ICC-ES Evaluation Report

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DIVISION: 03 00 00—CONCRETE
Section: 03 16 00—Concrete Anchors

REPORT HOLDER:

SIMPSON STRONG-TIE COMPANY INC.
5956 WEST LAS POSITAS BOULEVARD
PLEASANTON, CALIFORNIA 94588
(925)560-9000
www.strongtie.com

EVALUATION SUBJECT:

SIMPSON STRONG-TIE® STRONG-BOLT® WEDGE ANCHOR FOR CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2012, 2009, 2006, 2003 *International Building Code®* (IBC)
- 2012, 2009, 2006, 2003 *International Residential Code®* (IRC)

Properties evaluated:

Structural

2.0 USES

The Simpson Strong-Tie® Strong-Bolt® wedge anchor is used to resist static, wind and seismic tension and shear loads in cracked and uncracked normal-weight concrete and sand-lightweight concrete members having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

The Strong-Bolt® complies with Section 1909 of the 2012 IBC, Section 1912 of the 2009 and 2006 IBC, and Section 1913 of the 2003 IBC. The anchors are an alternative to cast-in-place anchors described in Section 1908 of the 2012 IBC, Sections 1911 of the 2009 IBC and 2006 IBC, and Sections 1912 of the 2003 IBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

3.0 DESCRIPTION

3.1 Strong-Bolt®:

Strong-Bolt® anchors are torque-controlled mechanical expansion anchors consisting of an anchor body, expansion clip, nut, and washer. A typical anchor is shown in Figure 1. The $^1/_2$-inch-, $^5/_8$-inch-, and $^3/_4$-inch-diameter (12.7 mm, 15.9 mm, and 19.1 mm) anchor bodies are manufactured from carbon steel conforming to SAE J403, Grade 1030 to 1035. The 1-inch-diameter (25.4 mm) anchor body is manufactured from carbon steel conforming to SAE J403 Grade 12L14. The anchor bodies are zinc plated in accordance with ASTM B633, SC1, Type III. The expansion clip is fabricated from ASTM A240, Grade 316, stainless steel. The washer conforms to ASTM F844. The hex nut conforms to ASTM A563, Grade A.

The anchor body has a tapered mandrel formed on the installed end of the anchor and a threaded section at the opposite end. The taper of the mandrel increases in diameter toward the installed end of the anchor. The three-segment expansion clip wraps around the tapered mandrel. Before installation, this expansion clip is free to rotate about the mandrel. The anchor is installed in a predrilled hole. When the anchor is set using an applied torque to the hex nut, the mandrel is drawn into the expansion clip, which engages the drilled hole and transfers the load to the base material. Pertinent dimensions are as set forth in Table 1.

3.2 Concrete:

Normal-weight and sand-lightweight concrete must conform to Sections 1903 and 1905 of the IBC, as applicable.

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Design strength of anchors complying with the 2012 and 2003 IBC, as well as Section R301.1.3 of the 2012 and 2003 IRC must be determined in accordance with ACI 318-11 Appendix D and this report.

Design strength of anchors complying with the 2009 IBC and Section R301.1.3 of the 2009 IRC must be in accordance with ACI 318-08 Appendix D and this report.

Design strength of anchors complying with the 2006 IBC as well as Section R301.1.3 of the 2006 IRC must be determined in accordance with ACI 318-05 Appendix D and this report.

Design parameters provided in Tables 2 and 3 and references to ACI 318 are based on the 2012 IBC (ACI 318-11) unless noted otherwise in Sections 4.1.1 through 4.1.12 of this report. The strength design of anchors must comply with ACI 318 D.4.1, except as required in ACI 318 D.3.3. A design example in accordance with the 2009 IBC is given in Figure 4 of this report.

Strength reduction factors, ϕ, as given in ACI 318-11 D.4.3, must be used for load combinations calculated in accordance with Section 1605.2.1 of the IBC, or Section 9.2 of ACI 318. Strength reduction factors, ϕ, as given in ACI 318-11 D.4.4 must be used for load combinations calculated in accordance with Appendix C of ACI 318.

***Revised March 2012**

4.1.2 Requirements for Static Steel Strength in Tension: The nominal steel strength of a single anchor in tension, N_{sa}, in accordance with ACI 318 D.5.1.2, is given in Table 2 of this report. The strength reduction factor, ϕ_{sa}, corresponding to a ductile steel element must be used for $^1/_2$-inch- and $^5/_8$-inch-diameter (12.7 mm and 15.9 mm) anchors, and the strength reduction factor for a brittle steel element must be used for the $^3/_4$-inch- and 1-inch-diameter (19.1 mm and 25.4 mm) anchors, as described in Table 2 of this report.

4.1.3 Requirements for Static Concrete Breakout Strength in Tension: The nominal concrete breakout strength of a single anchor or group of anchors in tension, N_{cb} and N_{cbg}, respectively, must be calculated in accordance with ACI 318 D.5.2, with modifications as described in this section. The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, must be calculated in accordance with ACI 318 D.5.2.2 using the values of h_{ef} and k_{cr} as given in Table 2 of this report. The value of f'_c must be limited to 8,000 psi (55.2 MPa), in accordance with ACI 318-11 D.3.7. The nominal concrete breakout strength in tension, N_{cb} or N_{cbg}, in regions of a concrete member where analysis indicates no cracking at service load levels in accordance with ACI 318 D.5.2.6, must be calculated with the value of k_{uncr} as given in Table 2 of this report and with $\psi_{c,N}$ = 1.0, as described in Table 2 of this report.

