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DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

SIMPSON STRONG-TIE COMPANY INC.

5956 WEST LAS POSITAS BOULEVARD
PLEASANTON, CALIFORNIA 94588

EVALUATION SUBJECT:

SIMPSON STRONG-TIE® STRONG-BOLT® 2 WEDGE ANCHOR FOR CRACKED AND UNCRACKED CONCRETE

ICC-ES Evaluation Report

ESR-3037*

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

DIVISION: 05 00 00—METALS
Section: 05 05 19—Post-installed Concrete Anchors

REPORT HOLDER:

SIMPSON STRONG-TIE COMPANY INC.
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PLEASANTON, CALIFORNIA 94588
(925) 560-9000
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EVALUATION SUBJECT:

SIMPSON STRONG-TIE® STRONG-BOLT® 2 WEDGE ANCHOR FOR CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2015, 2012, 2009, and 2006 *International Building Code®* (IBC)
- 2015, 2012, 2009, and 2006 *International Residential Code®* (IRC)

Property evaluated:

Structural

2.0 USES

The Simpson Strong-Tie® Strong-Bolt® 2 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 having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

The 3/8-inch-, 1/2-inch-, 5/8-inch- and 3/4-inch-diameter (9.5 mm, 12.7 mm, 15.9 mm and 19.1 mm) anchors may be installed in the soffit of cracked and uncracked normal-weight or sand-lightweight concrete-filled steel deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa).

The 3/8-inch- and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors may be installed in the topside of cracked and uncracked normal-weight or sand-lightweight concrete-filled steel deck having a minimum member thickness, $h_{min,deck}$, as noted in Tables 5A and 5B of this report and a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

The Strong-Bolt® 2 complies with Section 1901.3 of the 2015 IBC and Section 1909 of the 2012 IBC, Section 1912 of the 2009 and 2006 IBC. The anchors are alternatives to cast-in-place anchors described in Section 1908 of the 2012 IBC, Section 1911 of the 2009 and 2006 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® 2:

3.1.1 General: Strong-Bolt® 2 anchors are torque-controlled, mechanical expansion anchors consisting of an anchor body, expansion clip, nut, and washer. A typical anchor (carbon steel version) is shown in Figure 1 of this report. 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 by applying 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 Tables 1A and 1B of this report.

3.1.2 Strong-Bolt® 2, Carbon Steel: The anchor bodies are manufactured from carbon steel material with zinc plating conforming to ASTM B633, SC1, Type III. The expansion clip for the 1/4-inch-, 3/8-inch-, 1/2-inch-, 5/8-inch- and 3/4-inch-diameter carbon steel Strong-Bolt 2 anchors is fabricated from carbon steel and conforms to ASTM A568. The expansion clip for the 1-inch-diameter carbon steel Strong-Bolt 2 anchor is fabricated from stainless steel and conforms to ASTM A240, Grade 316. The hex nut for the carbon steel Strong-Bolt 2 anchor conforms to ASTM A563, Grade A. The washer for the carbon steel Strong-Bolt 2 anchor conforms to ASTM F844. The available anchor diameters under this report are 1/4 inch, 3/8 inch, 1/2 inch, 5/8 inch, 3/4 inch and 1 inch (6.4 mm, 9.5 mm, 12.7 mm, 15.9 mm, 19.1 mm, and 25.4 mm).

3.1.3 Strong-Bolt® 2, Stainless Steel: The anchor body of the ¼-inch-diameter stainless steel Strong-Bolt 2 anchor is manufactured from either AISI Type 304 or AISI Type 316 stainless steel. The anchor bodies of the 3/8-inch-, ½-inch-, 5/8-inch-, and ¾-inch-diamater stainless steel Strong-Bolt 2 anchors are manufactured from AISI Type 316 stainless steel. The expansion clip for the stainless steel Strong-Bolt 2 anchor conform to AISI Type 316 stainless steel. The hex nut and washer for the Type 304

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and Type 316 stainless steel Strong-Bolt 2 conform to AISI Type 304 and Type 316 steel, respectively. The available anchor diameters under this report are $^1/_4$ inch, $^3/_8$ inch, $^1/_2$ inch, $^5/_8$ inch and $^3/_4$ inch (6.4 mm, 9.5 mm, 12.7 mm, 15.9 mm and 19.1 mm).

3.2 Concrete:

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

3.3 Profile Steel Deck:

The profile steel deck must comply with the configuration in Figures 4 and 5 and have a minimum base-steel thickness of 0.035 inch (0.889 mm) [20 gauge]. Steel must comply with ASTM A653/A653M SS Grade 33 with a minimum yield strength of 33,000 psi (228 MPa).

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Design strength of anchors complying with the 2015 IBC as well as Section R301.1.3 of the 2015 IRC, must be determined in accordance with ACI 318-14 and this report.

Design strength of anchors complying with the 2012 IBC, as well as Section R301.1.3 of the 2012 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 and Section R301.1.3 of the 2006 IRC must be in accordance with ACI 318-05 Appendix D and this report.

Design parameters provided in Tables 1A through 6 and references to ACI 318 are based on the 2015 IBC (ACI 318-14) and 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 318-14 17.3.1 or ACI 318-11 D.4.1, as applicable, except as required in ACI 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable. A design example in accordance with the 2009 IBC is given in Figure 7 of this report.

Strength reduction factors, ϕ, as given in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable, must be used for load combinations calculated in accordance with Section 1605.2 of the IBC and Section 5.3 of ACI 318-14 or Section 9.2 of ACI 318-11, as applicable. Strength reduction factors, ϕ, as given in ACI 318-11 D.4.4 must be used for load combinations calculated in accordance with ACI 318-11 Appendix C.

The value of f'_c used in the calculations must be limited to 8,000 psi (55.2 MPa), maximum, in accordance with ACI 318-14 17.2.7 or ACI 318-11 D.3.7, as applicable.

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 318-14 17.4.1.2 or ACI 318-11 D.5.1.2, as applicable, is given in Tables 2A and 2B of this report. The strength reduction factor, ϕ, corresponding to a brittle steel element must be used for the carbon steel 1-inch-diameter anchor as described in Table 2A of this report. For all other anchors the strength reduction factor, ϕ, corresponding to a ductile steel element must be used as described in Tables 2A and 2B 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}, must be calculated in accordance with ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, with modifications as described in this section. The basic concrete breakout strength in tension, N_b, must be calculated in accordance with ACI 318-14 17.4.2.2 or ACI 318-11 D.5.2.2, as applicable, using the values of h_{ef} and k_{cr} as described in Tables 2A and 2B of this report. 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 loads in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.2.6, as applicable, must be calculated with the value of k_{uncr} as given in Tables 2A and 2B of this report and with $\Psi_{c,N}$ = 1.0, as described in Tables 2A and 2B of this report.

