.9-.2 \cdot S_{DS})W_p$
= **2780** ← Net Downward Force

ASD Seismic Load Effects

LC 8 $1.0D + .7E_v + .7E_h$ (Shear Condition) D = 0, E_v = 0
= 0.7 Q_E
= 0.7 x 0.38 W_p
= **0.26** W_p
= **1123 lbs.** ← Shear Force

LC 10 $.6D - 0.7E_v + 0.7E_h$ (Uplift Condition) E_h = 0
= 0.6 D - 0.7 E_v
= 0.6 W_p - 0.7 $0.2 \cdot S_{DS} \cdot W_p$
= 0.6 W_p - **0.18** W_p
= **0.43** W_p → $(.6-.14 \cdot S_{DS})W_p$
= **1818 lbs.** ← Net Downward Force

LRFD Seismic Load Effects Including Overstrength **12.14.3.2.3**

LC **5** $(1.2 + .2S_{DS})D + E_{mh}$
= 1.45 D + 2 Q_E
= 1.45 W_p + 2 x 0.38 W_p
= 1.45 W_p + **0.75** W_p
= **0** W_p + **3208 lbs** ← Shear Force

ASD Seismic Load Effects Including Overstrength **12.14.3.2.3**

LC **5** $(1.0 + .14S_{DS})D + 0.7 E_{mh}$
= 1.18 D + 2 x 0.7 Q_E
= 1.18 W_p + 2 x ### W_p
= 1.18 W_p + **0.53** W_p
= **0** W_p + **2245 lbs** ← Shear Force

Net Seismic Design Force Table		
	LRFD	ASD
$F_{p\,(H)}$ =	**0.38 W_p**	**0.26 W_p**
$F_{p\,(V)}$ =	**0.65 W_p** ↓	**0.43 W_p** ↓

Net Seismic Design Force Table w/ Overstrength*		
	LRFD	ASD
$\Omega F_{p\,(H)}$ =	**0.75 W_p**	**0.53 W_p**

* No overstrength required for $F_{p(v)}$

GENERATOR:

SEISMIC LOADS:

$F_p = \boxed{1{,}604\ \#}$ (1.0E)

– WIND LOADS

CH. 29, OTHER STRUCTURES

$F = q_z G C_F A_f = \boxed{1{,}198\ \#}$ (SEISMIC CONTROLS)

$q_z = 0.00256\ K_z K_{zt} K_d K_e V^2 = 17.67\ psf$

$K_z = 0.85$, EXPOSURE C, RISK CATEGORY II, $h < 15'$

$K_{zt} = 1.0$,

$K_d = 0.90$, SQUARE CHIMNEYS, TANKS, AND SIMILAR STRUCTURES

$K_e = 1.0$,

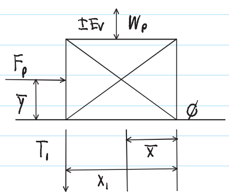
$V = 95$ mph

$G = 0.85$,

$C_F = 1.35$, $h = 5.67'$, $D = 3.75'$, $h/D = 1.51$

$A_f = L \times H = 10.42' \times 5.67' = 59.1\ ft^2$

GLOBAL LOAD ANALYSIS:



$M_{eØ} = M_o - M_r = 0$

$M_{o1} = F_p * \bar{y}$

$M_{o2} = Ev * \bar{x} = 0.2 S_{DS} W_p \bar{x}$

$M_{r1} = T_1 * x_1$

$M_{r2} = W_p * \bar{x}$

$F_p = 1{,}604\ \#$, $\bar{y} = 34''$, $S_{DS} = 1.75$

$W_p = 4{,}277\ \#$, $\bar{x} = 22.5''$, $x_1 = 45''$

ISOLATE FOR T_1,

$F_p \bar{y} + 0.2 S_{DS} W_p \bar{x} - T_1 x_1 - W_p \bar{x} = 0$

$T_1 = \dfrac{F_p \bar{y} + 0.2 S_{DS} W_p \bar{x} - W_p \bar{x}}{x_1}$,

$F_p \bar{y} = 54{,}536$ #-in (1.0E)

$0.2 S_{DS} W_p \bar{x} = 24{,}058$ #-in (1.0E)

$W_p \bar{x} = 96{,}233$ #-in (1.0D)