4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in tension in accordance with ACI 318 D.5.3 in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Table 2 of this report. Where analysis indicates no cracking at service load levels in accordance with ACI 318 D.5.3.6, the nominal pullout strength in uncracked concrete, $N_{p,uncr}$ applies. Where values for $N_{p,cr}$ or $N_{p,uncr}$ are not provided in Table 2, the pullout strength does not need to be considered. In lieu of ACI 318 D.5.3.6, $\Psi_{c,P}$ = 1.0 for all design cases. The nominal pullout strengths must be adjusted for concrete strengths according to Eq.1:

$$N_{p,f'_c} = N_{p,cr/uncr}\left(\frac{f'_c}{2500}\right)^n \quad \text{(lb, psi)} \qquad \text{(Eq-1)}$$

$$N_{p,f'_c} = N_{p,cr/uncr}\left(\frac{f'_c}{17.2}\right)^n \quad \text{(kN, MPa)}$$

where f'_c is the specified compressive strength and n is the factor defining the influence of concrete compressive strength on the nominal pullout strength. For the $^5/_8$-inch-diameter anchor, n is 0.7. For all other cases, n is 0.5.

4.1.5 Requirements for Static Steel Strength in Shear: The nominal steel strength in shear, V_{sa}, of a single anchor in accordance with ACI 318 D.6.1.2, is given in Table 3 of this report and must be used in lieu of values derived by calculation from ACI 318-11, Eq. D-29. The strength reduction factor, ϕ_{sa}, corresponding to a ductile steel element must be used for $^1/_2$-inch- and $^5/_8$-inch-diameter (12.7 mm and 15.9 mm) anchors, and the strength reduction factor corresponding to a brittle steel element must be used for the $^3/_4$-inch- and 1-inch-diameter (19.1 mm and 25.4 mm) anchors, described in Table 3 of this report.

4.1.6 Requirements for Static Concrete Breakout Strength in Shear: The nominal concrete breakout strength for a single anchor or group of anchors in shear, V_{cb} and V_{cbg}, respectively, must be calculated in accordance with ACI 318 D.6.2, with modifications as described in this section. The basic concrete breakout strength in shear, V_b, must be calculated in accordance with ACI 318 D.6.2.2 using the values of ℓ_e and d_a described in Table 3 of this report. The value of f'_c must be limited to a maximum of 8,000 psi (55.2 MPa) in accordance with ACI 318-11 D.3.7.

4.1.7 Requirements for Static Concrete Pryout Strength in Shear: The nominal concrete pryout strength for a single anchor or group of anchors in shear, V_{cp} and V_{cpg}, respectively, must be calculated in accordance with ACI 318 D.6.3, using the value of k_{cp} described in Table 3 of this report and the value of N_{cb} or N_{cbg} as calculated in Section 4.1.3 of this report.

4.1.8 Requirements for Seismic Design:

4.1.8.1 General: For load combinations including seismic, the design must be performed in accordance with ACI 318 D.3.3, as modified by Section 1905.1.9 of the 2012 IBC, Section 1908.1.9 of the 2009 IBC, or Section 1908.1.16 of the 2006 IBC or the following:

CODE	ACI 318 D.3.3 SEISMIC REGION	CODE EQUIVALENT DESIGNATION
2003 IBC and 2003 IRC	Moderate or high seismic risk	Seismic Design Categories C, D, E, and F

The $^1/_2$-inch- and $^5/_8$-inch-diameter (12.7 mm and 15.9 mm) anchors comply with ACI 318 D.1 as ductile steel elements. The $^3/_4$-inch- and 1-inch-diameter (19.1 mm and 25.4 mm) anchors comply with ACI 318 D.1 as brittle steel elements. The anchors must be designed in accordance with ACI 318-11 D.3.3.4, D.3.3.5, or D.3.3.6 or ACI 318-08 D.3.3.4, D.3.3.5 or D.3.3.6, or ACI 318-05 D.3.3.4 or D.3.3.5, as applicable, with the modifications noted above.

4.1.8.2 Seismic Tension: The nominal steel strength and concrete breakout strength in tension must be calculated in accordance with ACI 318 D.5.1 and D.5.2, as described in Sections 4.1.2 and 4.1.3 of this report. In accordance with ACI 318 D.5.3.2, the appropriate value for nominal pullout strength in tension for seismic loads, $N_{p,eq}$ described in Tables 2 of this report must be used in lieu of N_p. If no values for $N_{p,eq}$ are given in Table 2 of this report, the pullout strength for seismic loads need not be evaluated. The values of $N_{p,eq}$ can be adjusted for concrete strength according to Section 4.1.4 Eq-1 of this report.

4.1.8.3 Seismic Shear: The nominal concrete breakout and concrete pryout strength in shear must be calculated in accordance with ACI 318 D.6.2 and D.6.3, as described in Sections 4.1.6 and 4.1.7 of this report. In accordance with ACI 318 D.6.1.2, the appropriate value for nominal steel strength in shear for seismic loads, $V_{sa,eq}$ described in Table 3 of this report, must be used in lieu of V_{sa}.

4.1.9 Requirements for Interaction of Tensile and Shear Forces: For loadings that include combined tension and shear, the design must be performed in accordance with ACI 318 D.7.

4.1.10 Requirements for Critical Edge Distance: In applications where $c < c_{ac}$ and supplemental reinforcement to control splitting of the concrete is not present, the concrete breakout strength in tension for uncracked concrete, calculated according to ACI 318 D.5.2, must be further multiplied by the factor $\Psi_{cp,N}$ given by Eq-2:

$$\Psi_{cp,N} = \frac{c}{c_{ac}} \qquad \text{(Eq-2)}$$

where the factor $\Psi_{cp,N}$ need not be taken as less than $\frac{1.5h_{ef}}{c_{ac}}$. For all other cases, $\Psi_{cp,N} = 1.0$. In lieu of ACI 318 D.8.6, values of c_{ac} provided in Table 1 of this report must be used.