For anchors installed in the soffit of sand-lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, as shown in Figure 4, determination of the concrete breakout strength in accordance with ACI 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, is not required.

4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in tension in accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, is given in Tables 2A and 2B of this report. Where analysis indicates no cracking at service load levels in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, 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 Tables 2A and 2B, the pullout strength does not need to be considered. In lieu of ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, $\Psi_{c,p}$ = 1.0 for all design cases. The nominal pullout strength in cracked concrete must be adjusted for concrete strengths according to Eq-1:

$$N_{p,f'c} = N_{p,cr}\left(\frac{f'_c}{2,500}\right)^n \quad \text{(lb, psi)} \qquad \text{(Eq-1)}$$

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

where f'_c is the specified compressive strength and n is the factor defining the influence of concrete strength on the pullout strength. For the stainless steel $^3/_8$-inch-diameter anchor in cracked concrete n is 0.3. For the stainless steel $^5/_8$-inch-diameter anchor in cracked concrete n is 0.4. For all other cases n is 0.5.

In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318 D.5.3.6, as applicable, the nominal pullout strength in tension must be adjusted by calculation according to Eq-2:

$$N_{p,f'c} = N_{p,uncr}\left(\frac{f'_c}{2,500}\right)^n \quad \text{(lb, psi)} \qquad \text{(Eq-2)}$$

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

where f'_c is the specified compressive strength and n is the factor defining the influence of concrete strength on the pullout strength. For the stainless steel $^3/_8$-inch-diameter anchor in uncracked concrete, n is 0.3. For the stainless steel $^1/_4$-inch-diameter anchor and stainless steel $^3/_4$-inch-diameter anchor in uncracked concrete, n is 0.4. For all other cases, n is 0.5.

The pullout strength in cracked and uncracked concrete for anchors installed in the soffit of sand-lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, as shown in Figure 4, is given in Tables

4A and 4B of this report. The nominal pullout strength in cracked concrete must be adjusted for concrete strength according to Eq-1, using the value of $N_{p,deck,cr}$ in lieu of $N_{p,cr}$, and the value of 3,000 psi (20.7 MPa) must be substituted for the value of 2,500 psi (17.2 MPa) in the denominator. Where analysis indicates no cracking at service load levels in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in uncracked concrete must be adjusted for concrete strength according to Eq-2, using the value of $N_{p,deck,uncr}$ in lieu of $N_{p,uncr}$, and the value of 3,000 psi (20.7 MPa) must be substituted for the value of 2,500 psi (17.2 MPa) in the denominator. The value of $\Psi_{c,p}$ = 1.0 for all cases.

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 318-14 17.5.1.2 or ACI 318-11 D.6.1.2, as applicable, is given in Tables 3A and 3B of this report and must be used in lieu of values derived by calculation from ACI 318-14 Eq. 17.5.1.2a or ACI 318-11, Eq. D-29, as applicable. The strength reduction factor, ϕ, corresponding to a brittle steel element must be used for the carbon steel 1-inch-diameter anchor as described in Table 3A of this report. For all other anchors the strength reduction factor, ϕ, corresponding to a ductile steel element must be used for all anchors as described in Tables 3A and 3B of this report.

The shear strength, $V_{sa,deck}$, of anchors installed in the soffit of sand-lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, as shown in Figure 4, is given in Tables 4A and 4B of this report.

4.1.6 Requirements for Static Concrete Breakout Strength in Shear: The nominal concrete breakout strength of a single anchor or group of anchors in shear, V_{cb} or V_{cbg}, must be calculated in accordance with ACI 318-14 17.5.2 or ACI 318-11 D.6.2, as applicable, with modifications as described in this section. The basic concrete breakout strength in shear, V_b, must be calculated in accordance with ACI 318-14 17.5.2.2 or ACI 318-11 D.6.2.2, as applicable, using the values of ℓ_e and d_a provided in Tables 3A and 3B of this report.

For anchors installed in the topside of concrete-filled steel deck assemblies, as shown in Figure 5, the nominal concrete breakout strength of a single anchor or group of anchors in shear, V_{cb} or V_{cbg}, respectively, must be calculated in accordance with ACI 318-14 17.5.2 or ACI 318-11 D.6.2, as applicable, using the actual member thickness, $h_{min,deck}$, in the determination of A_{Vc}. Minimum member topping thickness for anchors in the topside of concrete-filled steel deck assemblies is given in Tables 5A and 5B of this report.

For anchors installed in the soffit of sand-lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, as shown in Figure 4, calculation of the concrete breakout strength in accordance with ACI 318-14 17.5.2 or ACI 318-11 D.6.2, as applicable, is not required.

4.1.7 Requirements for Static Concrete Pryout Strength in Shear: The nominal concrete pryout strength of a single anchor or group of anchors in shear, V_{cp} or V_{cpg}, must be calculated in accordance with ACI 318-14 17.5.3.1 or ACI 318-11 D.6.3, as applicable, modified by using the value of k_{cp} described in Tables 3A and 3B of this report and the value of N_{cb} or N_{cbg} as calculated in accordance with Section 4.1.3 of this report.

For anchors installed in the soffit of sand-lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, as shown in Figure 4, calculation of the concrete pryout strength in accordance with ACI 318-14 17.5.3.1 or ACI 318-11 D.6.3, as applicable, is not required.

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 318-14 17.2.3 or ACI 318-11 D.3.3, as applicable. Modifications to ACI 318-14 2.3 17.2.3 shall be applied under Section 1905.1.8 of the 2015 IBC. For the 2012 IBC, Section 1905.1.9 must be omitted. Modifications to ACI 318-08 and ACI 318-05 D.3.3, as applicable, must be applied under Section 1908.1.9 of the 2009 IBC, Section 1908.1.16 of the 2006 IBC, respectively.

The carbon steel 1-inch-diameter anchor complies with ACI 318-14 2.3 or ACI 318-11 D.1, as applicable, as a brittle steel element. All other anchors comply with ACI 318-14 2.3 or ACI 318-11 D.1, as applicable, as ductile steel elements and must be designed in accordance with ACI 318-14 Section 17.2.3.4, 17.2.3.5, or 17.2.3.6 or ACI 318-11 Section D.3.3.4, D.3.3.5, or D.3.3.6 or ACI 318-08 Section D.3.3.4, D.3.3.5 or D.3.3.6, or ACI 318-05 Section 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 nominal concrete breakout strength for anchors in tension must be calculated in accordance with ACI 318-14 17.4.1 an 17.4.2 or ACI 318-11 D.5.1 and D.5.2, as applicable, as described in Sections 4.1.2 and 4.1.3 of this report.