LOAD COMBOS: TENSION

1) $0.6D + 0.7E_H + 0.7E_V$: $T_1 = -61\ \#$, no uplift, $n = 2$ anchors, $T_{anchor} = 0\ \#$
2) $0.9D + E_H + E_V$: $T_1 = -178\ \#$, no uplift, $n = 2$, $T_{anchor} = 0\ \#$
3) $0.6D + 0.7\Omega E_H + 0.7E_V$: $T_1 = 787\ \#$, $n = 2$, $T_{anchor} = 394\ \#$
4) $0.9D + \Omega E_H + E_V$: $T_1 = 1{,}034\ \#$, $n = 2$, $T_{anchor} = 517\ \#$

LOAD COMBOS: SHEAR

1) $0.6D + 0.7E_H + 0.7E_V$: $V = 1{,}123\ \#$, $n = 4$ anchors, $V_{anchor} = 281\ \#$
2) $0.9D + E_H + E_V$: $V = 1{,}604\ \#$, $n = 4$, $V_{anchor} = 401\ \#$
3) $0.6D + 0.7\Omega E_H + 0.7E_V$: $V = 2{,}245\ \#$, $n = 4$, $V_{anchor} = 561\ \#$
4) $0.9D + \Omega E_H + E_V$: $V = 3{,}208\ \#$, $n = 4$, $V_{anchor} = 802\ \#$

INNOVATIVE
STRUCTURAL ENGINEERING

40810 COUNTY CENTER DR. #110
TEMECULA, CA 92591
ISEENGINEERS.COM

PROJECT: San Bernardino, Public Works, Rancho Yard Maintenance - Generator

JOB NO: 21-7178

CALCULATED BY: SK

DATE: 05/21/21 SHEET NO. 2 OF 2

ANCHORAGE DESIGN:

- USE OVERSTRENGTH REACTIONS FOR DESIGN.

V_{anchor} = 802 #/anchor (ΩE)
T_{anchor} = 517 #/anchor (ΩE)

Company:	Innovative Structural Engr.	Date:	5/21/2021
Engineer:	SK	Page:	1/6
Project:	21-7178		
Address:	27369 Via Industria, Temecula, CA 92590		
Phone:	(951) 600-0032		
E-mail:	scott@iseengineers.com		

1.Project information

Customer company:
Customer contact name:
Customer e-mail:
Comment:

Project description: Equipment Anchorage & Handrail Connections
Location: Generator Containment
Fastening description: CIP Concrete Anchor

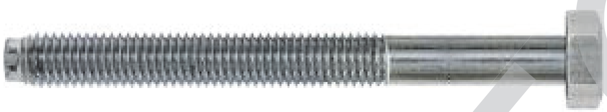
2. Input Data & Anchor Parameters

General
Design method:ACI 318-14
Units: Imperial units

Anchor Information:
Anchor type: Cast-in-place
Material: F1554 Grade 36
Diameter (inch): 0.500
Effective Embedment depth, h_{ef} (inch): 2.750
Anchor category: -
Anchor ductility: Yes
h_{min} (inch): 4.00
C_{min} (inch): 3.00
S_{min} (inch): 3.00

Base Material
Concrete: Normal-weight
Concrete thickness, h (inch): 12.00
State: Cracked
Compressive strength, f'$_c$ (psi): 2500
$\Psi_{c,V}$: 1.0
Reinforcement condition: B tension, B shear
Supplemental reinforcement: Not applicable
Reinforcement provided at corners: No
Ignore concrete breakout in tension: No
Ignore concrete breakout in shear: No
Ignore 6do requirement: No
Build-up grout pad: No

Recommended Anchor
Anchor Name: Heavy Hex Bolt - 1/2"Ø Heavy Hex Bolt, F1554 Gr. 36