4.1.11 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: In lieu of ACI 318 D.8.1 and D.8.3, values of c_{min} and s_{min} provided in Table 1 of this report must be used. In lieu of using ACI 318 D.8.5, minimum member thickness, h_{min}, must be in accordance with Table 1 of this report.

4.1.12 Sand-lightweight Concrete: For ACI 318-11 and ACI 318-08, when anchors are used in sand-lightweight concrete, the modification factor λ_a or λ, respectively,for concrete breakout must be taken as 0.6 in lieu of ACI 318-11 D.3.6 (2012 IBC) or ACI 318-08 D.3.4 (2009 IBC). In addition, the pullout strength $N_{p,cr}$, $N_{p,uncr}$ and $N_{p,eq}$ must be multiplied by 0.60, as applicable.

For ACI 318-05, when anchors are used in sand-lightweight concrete, N_b, $N_{p,cr}$, $N_{p,uncr}$, N_{eq} and V_b determined in accordance with this report must be multiplied by 0.60, in lieu of ACI 318 D.3.4.

4.2 Allowable Stress Design (ASD):

4.2.1 General: Design values for use with allowable stress design load combinations calculated in accordance with Section 1605.3 of the IBC, must be established using the following relationships:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha} \quad \text{(Eq-3)}$$

and

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha} \quad \text{(Eq-4)}$$

where:

$T_{allowable,ASD}$ = Allowable tension load (lbf or kN)

$V_{allowable,ASD}$ = Allowable shear load (lbf or kN)

ϕN_n = The lowest design strength of an anchor or anchor group in tension as determined in accordance with ACI 318 Appendix D, Section 4.1 of this report, and 2012 IBC Section 1905.1.9, 2009 IBC Section 1908.1.16, as applicable. (lbf or kN).

ϕV_n = The lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318 Appendix C, Section 4.1 of this report, and 2012 IBC Section 1905.1.9, 2009 IBC Section 1908.1.9 or 2006 IBC Section 1908.1.16, as applicable. (lbf or kN).

α = A conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α shall include all applicable factors to account for non-ductile failure modes and required over-strength.

The requirements for member thickness, edge distance and spacing, as described in this report, must apply. An example calculation for the derivation of allowable stress design tension values is presented in Table 4.

4.2.2 Interaction of Tensile and Shear Forces: The interaction of tension and shear loads must be consistent with ACI 318 D.7 as follows:

If $T_{applied} \leq 0.2T_{allowable,ASD}$, then the full allowable strength in shear, $V_{allowable,ASD}$, must be permitted.

If $V_{applied} \leq 0.2V_{allowable,ASD}$, then the full allowable strength in tension, $T_{allowable,ASD}$, must be permitted.

For all other cases: $\frac{T_{applied}}{T_{allowable,ASD}} + \frac{V_{applied}}{V_{allowable,ASD}} \leq 1.2$

4.3 Installation:

Installation parameters are provided in Table 1 and in Figure 2. Anchor locations must comply with this report and the plans and specifications approved by the code official. The Strong-Bolt® must be installed in accordance with the manufacturer's published installation instructions and this report. Anchors must be installed in holes drilled into the concrete using carbide-tipped drill bits conforming to ANSI B212.15-1994. The nominal drill bit diameter must be equal to the nominal diameter of the anchor. The minimum drilled hole depth is given in Table 1. The drilled hole must be cleaned, with all dust and debris removed using compressed air. The anchor, nut, and washer must be assembled so that the top of the nut is flush with the top of the anchor. The anchor must be driven into the hole using a hammer until the proper nominal embedment depth is achieved. The nut and washer must be tightened against the base material or material to be fastened until the appropriate installation torque value specified in Table 1 is achieved.

4.4 Special Inspection:

Periodic special inspection is required in accordance with Section 1705.1.1 of the 2012 IBC or Section 1704.15 of the 2009 IBC, or Section 1704.13 of the 2006 or 2003 IBC, as applicable. The special inspector must make periodic inspections during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, drill-bit type, hole dimensions, hole cleaning procedures, anchor spacing, edge distances, concrete member thickness, anchor embedment, tightening torque and adherence to the manufacturer's published installation instructions. The special inspector must be present as often as required by the "statement of special inspection." Under the IBC, additional requirements as set forth in Sections 1705, 1706 and 1707 must be observed, where applicable.

5.0 CONDITIONS OF USE

The Simpson Strong-Tie® Strong-Bolt® wedge anchor described in this report complies with, or is a suitable alternative to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 The anchors must be installed in accordance with the manufacturer's published installation instructions and this report. In cases of a conflict, this report governs.

5.2 Anchor sizes, dimensions, minimum embedment depths, and other installation parameters are as set forth in the tables of this report.

5.3 The anchors must be installed in cracked and uncracked normal-weight and sand-lightweight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

5.4 The value of f'_c used for calculation purposes must not exceed 8,000 psi (55.2 MPa).

5.5 Strength design values must be established in accordance with Section 4.1 of this report.

5.6 Allowable stress design values are established in accordance with Section 4.2 of this report.

5.7 Anchor spacing and edge distance, as well as minimum member thickness, must comply with Table 1 of this report.

5.8 Prior to anchor installation, calculations and details demonstrating compliance with this report must be submitted to the code official. The calculations and details must be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.9 Since an ICC-ES acceptance criteria for evaluating data to determine the performance of expansion anchors subjected to fatigue or shock loading is unavailable at this time, the use of these anchors under such conditions is beyond the scope of this report.