In accordance with ACI 318-14 17.4.3.2 or ACI 318-11 D.5.3.2, as applicable, the appropriate value for nominal pullout strength in tension for seismic loads, $N_{p,eq}$ or $N_{p,deck,eq}$, provided in Tables 2A, 2B, 4A and 4B of this report, must be used in lieu of N_p. If no values for $N_{p,eq}$ or $N_{p,deck,eq}$ are given in Table 2A, 2B, 4A or 4B, the pullout strength for seismic loads need not be evaluated. The values of $N_{p,eq}$ or $N_{p,deck,eq}$ can be adjusted for concrete strength according to Section 4.1.4.

4.1.8.3 Seismic Shear: The nominal concrete breakout and concrete pryout strength for anchors in shear must be calculated in accordance with ACI 318-14 17.5.2 and 17.5.3 or ACI 318-11 D.6.2 and D.6.3, as applicable, as described in Sections 4.1.6 and 4.1.7 of this report. In accordance with ACI 318-14 17.5.1.2 or ACI 318-11 D.6.1.2, as applicable, the appropriate value for nominal steel strength in shear for seismic loads, $V_{sa,eq}$ or $V_{sa,deck,eq}$, provided in Tables 3A, 3B, 4A and 4B 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 318-14 17.6 or ACI 318-11 D.7, as applicable.

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 318-14 17.4.2 or ACI 318-11 D.5.2, as applicable, must be further multiplied by the factor $\Psi_{cp,N}$ given by Eq-3:

$$\Psi_{cp,N} = \frac{c}{c_{ac}} \qquad \text{(Eq-3)}$$

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 318-14 17.7.6 or ACI 318-11 D.8.6, as applicable, values of c_{ac} provided in Tables 1A and 1B 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 318-14 17.7.1 and 17.7.3 or ACI 318-11 D.8.1 and D.8.3, as applicable, values of s_{min} and c_{min} provided in Tables 1A and 1B of this report must be used. In lieu of ACI 318-14 17.7.5 or ACI 318-11 D.8.5, as applicable, minimum member thickness, h_{min}, must be in accordance with Tables 1A and 1B of this report.

For $^3/_4$-inch-diameter carbon steel, and $^3/_8$-inch-, $^1/_2$-inch- and $^5/_8$-inch-diameter stainless steel Strong-Bolt® 2 anchors, additional combinations for minimum edge distance c_{min} and minimum spacing s_{min} may be derived by linear interpolation between the boundary given in Tables 1A and 1B and as shown in Figure 6 of this report.

For anchors installed in the topside of normal-weight or sand-lightweight concrete over profile steel deck floor and roof assemblies, the anchor must be installed in accordance with Table 5A for carbon steel anchors and Table 5B for stainless steel anchors, and Figure 5 of this report.

For anchors installed in the soffit of steel deck assemblies, the anchors must be installed in accordance with Figure 4 and must have a minimum axial spacing along the flute equal to the greater of $3h_{ef}$ or 1.5 times the flute width.

4.1.12 Sand-lightweight Concrete: For ACI 318-14, 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 318-14 17.2.6 (2015 IBC) or 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 D.3.4, when anchors are used in sand-lightweight concrete, N_b, $N_{p,cr}$, $N_{p,uncr}$, $N_{p,eq}$ and V_b determined in accordance with this report must be multiplied by 0.60, in lieu of ACI 318 D.3.4.

For anchors installed in the lower or upper flute of the soffit of sand-lightweight concrete filled profile steel deck floor and roof assemblies, this reduction is not required.

4.2 Allowable Stress Design (ASD):

4.2.1 General: Where design values for use with allowable stress design (working stress design) load combinations calculated in accordance with Section 1605.3 of the IBC, must be established using the following equations:

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

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 = Lowest design strength of an anchor or anchor group in tension as determined in accordance with ACI 318-14 Chapter 17 and 2015 IBC Section 1905.1.8, ACI 318-11 Appendix D, ACI 318-08 Appendix D, and 2009 IBC Section 1908.1.9, ACI 318-05 Appendix D an IBC Section 1908.1.16, and Section 4.1 of this report, as applicable. (lbf or kN).

ϕV_n = Lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318-14 Chapter 17 and 2015 IBC Section 1905.1.8, ACI 318-11 Appendix D, ACI 318-08 Appendix D, and 2009 IBC Section 1908.1.9 or 2006 IBC Section 1908.1.16, and Section 4.1 of this report, 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 6.

4.2.2 Interaction of Tensile and Shear Forces: The interaction of tension and shear loads must be consistent with ACI 318-14 17.6 or ACI 318-11, -08, -05 D.7, as applicable, 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 Tables 1A and 1B and 4A and 4B, and in Figures 2, 3 and 4. Anchor locations must comply with this report and the plans and specifications approved by the code official. The Strong-Bolt® 2 must be installed in accordance with the manufacturer's published 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, h_{hole}, is given in Tables 1A and 1B. 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 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 Tables 1A and 1B is achieved.

For anchors installed in the topside of normal-weight or sand-lightweight concrete over profile steel deck floor and roof assemblies, installation parameters are provided in Tables 5A and 5B and in Figure 5 of this report.

For installation in the soffit of normal-weight or sand-lightweight concrete over profile steel deck floor and roof assemblies, the hole diameter in the steel deck must not exceed the diameter of the hole in the concrete by more than $^1/_8$ inch (3.2 mm). The minimum drilled hole depth, h_{hole}, is given in Tables 4A and 4B. For edge distance and member thickness requirements for installations into the soffit of concrete over steel deck assemblies, see Figure 4. For installation in the soffit of sand-lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, torque must be applied until the appropriate installation torque value specified in Tables 4A and 4B is achieved.

4.4 Special Inspection:

Periodic special inspection is required in accordance with Section 1705.1.1 and Table 1705.3 of the 2015 IBC and of the 2012 IBC or Section 1704.15 of the 2009 IBC, or Section 1704.13 of the 2006 IBC. 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® 2 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 case of a conflict, this report governs.

5.2 Anchor sizes, dimensions and minimum embedment depths are as set forth in this report.

5.3 The $^1/_4$-inch-diameter (6.4 mm) anchors must be limited to use in uncracked normal-weight concrete 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).

The anchor may also be installed in the top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Tables 1A & 1B.

5.4 The $^3/_8$-inch- through 1-inch-diameter (9.5 mm through 25.4 mm) 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).

The anchors may also be installed in the top of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Tables 1A & 1B.