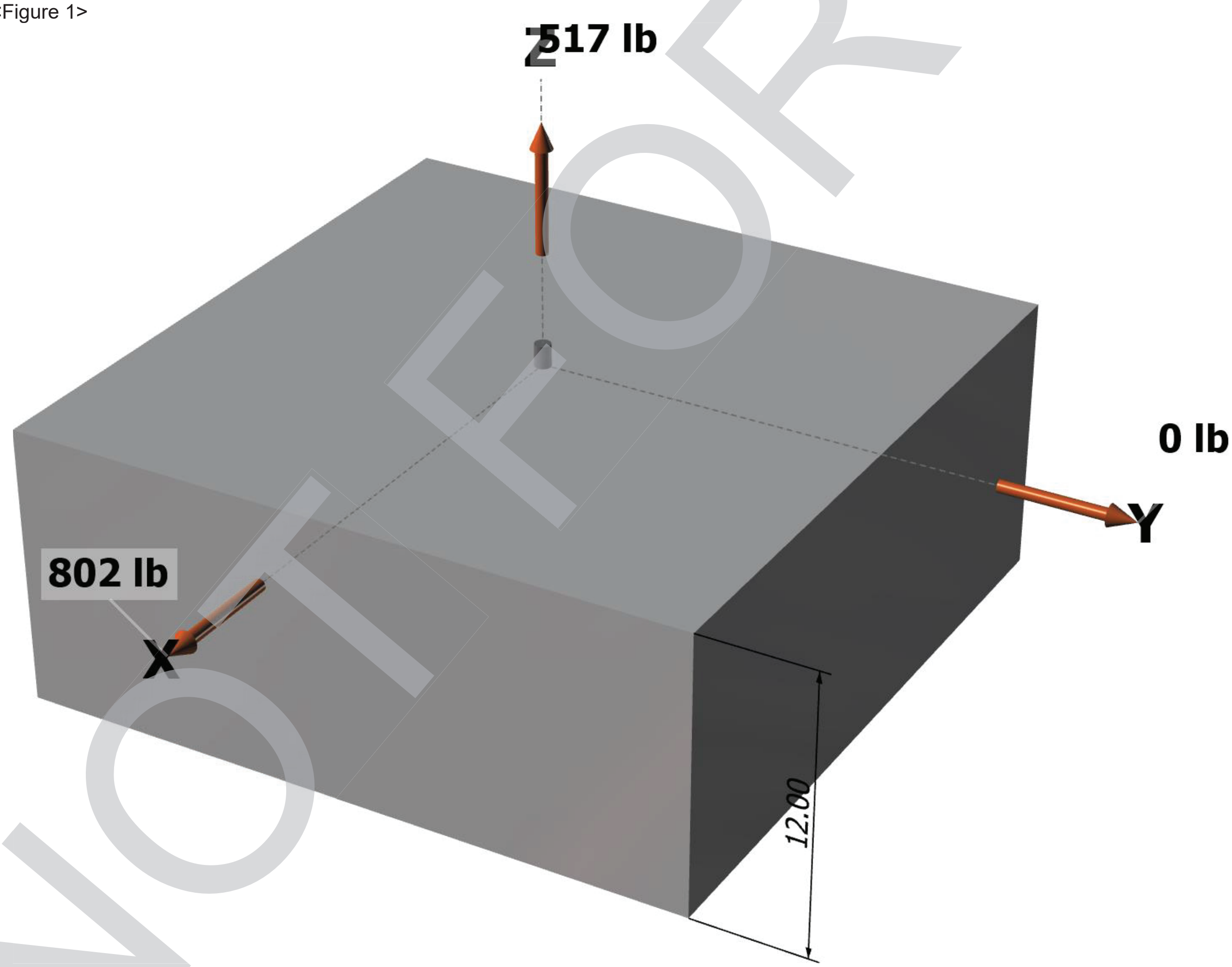


Load and Geometry
Load factor source: ACI 318 Section 5.3
Load combination: not set
Seismic design: Yes
Anchors subjected to sustained tension: Not applicable
Ductility section for tension: 17.2.3.4.3 (d) is satisfied
Ductility section for shear: 17.2.3.5.3 (c) is satisfied
Ω_0 factor: not set
Apply entire shear load at front row: No
Anchors only resisting wind and/or seismic loads: Yes

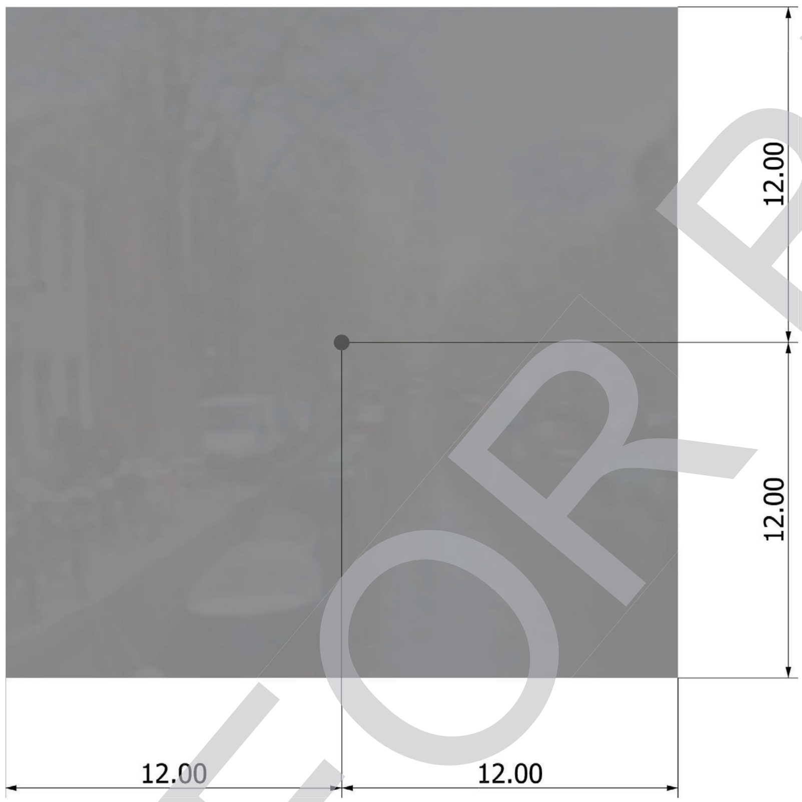
Strength level loads:

N_{ua} [lb]: 517
V_{uax} [lb]: 802
V_{uay} [lb]: 0

<Figure 1>



<Figure 2>



3. Resulting Anchor Forces

Anchor	Tension load, N_{ua} (lb)	Shear load x, V_{uax} (lb)	Shear load y, V_{uay} (lb)	Shear load combined, $\sqrt{(V_{uax})^2+(V_{uay})^2}$ (lb)
1	517.0	802.0	0.0	802.0
Sum	517.0	802.0	0.0	802.0

Maximum concrete compression strain (‰): 0.00
Maximum concrete compression stress (psi): 0
Resultant tension force (lb): 517
Resultant compression force (lb): 0
Eccentricity of resultant tension forces in x-axis, e'_{Nx} (inch): 0.00
Eccentricity of resultant tension forces in y-axis, e'_{Ny} (inch): 0.00
Eccentricity of resultant shear forces in x-axis, e'_{Vx} (inch): 0.00
Eccentricity of resultant shear forces in y-axis, e'_{Vy} (inch): 0.00

4. Steel Strength of Anchor in Tension (Sec. 17.4.1)

N_{sa} (lb)	ϕ	ϕN_{sa} (lb)
8235	0.75	6176

5. Concrete Breakout Strength of Anchor in Tension (Sec. 17.4.2)

$N_b = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5}$ (Eq. 17.4.2.2a)

k_c	λ_a	f'_c (psi)	h_{ef} (in)	N_b (lb)
24.0	1.00	2500	2.750	5472

$0.75\phi N_{cb} = 0.75\phi\,(A_{Nc} / A_{Nco})\,\Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}N_b$ (Sec. 17.3.1 & Eq. 17.4.2.1a)

A_{Nc} (in^2)	A_{Nco} (in^2	$c_{a,min}$ (in)	$\Psi_{ed,N}$	$\Psi_{c,N}$	$\Psi_{cp,N}$	N_b (lb)	ϕ	$0.75\phi N_{cb}$ (lb)
68.06	68.06	12.00	1.000	1.00	1.000	5472	0.70	2873

6. Pullout Strength of Anchor in Tension (Sec. 17.4.3)

$0.75\phi N_{pn} = 0.75\phi\Psi_{c,P}N_p = 0.75\phi\Psi_{c,P}8A_{brg}f'_c$ (Sec. 17.3.1, Eq. 17.4.3.1 & 17.4.3.4)

$\Psi_{c,P}$	A_{brg} (in^2)	f'_c (psi)	ϕ	$0.75\phi N_{pn}$ (lb)
1.0	0.47	2500	0.70	4904

8. Steel Strength of Anchor in Shear (Sec. 17.5.1)

V_{sa} (lb)	ϕ_{grout}	ϕ	$\phi_{grout}\phi V_{sa}$ (lb)
4940	1.0	0.65	3211

9. Concrete Breakout Strength of Anchor in Shear (Sec. 17.5.2)

Shear perpendicular to edge in x-direction:

$V_{bx} = \min|7(l_e / d_a)^{0.2}\sqrt{d_a}\lambda_a\sqrt{f'_c}c_{a1}^{1.5}; 9\lambda_a\sqrt{f'_c}c_{a1}^{1.5}|$ (Eq. 17.5.2.2a & Eq. 17.5.2.2b)

l_e (in)	d_a (in)	λ_a	f'_c (psi)	c_{a1} (in)	V_{bx} (lb)
2.75	0.500	1.00	2500	8.00	7875

$\phi V_{cbx} = \phi (A_{Vc} / A_{Vco}) \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_{bx}$ (Sec. 17.3.1 & Eq. 17.5.2.1a)

A_{Vc} (in^2)	A_{Vco} (in^2)	$\Psi_{ed,V}$	$\Psi_{c,V}$	$\Psi_{h,V}$	V_{bx} (lb)	ϕ	ϕV_{cbx} (lb)
288.00	288.00	1.000	1.000	1.000	7875	0.70	5513