5.10 Anchors may be installed in regions of concrete where cracking has occurred or where analysis indicates cracking may occur ($f_t > f_r$), subject to the conditions of this report.

5.11 Anchors may be used to resist short-term loading due to wind or seismic forces, subject to the conditions of this report.

5.12 Where not otherwise prohibited in the code, Strong-Bolt® anchors are permitted for use with fire-resistance-rated construction provided that at least one of the following conditions is fulfilled:

- Anchors are used to resist wind or seismic forces only.
- Anchors that support a fire-resistance-rated envelope or a fire-resistance-rated membrane, are protected by approved fire-resistance-rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards.
- Anchors are used to support nonstructural elements.

5.13 Use of zinc-plated carbon steel anchors is limited to dry, interior locations.

5.14 Periodic special inspection must be provided in accordance with Section 4.4 of this report.

5.15 The anchors are manufactured by Simpson Strong-Tie Company, Inc., under an approved quality control program with inspections by CEL Consulting (AA-639).

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193), dated March 2012, including optional suitability tests for seismic tension and shear; and quality control documentation.

7.0 IDENTIFICATION

The Strong-Bolt® anchors are identified in the field by dimensional characteristics and packaging. The Strong-Bolt® anchor has the Simpson Strong-Tie Company Inc., No Equal logo ≠ stamped on the expansion clip, and a length identification code embossed on the exposed threaded end. Table 5 shows the length identification codes. The packaging label bears the manufacturer's name and contact information, anchor name, anchor size and length, quantity, the evaluation report number (ICC-ES ESR-1771), and the name of the inspection agency (CEL Consulting).

TABLE 1—STRONG-BOLT® ANCHOR INSTALLATION INFORMATION[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)										
			$^1/_2$			$^5/_8$			$^3/_4$			1	
Installation Information													
Nominal Diameter	d_a[3]	in.	$^1/_2$			$^5/_8$			$^3/_4$			1	
Drill Bit Diameter	d	in.	$^1/_2$			$^5/_8$			$^3/_4$			1	
Min. Baseplate Clearance Hole Diameter[2]	d_c	in.	$^9/_{16}$			$^{11}/_{16}$			$^7/_8$			$1\,^1/_8$	
Installation Torque	T_{inst}	ft-lbf	50			85			180			230	
Nominal Embedment Depth	h_{nom}	in.	$2^3/_4$	$3^7/_8$	5	$3^3/_8$	$5^1/_8$	$6^1/_8$	$4^1/_8$	$5^3/_4$	$7^1/_2$	$5^1/_4$	$9^3/_4$
Effective Embedment Depth	h_{ef}	in.	2¼	$3^3/_8$	$4^1/_2$	$2^3/_4$	$4^1/_2$	$5^1/_2$	$3^3/_8$	5	$6^3/_4$	$4\,^1/_2$	9
Minimum Hole Depth	h_{hole}	in.	3	$4^1/_8$	$5^1/_4$	$3^5/_8$	$5^3/_8$	$6^3/_8$	$4^3/_8$	6	$7^3/_4$	$5^1/_2$	10
Critical Edge Distance	c_{ac}	in.	9	$7^7/_8$	$6^3/_4$	11	$9^5/_8$	$8^1/_4$	$13^1/_2$	$11^3/_4$	$10^1/_8$	18	$13^1/_2$
Minimum Edge Distance	c_{min}	in.	4			5			6			8	
Minimum Spacing	s_{min}	in.	4			$6^1/_4$			$6^1/_4$			8	
Minimum Concrete Thickness	h_{min}	in.	$4^1/_2$	6	$6^3/_4$	$5^1/_2$	$7^7/_8$	$8^1/_4$	$6^3/_4$	$8^3/_4$	$10^1/_8$	9	$13^1/_2$
Anchor Data													
Specified Yield Strength of Anchor Steel	f_{ya}	psi	108,000									60,000	
Specified Tensile Strength of Anchor Steel	f_{uta}[4]	psi	125,000									78,000	
Effective Tensile and Shear Stress Area	A_{se}	in^2	0.108			0.167			0.273			0.472	
Axial Stiffness in Service Load Range – Cracked and Uncracked Concrete	β	lb/in.	125,000			141,000			225,000			299,600	

For **SI:** 1 inch = 25.4 mm, 1 ft-lbf = 1.356 N-m, 1 psi = 6.89 Pa, 1 in^2 = 645 mm^2, 1 lb/in = 0.175 N/mm.

[1]The information presented in this table is to be used in conjunction with the design criteria of ACI 318 Appendix D.
[2]The clearance must comply with applicable code requirements for the connected element.
[3]For the 2006 IBC d_o replaces d_a.
[4]For the 2003 IBC f_{ut} replaces f_{uta}.