5.5 The $^3/_8$-inch through $^3/_4$-inch-diameter (9.5 mm through 19.1 mm) anchors must be installed in the soffit of cracked and uncracked sand-lightweight or normal-weight concrete over profile steel deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa).

5.6 The $^3/_8$-inch- and $^1/_2$-inch-diameter (9.5 mm and 12.7 mm) anchors may be installed in the topside of cracked and uncracked normal-weight or sand-lightweight concrete-filled steel deck having a minimum specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

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

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

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

5.10 Anchor spacing and edge distance, as well as minimum member thickness, must comply with Tables 1A, 1B, 4A, 4B, 5A, 5B; and Figures 4, 5, and 6, of this report.

5.11 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.

5.12 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.

5.13 The $^3/_8$-inch through 1-inch (9.5 mm through 25.4 mm) 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.

5.14 The $^1/_4$-inch-diameter (6.4 mm) anchors may be used to resist short-term loading due to wind or seismic forces, in locations designated as Seismic Design Categories A and B under the IBC, subject to the conditions of this report.

5.15 The $^3/_8$-inch through 1-inch (9.5 mm through 25.4 mm) anchors may be used to resist short-term loading due to wind or seismic forces, in locations designated as Seismic Design Categories A through F under the IBC, subject to the conditions of this report.

5.16 Where not otherwise prohibited in the code, Strong-Bolt® 2 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.

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

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

5.19 The anchors are manufactured by Simpson Strong-Tie Company Inc., under an approved quality-control program with inspections by ICC-ES.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193), dated June 2012 (editorially revised April 2015), including optional suitability tests for seismic tension and shear; profile steel deck soffit tests; and quality control documentation.

7.0 IDENTIFICATION

The Strong-Bolt® 2 anchors are identified in the field by dimensional characteristics, head stamp, material specifications and packaging. The Strong-Bolt® 2 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 7 shows the length identification codes. The packaging label bears the manufacturer's name and contact information, anchor name, anchor size and length, quantity, and the evaluation report number (ESR-3037).

TABLE 1A—CARBON STEEL STRONG-BOLT® 2 ANCHOR INSTALLATION INFORMATION1

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR SIZE											
			Carbon Steel											
			1/4 inch[5]	3/8 inch[6]		1/2 inch[6]			5/8 inch[6]		3/4 inch[6]		1 inch[6]	
Installation Information														
Nominal Diameter	d_a[3]	in.	1/4	3/8		1/2			5/8		3/4		1	
Drill Bit Diameter	d	in.	1/4	3/8		1/2			5/8		3/4		1	
Baseplate Clearance Hole Diameter[2]	d_c	in.	5/16	7/16		9/16			11/16		7/8		1 1/8	
		(mm)	(7.9)	(11.1)		(14.3)			(17.5)		(22.2)		(28.6)	
Installation Torque	T_{inst}	ft-lbf	4	30		60			90		150		230	
		(N-m)	(5.4)	(40.7)		(81.3)			(122.0)		(203.4)		(311.9)	
Nominal Embedment Depth	h_{nom}	in.	1 3/4	1 7/8	2 7/8	2 3/4		3 7/8	3 3/8	5 1/8	4 1/8	5 3/4	5 1/4	9 3/4
		(mm)	(45)	(48)	(73)	(70)		(98)	(86)	(130)	(105)	(146)	(133)	(248)
Effective Embedment Depth	h_{ef}	in.	1 1/2	1 1/2	2 1/2	2 1/4		3 3/8	2 3/4	4 1/2	3 3/8	5	4 1/2	9
		(mm)	(38)	(38)	(64)	(57)		(86)	(70)	(114)	(86)	(127)	(114)	(229)
Minimum Hole Depth	h_{hole}	in.	1 7/8	2	3	3		4 1/8	3 5/8	5 3/8	4 3/8	6	5 1/2	10
		(mm)	(48)	(51)	(76)	(76)		(105)	(92)	(137)	(111)	(152)	(140)	(254)
Minimum Overall Anchor Length	ℓ_{anch}	in.	2 1/4	2 3/4	3 1/2	3 3/4		5 1/2	4 1/2	6	5 1/2	7	7	13
		(mm)	(57)	(70)	(89)	(95)		(140)	(114)	(152)	(140)	(178)	(178)	(330)
Critical Edge Distance	c_{ac}	in.	2 1/2	6 1/2	6	6 1/2	6 1/2	7 1/2	7 1/2	9	9	8	18	13 1/2
		(mm)	(64)	(165)	(152)	(165)	(165)	(191)	(191)	(229)	(229)	(203)	(457)	(343)
Minimum Edge Distance	c_{min}	in.	1 3/4	6		7	4	4	6 1/2		6 1/2		8	
		(mm)	(45)	(152)		(178)	(102)	(102)	(165)		(165)		(203)	
	for $s \geq$	in.	-	-		-	-	-	-		8		-	
		(mm)	-	-		-	-	-	-		(203)		-	
Minimum Spacing	s_{min}	in.	2 1/4	3		7	4	4	5		7		8	
		(mm)	(57)	(76)		(178)	(102)	(102)	(127)		(178)		(203)	
	for $c \geq$	in.	-	-		-	-	-	-		8		-	
		(mm)	-	-		-	-	-	-		(203)		-	
Minimum Concrete Thickness	h_{min}	in.	3 1/4	3 1/4	4 1/2	4 1/2	5 1/2	6	5 1/2	7 7/8	6 3/4	8 3/4	9	13 1/2
		(mm)	(83)	(83)	(114)	(114)	(140)	(152)	(140)	(200)	(172)	(222)	(229)	(343)
Additional Data														
Specified Yield Strength	f_{ya}	psi	56,000	92,000		85,000					70,000		60,000	
		(MPa)	(386)	(634)		(586)					(483)		(414)	
Specified Tensile Strength	f_{uta}	psi	70,000	115,000							110,000		78,000	
		(MPa)	(483)	(793)							(758)		(538)	
Minimum Tensile and Shear Stress Area	A_{se}[3]	in^2	0.0318	0.0514		0.105			0.166		0.270		0.472	
		(mm^2)	(21)	(33)		(68)			(107)		(174)		(305)	
Axial Stiffness in Service Load Range - Cracked and Uncracked Concrete[4]	β	lb./in	73,700[4]	34,820		63,570			91,370		118,840		299,600	
		(N/mm)	(12,898)[4]	(6,098)		(11,133)			(16,001)		(20,812)		(52,468)	

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 lbf/in = 0.175 N/mm.

[1]The information presented in this table is to be used in conjunction with the design criteria of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable.

[2]The clearance must comply with applicable code requirements for the connected element.