Shear parallel to edge in x-direction:

$V_{by} = \min|7(l_e / d_a)^{0.2}\sqrt{d_a}\lambda_a\sqrt{f'_c}c_{a1}^{1.5}; 9\lambda_a\sqrt{f'_c}c_{a1}^{1.5}|$ (Eq. 17.5.2.2a & Eq. 17.5.2.2b)

l_e (in)	d_a (in)	λ_a	f'_c (psi)	c_{a1} (in)	V_{by} (lb)
2.75	0.500	1.00	2500	8.00	7875

$\phi V_{cbx} = \phi (2)(A_{Vc} / A_{Vco}) \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_{by}$ (Sec. 17.3.1, 17.5.2.1(c) & Eq. 17.5.2.1a)

A_{Vc} (in^2)	A_{Vco} (in^2)	$\Psi_{ed,V}$	$\Psi_{c,V}$	$\Psi_{h,V}$	V_{by} (lb)	ϕ	ϕV_{cbx} (lb)
288.00	288.00	1.000	1.000	1.000	7875	0.70	11025

10. Concrete Pryout Strength of Anchor in Shear (Sec. 17.5.3)

$\phi V_{cp} = \phi k_{cp} N_{cb} = \phi k_{cp} (A_{Nc} / A_{Nco}) \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$ (Sec. 17.3.1 & Eq. 17.5.3.1a)

k_{cp}	A_{Nc} (in^2)	A_{Nco} (in^2)	$\Psi_{ed,N}$	$\Psi_{c,N}$	$\Psi_{cp,N}$	N_b (lb)	ϕ	ϕV_{cp} (lb)
2.0	68.06	68.06	1.000	1.000	1.000	5472	0.70	7661

11. Results

Interaction of Tensile and Shear Forces (Sec. 17.6.)

Tension	Factored Load, N_{ua} (lb)	Design Strength, $øN_n$ (lb)	Ratio	Status
Steel	517	6176	0.08	Pass
Concrete breakout	**517**	**2873**	**0.18**	**Pass (Governs)**
Pullout	517	4904	0.11	Pass

Shear	Factored Load, V_{ua} (lb)	Design Strength, $øV_n$ (lb)	Ratio	Status
Steel	**802**	**3211**	**0.25**	**Pass (Governs)**
T Concrete breakout x+	802	5513	0.15	Pass
|| Concrete breakout y-	802	11025	0.07	Pass
Pryout	802	7661	0.10	Pass

Interaction check	$N_{ua}/\phi N_n$	$V_{ua}/\phi V_n$	Combined Ratio	Permissible	Status
Sec. 17.6..2	0.00	0.25	25.0%	1.0	Pass

1/2"Ø Heavy Hex Bolt, F1554 Gr. 36 with hef = 2.750 inch meets the selected design criteria.

12. Warnings

- Per designer input, ductility requirements for tension have been determined to be satisfied – designer to verify.

- Per designer input, ductility requirements for shear have been determined to be satisfied – designer to verify.

- Designer must exercise own judgement to determine if this design is suitable.

1.Project information

Customer company:
Customer contact name:
Customer e-mail:
Comment:

Project description: Equipment Anchorage & Handrail Connections
Location: Generator Containment
Fastening description: PI Concrete Anchor

2. Input Data & Anchor Parameters

General
Design method:ACI 318-14
Units: Imperial units

Anchor Information:
Anchor type: Torque controlled expansion anchor
Material: Carbon Steel
Diameter (inch): 0.500
Nominal Embedment depth (inch): 2.750
Effective Embedment depth, h_{ef} (inch): 2.250
Code report: ICC-ES ESR-3037
Anchor category: 1
Anchor ductility: Yes
h_{min} (inch): 4.00
c_{ac} (inch): 6.00
C_{min} (inch): 4.00
S_{min} (inch): 2.75

Base Material
Concrete: Normal-weight
Concrete thickness, h (inch): 12.00
State: Cracked
Compressive strength, f'_c (psi): 2500
$\Psi_{c,V}$: 1.0
Reinforcement condition: B tension, B shear
Supplemental reinforcement: Not applicable
Reinforcement provided at corners: No
Ignore concrete breakout in tension: No
Ignore concrete breakout in shear: No
Ignore 6do requirement: Not applicable
Build-up grout pad: No

Recommended Anchor
Anchor Name: Strong-Bolt® 2 - 1/2"Ø CS Strong-Bolt 2, hnom:2.75" (70mm)
Code Report: ICC-ES ESR-3037