TABLE 2—STRONG-BOLT® ANCHOR CHARACTERISTIC TENSION STRENGTH DESIGN VALUES[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)										
			$^{1}/_{2}$			$^{5}/_{8}$			$^{3}/_{4}$			1	
Anchor Category	1, 2 or 3	—	1			1			2			2	
Nominal Embedment Depth	h_{nom}	in.	$2^{3}/_{4}$	$3^{7}/_{8}$	5	$3^{3}/_{8}$	$5^{1}/_{8}$	$6^{1}/_{8}$	$4^{1}/_{8}$	$5^{3}/_{4}$	$7^{1}/_{2}$	$5^{1}/_{4}$	$9^{3}/_{4}$
Steel Strength in Tension (ACI 318 D.5.1)													
Tension Resistance of Steel	N_{sa}	lbf	13,500			20,875			34,125			36,815	
Strength Reduction Factor–Steel Failure	ϕ_{sa}	—	0.75[2]			0.75[2]			0.65[2]			0.65[2]	
Concrete Breakout Strength in Tension (ACI 318 D.5.2)													
Effective Embedment Depth	h_{ef}	in.	$2^{1}/_{4}$	$3^{3}/_{8}$	$4^{1}/_{2}$	$2^{3}/_{4}$	$4^{1}/_{2}$	$5^{1}/_{2}$	$3^{3}/_{8}$	5	$6^{3}/_{4}$	$4\ ^{1}/_{2}$	9
Critical Edge Distance	c_{ac}	in.	9	$7^{7}/_{8}$	$6^{3}/_{4}$	11	$9^{5}/_{8}$	$8^{1}/_{4}$	$13^{1}/_{2}$	$11^{3}/_{4}$	$10^{1}/_{8}$	18	$13^{1}/_{2}$
Effectiveness Factor–Uncracked Concrete	k_{uncr}	—	24			24			24			24	
Effectiveness Factor–Cracked Concrete	k_{cr}	—	17			17			17			17	
Modification Factor	$\psi_{c,N}$[8]	—	1.0			1.0			1.0			1.0	
Strength Reduction Factor–Concrete Breakout Failure	ϕ_{cb}	—	0.65[3]			0.65[3]			0.55[3]			0.55[3]	
Pull-Out Strength in Tension (ACI 318 D.5.3)													
Pull-Out Resistance Cracked Concrete (f'_c= 2,500 psi)	$N_{p,cr}$	lbf	N/A[4]	2,995[6]	2,995[6]	N/A[4]	5,200[5]	5,260[5]	N/A[4]	N/A[4]	9,850[6]	7,700[6]	11,185[6]
Pull-Out Resistance Uncracked Concrete (f'_c= 2,500 psi)	$N_{p,uncr}$	lbf	N/A[4]	4,120[6]	4,600[6]	N/A[4]	7,250[5]	7,300[5]	N/A[4]	9,420[6]	12,115[6]	8,360[6]	9,690[6]
Strength Reduction Factor–Pullout Failure	ϕ_p	—	0.65[7]			0.65[7]			0.55[7]			0.55[7]	
Tension Strength for Seismic Applications (ACI 318 D.3.3.3)													
Tension Resistance of Single Anchor for Seismic Loads (f'_c = 2,500 psi)	$N_{p,eq}$	lbf	N/A[4]	2,995[6]	2,995[6]	N/A[4]	5,200[5]	5,260[5]	N/A[4]	N/A[4]	9,850[6]	7,700[6]	11,185[6]
Strength Reduction Factor–Pullout Failure	ϕ_{eq}	—	0.65[7]			0.65[7]			0.55[7]			0.55[7]	

For **SI:** 1 inch = 25.4 mm, 1 lbf = 4.45 N.

[1]The information presented in this table must be used in conjunction with the design criteria of ACI 318 Appendix D.

[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2.1 of the IBC, or ACI 318 Section 9.2 are used. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318-11 D.4.4. The $^{1}/_{2}$ inch and $^{5}/_{8}$ inch diameter anchors are ductile steel elements as defined in ACI 318 D.1. The $^{3}/_{4}$ and 1 inch diameter anchors are brittle steel elements as defined in ACI 318 D.1.

[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2.1 of the IBC, or ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3(c) for Condition B are met. Condition B applies where supplementary reinforcement is not provided or where pullout strength governs. For installations where complying supplementary reinforcement can be verified, the ϕ_{cb} factors described in ACI 318-11 D.4.3 for Condition A are allowed. If the load combinations of ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3 for Condition A are met, the appropriate value of ϕ_{cb} must be determined in accordance with ACI 318-11 D.4.3(c). If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ_{cb} must be determined in accordance with ACI 318-11 D.4.4(c).

[4]As described in Section 4.1.4 of this report, N/A (Not Applicable) denotes that pullout resistance is not critical and does not need to be considered.

[5]The characteristic pull-out resistance for greater concrete compressive strengths may be increased by multiplying the tabular value by $(f'_c / 2{,}500)^{0.7}$ or $(f'_c / 17.2\text{MPa})^{0.7}$.

[6]The characteristic pull-out resistance for greater concrete compressive strengths may be increased by multiplying the tabular value by $(f'_c/ 2{,}500)^{0.5}$ or $(f'_c / 17.2\text{MPa})^{0.5}$.

[7]The tabulated value of ϕ_p or ϕ_{eq} applies when both the load combinations of ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3(c) for Condition B are met. Condition B applies where supplementary reinforcement is not provided or where pullout strength governs. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-11 D.4.3 for Condition A are allowed. If the load combinations of ACI 318 Appendix C are used, appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4(c).

[8]For the 2003 IBC Ψ_3 replaces $\Psi_{c,N}$.