[3]For the 2006 IBC d_o replaces d_a, $A_{se,N}$ replaces A_{se}.

[4] The tabulated value of β for 1/4-inch-diameter carbon steel Strong-Bolt® 2 anchor is for installations in uncracked concrete only.

[5] The 1/4-inch-diameter (6.4 mm) anchor may be installed in top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in this table.

[6]The 3/8-inch- through 1-inch-diameter (9.5 mm through 25.4 mm) anchors may be installed in topside of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in this table, and Tables 5A and 5B for the 3/8-inch and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors.

TABLE 1B—STAINLESS STEEL STRONG-BOLT® 2 ANCHOR INSTALLATION INFORMATION[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR SIZE									
			Stainless Steel									
			1/4 inch[5]	3/8 inch[6]		1/2 inch[6]			5/8 inch[6]		3/4 inch[6]	
Installation Information												
Nominal Diameter	d_a[3]	in.	1/4	3/8		1/2			5/8		3/4	
Drill Bit Diameter	*d*	in.	1/4	3/8		1/2			5/8		3/4	
Baseplate Clearance Hole Diameter[2]	d_c	in.	5/16	7/16		9/16			11/16		7/8	
		(mm)	(7.9)	(11.1)		(14.3)			(17.5)		(22.2)	
Installation Torque	T_{inst}	ft-lbf	4	30		60			80		150	
		(N-m)	(5.4)	(40.7)		(81.3)			(108.5)		(203.4)	
Nominal Embedment Depth	h_{nom}	in.	1 3/4	1 7/8	2 7/8	2 3/4	3 7/8		3 3/8	5 1/8	4 1/8	5 3/4
		(mm)	(45)	(48)	(73)	(70)	(98)		(86)	(130)	(105)	(146)
Effective Embedment Depth	h_{ef}	in.	1 1/2	1 1/2	2 1/2	2 1/4	3 3/8		2 3/4	4 1/2	3 3/8	5
		(mm)	(38)	(38)	(64)	(57)	(86)		(70)	(114)	(86)	(127)
Minimum Hole Depth	h_{hole}	in.	1 7/8	2	3	3	4 1/8		3 5/8	5 3/8	4 3/8	6
		(mm)	(48)	(51)	(76)	(76)	(105)		(92)	(137)	(111)	(152)
Minimum Overall Anchor Length	ℓ_{anch}	in.	2 1/4	2 3/4	3 1/2	3 3/4	5 1/2		4 1/2	6	5 1/2	7
		(mm)	(57)	(70)	(89)	(95)	(140)		(114)	(152)	(140)	(178)
Critical Edge Distance	c_{ac}	in.	2 1/2	6 1/2	8 1/2	4 1/2	7		7 1/2	9	8	8
		(mm)	(64)	(165)	(216)	(114)	(178)		(191)	(229)	(203)	(203)
Minimum Edge Distance	c_{min}	in.	1 3/4	6		6 1/2	5	4	4		6	
		(mm)	(45)	(152)		(165)	(127)	(102)	(102)		(152)	
	for s ≥	in.	-	10		-	-	8	8		-	
		(mm)	-	(254)		-	-	(203)	(203)		-	
Minimum Spacing	s_{min}	in.	2 1/4	3		8	5 1/2	4	6 1/4		6 1/2	
		(mm)	(57)	(76)		(203)	(140)	(102)	(159)		(165)	
	for c ≥	in.	-	10		-	-	8	5 1/2		-	
		(mm)	-	(254)		-	-	(203)	(140)		-	
Minimum Concrete Thickness	h_{min}	in.	3 1/4	3 1/4	4 1/2	4 1/2	6		5 1/2	7 7/8	6 3/4	8 3/4
		(mm)	(83)	(83)	(114)	(114)	(152)		(140)	(200)	(172)	(222)
Additional Data												
Specified Yield Strength	f_{ya}	psi	96,000	80,000		92,000			82,000		68,000	
		(MPa)	(662)	(552)		(634)			(565)		(469)	
Specified Tensile Strength	f_{uta}	psi	120,000	100,000		115,000			108,000		95,000	
		(MPa)	(827)	(689)		(793)			(745)		(655)	
Minimum Tensile and Shear Stress Area	A_{se}[3]	in^2	0.0255	0.0514		0.105			0.166		0.270	
		(mm^2)	(16)	(33)		(68)			(107)		(174)	
Axial Stiffness in Service Load Range - Cracked and Uncracked Concrete[4]	β	lb./in	54,430[4]	29,150		54,900			61,270		154,290	
		(N/mm)	(9,525)[4]	(5,105)		(9,614)			(10,730)		(27,020)	

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 lbf/in = 0.175 N/mm.

[1]The information presented in this table is to be used in conjunction with the design criteria of ACI 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable.

[2]The clearance must comply with applicable code requirements for the connected element.

[3]For the 2006 IBC d_o replaces d_a, $A_{se,N}$ replaces A_{se}.

[4]The tabulated value of β for 1/4-inch-diameter stainless steel Strong-Bolt® 2 anchor is for installations in uncracked concrete only.

[5]The 1/4-inch-diameter (6.4 mm) anchor may be installed in top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in this table.

[6]The 3/8-inch- through 3/4-inch-diameter (9.5 mm through 19.1 mm) anchors may be installed in top of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in this table, and Tables 5A and 5B for the 3/8-inch and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors.