TABLE 3—STRONG-BOLT® ANCHOR CHARACTERISTIC SHEAR STRENGTH DESIGN VALUES[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER (inch)										
			$^1/_2$			$^5/_8$			$^3/_4$			1	
Anchor Category	1, 2 or 3	—	1			1			2			2	
Nominal Embedment Depth	h_{nom}	in.	$2\frac{3}{4}$	$3\frac{7}{8}$	5	$3\frac{3}{8}$	$5\frac{1}{8}$	$6\frac{1}{8}$	$4\frac{1}{8}$	$5\frac{3}{4}$	$7\frac{1}{2}$	$5\frac{1}{4}$	$9\frac{3}{4}$
Steel Strength in Shear (ACI 318 D.6.1)													
Shear Resistance of Steel	V_{sa}	lbf	5,280			7,255			10,650			15,020	
Strength Reduction Factor–Steel Failure	ϕ_{sa}	—	0.65[2]			0.65[2]			0.60[2]			0.60[2]	
Concrete Breakout Strength in Shear (ACI 318 D.6.2)													
Nominal Diameter	d_a[5]	in.	0.5			0.625			0.75			1	
Load Bearing Length of Anchor in Shear	ℓ_e	in.	2.25	3.375	4.00	2.75	4.50	5.00	3.375	5.00	6.00	4.50	8
Strength Reduction Factor–Concrete Breakout Failure	ϕ_{cb}	—	0.70[3]										
Concrete Pryout Strength in Shear (ACI 318 D.6.3)													
Coefficient for Pryout Strength	k_{cp}	—	1.0	2.0									
Strength Reduction Factor–Concrete Pryout Failure	ϕ_{cp}	–	0.70[4]										
Shear Strength for Seismic Applications (ACI 318 D.3.3.3)													
Shear Resistance of Single Anchor for Seismic Loads (f'_c = 2,500 psi)	$V_{sa,eq}$	lbf	5,280			7,255			10,650			15,020	
Strength Reduction Factor–Steel Failure	ϕ_{eq}	–	0.65[2]			0.65[2]			0.60[2]			0.60[2]	

For **SI:** 1 inch = 25.4 mm, 1 lbf = 4.45 N.

[1]The information presented in this table must be used in conjunction with the design criteria of ACI 318 Appendix D.
[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2.1 of the IBC, or ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3(c) for Condition B are met. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318-11 D.4.4. The ½ inch and $^5/_8$ inch diameter anchors are ductile steel elements as defined in ACI 318 D.1. The $^3/_4$ inch and 1 inch diameter anchors are brittle steel elements as defined in ACI 318 D.1.
[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2.1 of the IBC, or ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3(c) for Condition B are met. Condition B applies where supplementary reinforcement is not provided or where pryout strength governs. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-11 D.4.3 for Condition A are allowed. If the load combinations of ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3 for Condition A are met, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.3(c). If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4(c).
[4]The tabulated value of ϕ_{cp} applies when both the load combinations of ACI 318 Section 9.2 are used and the requirements of ACI 318-11 D.4.3(c) for Condition B are met. Condition B applies where supplementary reinforcement is not provided or where pryout strength governs. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318-11 D.4.3(c) for Condition A are allowed. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4(c).
[5]For the 2006 IBC d_o replaces d_a.

TABLE 4—EXAMPLE STRONG-BOLT® ANCHOR ALLOWABLE STRESS DESIGN TENSION VALUES FOR ILLUSTRATIVE PURPOSES[1,2,3,4,5,6,7,8,9]

Nominal Anchor Diameter (in.)	Embed. Depth (in.)	Effective Embed. Depth, h_{ef} (in.)	Allowable Tension Load, $T_{allowable}$ (lbs.)
$^1/_2$	$2\ ^3/_4$	$2^1/_4$	1,775
	$3^7/_8$	$3^3/_8$	1,810
	5	$4^1/_2$	2,020*
$^5/_8$	$3^3/_8$	$2^3/_4$	2,400
	$5^1/_8$	$4^1/_2$	3,185
	$6^1/_8$	$5^1/_2$	3,205
$^3/_4$	$4^1/_8$	$3^3/_8$	2,760
	$5^3/_4$	5	3,500
	$7^1/_2$	$6^3/_4$	4,500
1	$5^1/_4$	$4^1/_2$	3,110
	$9^3/_4$	9	3,600

Design Assumptions:
1. Single anchor.
2. Static tension load only.
3. Concrete determined to remain uncracked for the life of the anchorage.
4. Load combinations taken from ACI 318 Section 9.2 (no seismic loading).
5. 30 percent Dead Load (D) and 70 percent Live Load (L); Controlling load combination is $1.2D + 1.6L$. Calculation of α based on weighted average: $\alpha = 1.2D + 1.6L = 1.2(0.3) + 1.6(0.7) = 1.48$
6. Normal weight concrete with f'_c = 2,500 psi
7. $c_{a1} = c_{a2} \geq c_{ac}$
8. $h \geq h_{min}$
9. Values are for Condition B (supplementary reinforcement in accordance with ACI 318-11 D.4.3 is not provided.)

* Illustrative Procedure (reference Table 2 of this report):
Strong-Bolt® $^1/_2$ inch (12.7 mm) diameter anchor with an effective embedment, $h_{ef} = 4^1/_2$

Step 1: Calculate steel strength in tension in accordance with ACI 318 D.5.1;
$\phi_{sa}N_{sa}$ = 0.75 x 13,500 = 10,125 lbs.

Step 2: Calculate concrete breakout strength in tension in accordance with ACI 318 D.5.2;
$\phi_{cb}N_{cb}$ = 0.65 x11,440 = 7,435 lbs.

Step 3: Calculate pullout strength in tension per ACI 318 D.5.3;
$\phi_p N_{p,uncr}$ = 0.65 x 4,600 = 2,990 lbs.

Step 4: The controlling value (from Steps 1, 2, and 3 above) in accordance with ACI 318 D.4.1.2;
ϕN_n = 2,990 lbs.

Step 5: Divide the controlling value by the conversion factor α as determined in footnote 5 and in accordance with Section 4.2.1 of this report:
$T_{allowable,ASD} = \phi N_n/\alpha$ = 2,990 / 1.48 = 2,020 lbs.

For single anchor and anchor groups, the edge distance, spacing and member thickness requirements in Table 1 of this report apply.

TABLE 5—STRONG-BOLT® ANCHOR LENGTH IDENTIFICATION CODES

Length Identification Head Marks on Strong-Bolt Anchors (corresponds to length of anchor – inches).

Mark	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
From	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13	14	15	16	17	18
UpTo But Not Including	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13	14	15	16	17	18	19

FIGURE 1—STRONG-BOLT® WEDGE ANCHOR

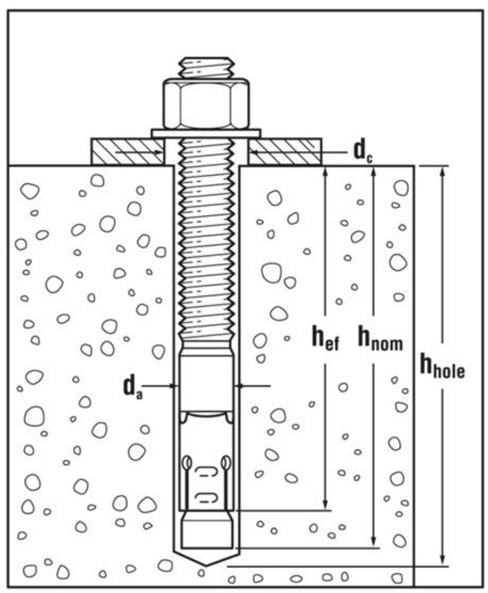


FIGURE 2—STRONG-BOLT® WEDGE ANCHOR INSTALLATION

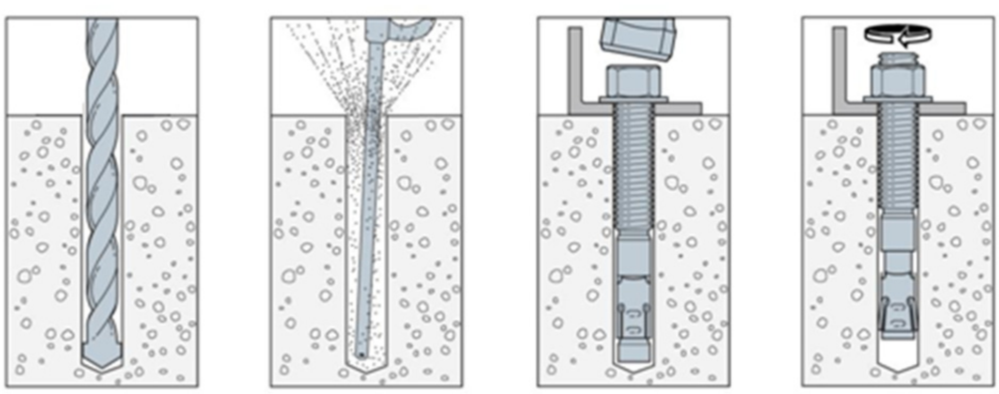
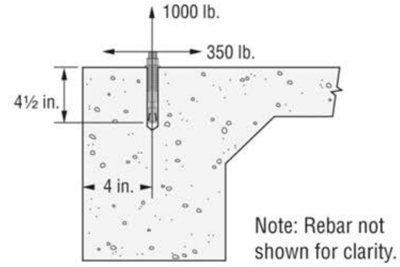


FIGURE 3—STRONG-BOLT® WEDGE ANCHOR INSTALLATION SEQUENCE

Determine if a single ½ inch diameter Strong-Bolt® torque-controlled expansion anchor with a minimum 5 inch embedment (h_{ef} = 4½ inches) installed 4 inches from the edge of a 12 inch deep spandrel beam is adequate for a service tension load of 1,000 lb. for wind and a reversible service shear load of 350 lb. for wind. The anchor will be in the tension zone, away from other anchors in f'_c = 3,000 psi normal-weight concrete.



	ACI 318-08 Code Ref.	Report Ref.
1. Determine the Factored Tension and Shear Design Loads:	9.2.1	
$N_{ua} = 1.6W = 1.6 \times 1{,}000 = 1{,}600$ lb.		
$V_{ua} = 1.6W = 1.6 \times 350 = 560$ lb.		
2. Steel Capacity under Tension Loading:	D.5.1	
$N_{sa} = 13{,}500$		Table 2
$\phi = 0.75$		Table 2
$n = 1$ (single anchor)		
Calculating for ϕN_{sa}:		
$\phi N_{sa} = 0.75 \times 1 \times 13{,}500 = 10{,}125$ lb.		
3. Concrete Breakout Capacity under Tension Loading:	D.5.2	
$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$	Eq. (D-4);	
where:		
$N_b = k_c \lambda \sqrt{f'_c}\, h_{ef}^{1.5}$	Eq. (D-7)	
substituting:		
$\phi N_{cb} = \phi \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} k_c \lambda \sqrt{f'_c}\, h_{ef}^{1.5}$		
where:		
$k_c = k_{cr} = 17$		Table 2
$\lambda = 1.0$ for normal-weight concrete	8.6.1	
$\Psi_{cp,N} = 1.0$	D.5.2.7	
$\Psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,min}}{1.5 h_{ef}}$ when $c_{a,min} < 1.5\, h_{ef}$	Eq. (D-11)	
by observation, $c_{a,min} = 4 < 1.5 h_{ef}$		
$\Psi_{ed,N} = 0.7 + 0.3 \frac{(4)}{1.5(4.5)} = 0.88$		
$\Psi_{c,N} = 1.0$ assuming cracking at service loads ($f_t > f_r$)	D.5.2.6	
$\phi = 0.65$ for Condition B (no supplementary reinforcement provided)		Table 2
$A_{Nco} = 9 h_{ef}^2 = 9(4.5)^2 = 182.25$ in.²	Eq. (D-6)	
$A_{Nc} = (c_{a1} + 1.5 h_{ef})(2 \times 1.5 h_{ef}) = (4 + 1.5(4.5))(2 \times 1.5(4.5)) = 145.13$ in.²	Fig. RD.5.2.1(a)	
$\frac{A_{Nc}}{A_{Nco}} = \frac{145.13}{182.25} = 0.8$		
Calculating for ϕN_{cb}:		
$\phi N_{cb} = 0.65 \times 0.8 \times 1.0 \times 0.88 \times 1.0 \times 17 \times 1.0 \times \sqrt{3{,}000} \times (4.5)^{1.5} = 4{,}067$ lb.		