TABLE 2A—CARBON STEEL STRONG-BOLT® 2 ANCHOR TENSION STRENGTH DESIGN DATA[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER										
			Carbon Steel										
			1/4 inch[8]	3/8 inch[9]		1/2 inch[9]		5/8 inch[9]		3/4 inch[9]		1 inch[9]	
Anchor Category	1,2 or 3	-	1									2	
Nominal Embedment Depth	h_{nom}	in. (mm)	1 3/4 (45)	1 7/8 (48)	2 7/8 (73)	2 3/4 (70)	3 7/8 (98)	3 3/8 (86)	5 1/8 (130)	4 1/8 (105)	5 3/4 (146)	5 1/4 (133)	9 3/4 (248)
Steel Strength in Tension (ACI 318-14 Section 17.4.1 or ACI 318-11 Section D.5.1)													
Steel Strength in Tension	N_{sa}	lb (kN)	2,225 (9.9)	5,600 (24.9)		12,100 (53.8)		19,070 (84.8)		29,700 (132.1)		36,815 (163.8)	
Strength Reduction Factor - Steel Failure[2]	ϕ_{sa}	-	0.75									0.65	
Concrete Breakout Strength in Tension (ACI 318-14 Section 17.4.2 or ACI 318-11 Section D.5.2)													
Effective Embedment Depth	h_{ef}	in. (mm)	1 1/2 (38)	1 1/2 (38)	2 1/2 (64)	2 1/4 (57)	3 3/8 (86)	2 3/4 (70)	4 1/2 (114)	3 3/8 (86)	5 (127)	4 1/2 (114)	9 (229)
Critical Edge Distance	c_{ac}	in. (mm)	2 1/2 (64)	6 1/2 (165)	6 (152)	6 1/2 (165)	7 1/2 (191)	7 1/2 (191)	9 (229)	9 (229)	8 (203)	18 (457)	13 1/2 (343)
Effectiveness Factor - Uncracked Concrete	k_{uncr}	-	24	24		24		24		24		24	
Effectiveness Factor - Cracked Concrete	k_{cr}	-	See Note 7	17		17		17		17		17	
Modification Factor	$\psi_{c,N}$	-	See Note 7	1.00		1.00		1.00		1.00		1.00	
Strength Reduction Factor - Concrete Breakout Failure[3]	ϕ_{cb}	-	0.65									0.55	
Pull-Out Strength in Tension (ACI 318-14 17.4.3.1 or ACI 318-11 Section D.5.3)													
Pull-Out Strength Cracked Concrete (f'_c = 2500 psi)	$N_{p,cr}$	lb (kN)	See Note 7 -	1,300[5] (5.8)[5]	2,775[5] (12.3)[5]	N/A[4] -	3,735[5] (16.6)[5]	N/A[4] -	6,895[5] (30.7)[5]	N/A[4] -	8,500[5] (37.8)[5]	7,700[5] (34.3)[5]	11,185[5] (49.8)[5]
Pull-Out Strength Uncracked Concrete (f'_c = 2500 psi)	$N_{p,uncr}$	lb (kN)	N/A[4] -	N/A[4] -	3,340[5] (14.9)[5]	3,615[5] (16.1)[5]	5,255[5] (23.4)[5]	N/A[4] -	9,025[5] (40.1)[5]	7,115[5] (31.6)[5]	8,870[5] (39.5)[5]	8,360[5] (37.2)[5]	9,690[5] (43.1)[5]
Strength Reduction Factor - Pullout Failure[6]	ϕ_p	-	0.65									0.55	
Tensile Strength for Seismic Applications (ACI 318-14 17.2.3.3 or ACI 318-11 Section D.3.3.3)													
Tension Resistance of Single Anchor for Seismic Loads (f'_c = 2500 psi)	$N_{p,eq}$	lb (kN)	See Note 7 -	1,300[5] (5.8)[5]	2,775[5] (12.3)[5]	N/A[4] -	3,735[5] (16.6)[5]	N/A[4] -	6,895[5] (30.7)[5]	N/A[4] -	8,500[5] (37.8)[5]	7,700[5] (34.3)[5]	11,185[5] (49.8)[5]
Strength Reduction Factor - Pullout Failure[6]	ϕ_{eq}	-	0.65									0.55	

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 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable.
[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318-11 D.4.4. The 3/8-inch-, 1/2-inch-, 5/8-inch- and 3/4-inch-diameter carbon steel Strong-Bolt® 2 anchors are ductile steel elements as defined in ACI 318-14 2.3 or ACI 318-11 D.1, as applicable. The 1-inch-diameter carbon steel Strong-Bolt® 2 anchor is a brittle steel element as defined in ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.
[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ_{cb} factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 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 does not need to be considered.
[5]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying the tabular value by $(f'_c$ / 2,500 psi$)^{0.5}$ or $(f'_c$ / 17.2 MPa$)^{0.5}$.
[6]The tabulated value of ϕ_p or ϕ_{eq} applies when the load combinations of IBC Section 1605.2, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable, are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c) for Condition B are met. For installations where complying supplementary reinforcement can be verified, the ϕ_p or ϕ_{eq} factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 Appendix C are used, appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4(c).
[7]The 1/4-inch-diameter carbon steel Strong-Bolt® 2 anchor installation in cracked concrete is beyond the scope of this report.
[8]The 1/4-inch-diameter (6.4 mm) anchor may be installed in top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1A.
[9]The 3/8-inch- through 1-inch-diameter (9.5 mm through 25.4 mm) anchors may be installed in top of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1A, and Tables 5A and 5B for the 3/8-inch and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors.

TABLE 2B—STAINLESS STEEL STRONG-BOLT® 2 ANCHOR TENSION STRENGTH DESIGN DATA[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER – Stainless Steel: 1/4 inch[10]	3/8 inch[11]		1/2 inch[11]		5/8 inch[11]		3/4 inch[11]	
Anchor Category	1,2 or 3	-	1								
Nominal Embedment Depth	h_{nom}	in. (mm)	1-3/4 (45)	1-7/8 (48)	2-7/8 (73)	2-3/4 (70)	3-7/8 (98)	3-3/8 (86)	5-1/8 (130)	4-1/8 (105)	5-3/4 (146)
Steel Strength in Tension (ACI 318-14 17.4.1 or ACI 318-11 Section D.5.1)											
Steel Strength in Tension	N_{sa}	Lb (kN)	3,060 (13.6)	5,140 (22.9)		12,075 (53.7)		17,930 (79.8)		25,650 (114.1)	
Strength Reduction Factor - Steel Failure[2]	ϕ_{sa}	-	0.75								
Concrete Breakout Strength in Tension (ACI 318-14 17.4.2 or ACI 318-11 Section D.5.2)											
Effective Embedment Depth	h_{ef}	in. (mm)	1-1/2 (38)	1-1/2 (38)	2-1/2 (64)	2-1/4 (57)	3-3/8 (86)	2-3/4 (70)	4-1/2 (114)	3-3/8 (86)	5 (127)
Critical Edge Distance	c_{ac}	in. (mm)	2-1/2 (64)	6-1/2 (165)	8-1/2 (216)	4-1/2 (114)	7 (178)	7-1/2 (191)	9 (229)	8 (203)	8 (203)
Effectiveness Factor - Uncracked Concrete	k_{uncr}	-	24	24		24		24		24	
Effectiveness Factor - Cracked Concrete	k_{cr}	-	See Note 9	17		17		17		17	
Modification Factor	$\psi_{c,N}$	-	See Note 9	1.00		1.00		1.00		1.00	
Strength Reduction Factor - Concrete Breakout Failure[3]	ϕ_{cb}	-	0.65								
Pull-Out Strength in Tension (ACI 318-14 17.4.3 or ACI 318-11 Section D.5.3)											
Pull-Out Strength Cracked Concrete (f'_c = 2500 psi)	$N_{p,cr}$	Lb (kN)	See Note 9 -	1,720[6] (7.7)[6]	3,145[6] (14.0)[6]	2,560[5] (11.4)[5]	4,305[5] (19.1)[5]	N/A[4] -	6,545[7] (29.1)[7]	N/A[4] -	8,230[5] (36.6)[5]
Pullout Strength Uncracked Concrete (f'_c = 2500 psi)	$N_{p,uncr}$	Lb (kN)	1,925[7] (8.6)[7]	N/A[4] -	4,770[6] (21.2)[6]	3,230[5] (14.4)[5]	4,495[5] (20.0)[5]	N/A[4] -	7,615[5] (33.9)[5]	7,725[7] (34.4)[7]	9,625[7] (42.8)[7]
Strength Reduction Factor - Pullout Failure[8]	ϕ_p	-	0.65								
Tensile Strength for Seismic Applications (ACI 318 17.2.3.3 or ACI 318-11 Section D.3.3.3)											
Tension Resistance of Single Anchor for Seismic Loads (f'_c = 2500 psi)	$N_{p,eq}$	Lb (kN)	See Note 9 -	1,720[6] (7.7)[6]	2,830[6] (12.6)[6]	2,560[5] (11.4)[5]	4,305[5] (19.1)[5]	N/A[4] -	6,545[7] (29.1)[7]	N/A[4] -	8,230[5] (36.6)[5]
Strength Reduction Factor - Pullout Failure[8]	ϕ_{eq}	-	0.65								