	ACI 318-08 Code Ref.	Report Ref.
4. Pullout Capacity:	D.5.3	
$N_{pn,cr} = 2{,}995 \times \left(\frac{3{,}000}{2{,}500}\right)^{0.5} = 3{,}281$ lb.		Table 2
$\phi = 0.65$		Table 2
$\phi N_{pn} = 0.65 \times 3{,}281 = 2{,}133.$		
5. Check All Failure Modes under Tension Loading:	D.4.1.2	
Summary:		
Steel Capacity = 10,125 lb.		
Concrete Breakout Capacity = 4,067 lb.		
Pullout Capacity = 2,133 lb. ← **Controls**		
∴ ϕN_n = 2,133 lb. as Pullout Capacity controls > N_{ua} = 1,600 lb. – OK		
6. Steel Capacity under Shear Loading:	D.6.1	
$V_{sa} = 5{,}280$ lb.		Table 3
$\phi = 0.65$		Table 3
Calculating for ϕV_{sa}:		
$\phi V_{sa} = 0.65 \times 5{,}280 = 3{,}432$ lb.		
7. Concrete breakout Capacity under Shear Loading:	D.6.2	
$V_{cb} = \frac{A_{Vc}}{A_{Vco}} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_b$	Eq. (D-21)	
where:		
$V_b = 7\left(\frac{\ell_e}{d_a}\right)^{0.2} \sqrt{d_a}\, \lambda \sqrt{f'_c}\, c_{a1}^{1.5}$	Eq. (D-24)	
substituting:		
$\phi V_{cb} = \phi \frac{A_{Vc}}{A_{Vco}} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} \Psi_{h,V}\, 7\left(\frac{\ell_e}{d_a}\right)^{0.2} \sqrt{d_a}\, \lambda \sqrt{f'_c}\, c_{a1}^{1.5}$		
where:		
$\phi = 0.70$ for Condition B (no supplementary reinforcement provided)		Table 3
$A_{Vco} = 4.5 c_{a1}^2 = 4.5(4)^2 = 72$ in.²	Eq. (D-23)	
$A_{Vc} = 2(1.5c_{a1})(1.5c_{a1}) = 2(1.5(4))(1.5(4)) = 72$ in.²	Fig. RD.6.2.1(a)	
$\frac{A_{Vc}}{A_{Vco}} = \frac{72}{72} = 1$	D.6.2.1	
$\Psi_{ed,V} = 1.0$ since $c_{a2} > 1.5c_{a1}$	Eq. (D-27)	
$\Psi_{c,V} = 1.0$ assuming cracking at service loads ($f_t > f_r$)	D.6.2.7	
$h_a = 12$ in.		
$\Psi_{h,v} = 1.0$ since $h_a > 1.5c_{a1}$	D.6.2.8	
$d_a = 0.5$ in.		
$\ell_e = 4$ in.	D.6.2.2	
$\lambda = 1.0$ for normal-weight concrete	8.6.1	
$c_{a1} = 4$ in.		
$\phi V_{cb} = 0.70 \times 1 \times 1.0 \times 1.0 \times 1.0 \times 7 \times \left(\frac{4}{0.5}\right)^{0.2} \times \sqrt{0.5} \times 1.0 \times \sqrt{3{,}000} \times (4)^{1.5} = 2{,}301$ lb.		

FIGURE 4—STRONG BOLT® ANCHOR EXAMPLE CALCULATION

	ACI 318-08 Code Ref.	Report Ref.
8. Concrete Pryout Strength:	*D.6.3*	
$V_{cp} = k_{cp} N_{cb}$	*Eq. (D-30)*	
where:		
$n = 1$		
$\phi = 0.70$		*Table 3*
$k_{cp} = 2.0$	*D.6.3.1*	
$k_{cp} N_{cb} = 2.0 \times \frac{4{,}067}{0.65} = 12{,}514$ lb.	*D.6.3.1*	
$\phi n V_{cp} = 0.70 \times 1 \times 12{,}514 = 8{,}760$ lb.		
9. Check All Failure Modes under Shear Loading:	*D.4.1.2*	
Summary:		
Steel Capacity = 3,432 lb.		
Concrete Breakout Capacity = 2,301 lb. ← **Controls**		
Pryout Capacity = 8,760 lb.		
∴ ϕV_n **= 2,301 lb. as Concrete Breakout Capacity controls >** V_{ua} **= 560 lb. – OK**		

	ACI 318-08 Code Ref.	Report Ref.
10. Check Interaction of Tension and Shear Forces:	*D.7*	
If $0.2\ \phi V_n \geq V_{ua}$, then the full tension design strength is permitted.	*D.7.1*	
By observation, this is not the case.		
If $0.2\ \phi N_n \geq N_{ua}$, then the full shear design strength is permitted	*D.7.2*	
By observation, this is not the case.		
Therefore:		
$\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2$	*Eq. (D-32)*	
$\frac{1{,}600}{2{,}133} + \frac{560}{2{,}301} = 0.75 + 0.24 = 0.99 < 1.2$ – OK		
11. Summary		
A single ½ in. diameter Strong-Bolt® anchor at a 5 in. embedment depth is adequate to resist the applied service tension and shear loads of 1,000 lb. and 350 lb., respectively.		

FIGURE 4—STRONG BOLT® ANCHOR EXAMPLE CALCULATION (Continued)