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 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable.

[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318-11 D.4.4. The stainless steel Strong-Bolt® 2 anchors are ductile steel elements as defined in ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.

[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ_{cb} factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 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 does not need to be considered.

[5]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying by $(\frac{f'_c}{2{,}500psi})^{0.5}$ or $(\frac{f'_c}{17.2\,MPa})^{0.5}$.

[6]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying by $(\frac{f'_c}{2{,}500psi})^{0.3}$ or $(\frac{f'_c}{17.2\,MPa})^{0.3}$.

[7]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying by $(\frac{f'_c}{2{,}500psi})^{0.4}$ or $(\frac{f'_c}{17.2\,MPa})^{0.4}$.

[8]The tabulated value of ϕ_p or ϕ_{eq} applies when the load combinations of IBC Section 1605.2.1, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition B are met. For installations where complying supplementary reinforcement can be verified, the ϕ_p or ϕ_{eq} factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 Appendix C are used, appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.4(c).

[9]The 1/4-inch-diameter stainless steel Strong-Bolt® 2 anchor installation in cracked concrete is beyond the scope of this report.

[10]The 1/4-inch-diameter (6.4 mm) anchor may be installed in top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1B.

[11]The 3/8-inch- through 3/4-inch-diameter (9.5 mm through 19.1 mm) anchors may be installed in top of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1B, and Tables 5A and 5B for the 3/8-inch and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors.

TABLE 3A—CARBON STEEL STRONG-BOLT® 2 ANCHOR SHEAR STRENGTH DESIGN DATA[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER										
			Carbon Steel										
			1/4 inch[7]	3/8 inch[8]		1/2 inch[8]		5/8 inch[8]		3/4 inch[8]		1 inch[8]	
Anchor Category	1,2 or 3	-	1									2	
Nominal Embedment Depth	h_{nom}	in.	1 3/4	1 7/8	2 7/8	2 3/4	3 7/8	3 3/8	5 1/8	4 1/8	5 3/4	5 1/4	9 3/4
		(mm)	(45)	(48)	(73)	(70)	(98)	(86)	(130)	(105)	(146)	(133)	(248)
Steel Strength in Shear (ACI 318-14 17.5.1.1 or ACI 318-11 Section D.6.1)													
Shear Resistance of Steel	V_{sa}	Lb	965	1,800		7,235		11,035		14,480		15,020	
		(kN)	(4.3)	(8.0)		(32.2)		(49.1)		(64.4)		(66.8)	
Strength Reduction Factor - Steel Failure[2]	ϕ_{sa}	-	0.65									0.60	
Concrete Breakout Strength in Shear (ACI 318-14 17.5.2 or ACI 318-11 Section D.6.2)													
Outside Diameter	d_a[5]	in.	0.250	0.375		0.500		0.625		0.750		1.000	
		(mm)	(6.4)	(9.5)		(12.7)		(15.9)		(19.1)		(25.4)	
Load Bearing Length of Anchor in Shear	ℓ_e	in.	1.500	1.500	2.500	2.250	3.375	2.750	4.500	3.375	5.000	4.500	8.000
		(mm)	(38)	(38)	(64)	(57)	(86)	(70)	(114)	(86)	(127)	(114)	(203)
Strength Reduction Factor - Concrete Breakout Failure[3]	ϕ_{cb}	-	0.70										
Concrete Pryout Strength in Shear (ACI 318-14 17.5.3 or ACI 318-11 Section D.6.3)													
Coefficient for Pryout Strength	k_{cp}	-	1.0	1.0	2.0	1.0	2.0	2.0		2.0		2.0	
Effective Embedment Depth	h_{ef}	in.	1 1/2	1 1/2	2 1/2	2 1/4	3 3/8	2 3/4	4 1/2	3 3/8	5	4 1/2	9
		(mm)	(38)	(38)	(64)	(57)	(86)	(70)	(114)	(86)	(127)	(114)	(229)
Strength Reduction Factor - Concrete Pryout Failure[4]	ϕ_{cp}	-	0.70										
Steel Strength in Shear for Seismic Applications (ACI 318-14 17.2.3.3 or ACI 318-11 Section D.3.3.3)													
Shear Strength of Single Anchor for Seismic Loads (f'_c = 2500 psi)	$V_{sa,eq}$	Lb	See Note 6	1,800		6,510		9,930		11,775		15,020	
		(kN)	-	(8.0)		(29.0)		(44.2)		(52.4)		(66.8)	
Strength Reduction Factor - Steel Failure[2]	ϕ_{sa}	-	0.65									0.60	

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 318-14 Chapter 17 or ACI 318-11 Appendix D, as applicable.

[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2 are used. If the load combinations of or ACI 318-11 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318-11 D.4.4. The 3/8-inch-, 1/2-inch-, 5/8-inch- and 3/4-inch-diameter carbon steel Strong-Bolt® 2 anchors are ductile steel elements as defined in ACI 318-14 2.3 or ACI 318-11 D.1, as applicable. The 1-inch-diameter carbon steel Strong-Bolt® 2 anchor is a brittle steel element as defined in ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.

[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable, are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c) for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ_{cb} factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ_{cb} must be determined in accordance with ACI 318-11 D.4.4(c).

[4]The tabulated value of ϕ_{cp} applies when the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 9.2 are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c) for Condition B are met. For installations where complying supplementary reinforcement can be verified, the ϕ_{cp} factors described in ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c), as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ_{cp} must be determined in accordance with ACI 318-11 D.4.4(c).

[5]For the 2006 IBC d_o replaces d_a.

[6]The 1/4-inch-diameter carbon steel Strong-Bolt® 2 anchor installation in cracked concrete is beyond the scope of this report.

[7]The 1/4-inch-diameter (6.4 mm) anchor may be installed in the top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1A.

[8]The 3/8-inch- through 1-inch-diameter (9.5 mm through 25.4 mm) anchors may be installed in the top of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1A, and Tables 5A and 5B for the 3/8-inch and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors.

TABLE 3B—STAINLESS STEEL STRONG-BOLT® 2 ANCHOR SHEAR STRENGTH DESIGN DATA[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER								
			Stainless Steel								
			1/4 inch[7]	3/8 inch[8]		1/2 inch[8]		5/8 inch[8]		3/4 inch[8]	
Anchor Category	1,2 or 3	-	1								
Nominal Embedment Depth	h_{nom}	in. (mm)	1 3/4 (45)	1 7/8 (48)	2 7/8 (73)	2 3/4 (70)	3 7/8 (98)	3 3/8 (86)	5 1/8 (130)	4 1/8 (105)	5 3/4 (146)
Steel Strength in Shear (ACI 318-14 17.5.1 or ACI 318-11 Section D.6.1)											
Shear Resistance of Steel	V_{sa}	Lb (kN)	1,605 (7.1)	3,085 (13.7)		7,245 (32.2)		6,745 (30.0)	10,760 (47.9)	15,045 (66.9)	
Strength Reduction Factor - Steel Failure[2]	ϕ_{sa}	-	0.65								
Concrete Breakout Strength in Shear (ACI 318-14 17.5.2 or ACI 318-11 Section D.6.2)											
Outside Diameter	d_a[5]	in. (mm)	0.250 (6.4)	0.375 (9.5)		0.500 (12.7)		0.625 (15.9)		0.750 (19.1)	
Load Bearing Length of Anchor in Shear	ℓ_e	in. (mm)	1.500 (38)	1.500 (38)	2.500 (64)	2.250 (57)	3.375 (86)	2.750 (70)	4.500 (114)	3.375 (86)	5.000 (127)
Strength Reduction Factor - Concrete Breakout Failure[3]	ϕ_{cb}	-	0.70								
Concrete Pryout Strength in Shear (ACI 318-14 17.5.2 or ACI 318-11 Section D.6.3)											
Coefficient for Pryout Strength	k_{cp}	-	1.0	1.0	2.0	1.0	2.0	2.0		2.0	
Effective Embedment Depth	h_{ef}	in. (mm)	1 1/2 (38)	1 1/2 (38)	2 1/2 (64)	2 1/4 (57)	3 3/8 (86)	2 3/4 (70)	4 1/2 (114)	3 3/8 (86)	5 (127)
Strength Reduction Factor - Concrete Pryout Failure[4]	ϕ_{cp}	-	0.70								
Steel Strength in Shear for Seismic Applications (ACI 318-14 17.2.3.3 or ACI 318-11 Section D.3.3.3)											
Shear Strength of Single Anchor for Seismic Loads (f'_c = 2500 psi)	$V_{sa,eq}$	Lb (kN)	See Note 6 -	3,085 (13.7)		6,100 (27.1)		6,745 (30.0)	10,760 (47.9)	13,620 (60.6)	
Strength Reduction Factor - Steel Failure[2]	ϕ_{sa}	-	0.65								

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 318-14 Chapter 17 or ACI 318-11 Appendix D.

[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable, are used. If the load combinations of or ACI 318-11 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318-11 D.4.4. The stainless steel Strong-Bolt® 2 anchors are ductile steel elements as defined in ACI 318-14 2.3 or ACI 318-11 D.1, as applicable.

[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2 of the IBC, ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable, are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c) for Condition B are met. Condition B applies where supplementary reinforcement is not provided. For installations where complying supplementary reinforcement can be verified, the ϕ_{cb} factors described in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ_{cb} must be determined in accordance with ACI 318-11 D.4.4(c).

[4]The tabulated value of ϕ_{cp} applies when the load combinations of IBC Section 1605.2, ACI 318-14 5.3 or ACI 318-11 9.2, as applicable, are used and the requirements of ACI 318-14 17.3.3(c) or ACI 318-11 D.4.3(c) for Condition B are met. For installations where complying supplementary reinforcement can be verified, the ϕ_{cp} factors described in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable, for Condition A are allowed. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ_{cp} must be determined in accordance with ACI 318-11 D.4.4(c).

[5]For the 2006 IBC d_o replaces d_a.

[6]The 1/4-inch-diameter stainless steel Strong-Bolt® 2 anchor installation in cracked concrete is beyond the scope of this report.

[7]The 1/4-inch-diameter (6.4 mm) anchor may be installed in the top of uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1B.

[8]The 3/8-inch- through 3/4-inch-diameter (9.5 mm through 19.1 mm) anchors may be installed in the top of cracked and uncracked normal-weight and sand-lightweight concrete over profile steel deck where concrete thickness above upper flute meets the minimum thicknesses specified in Table 1B, and Tables 5A and 5B for the 3/8-inch and 1/2-inch-diameter (9.5 mm and 12.7 mm) anchors.

TABLE 4A—CARBON STEEL STRONG-BOLT® 2 ANCHOR TENSION AND SHEAR STRENGTH DESIGN DATA FOR THE SOFFIT OF CONCRETE OVER PROFILE STEEL DECK, FLOOR AND ROOF ASSEMBLIES[1,2,6,8]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER								
			Lower Flute							Upper Flute	
			$^3/_8$ inch		$^1/_2$ inch		$^5/_8$ inch		$^3/_4$ inch	$^3/_8$ inch	$^1/_2$ inch
Nominal Embedment Depth	h_{nom}	in. (mm)	2 (51)	$3^3/_8$ (86)	$2^3/_4$ (70)	$4^1/_2$ (114)	$3^3/_8$ (86)	$5^5/_8$ (143)	$4^1/_8$ (105)	2 (51)	$2^3/_4$ (70)
Effective Embedment Depth	h_{ef}	in. (mm)	$1^5/_8$ (41)	3 (76)	$2^1/_4$ (57)	4 (102)	$2^3/_4$ (70)	5 (127)	$3^3/_8$ (86)	$1^5/_8$ (41)	$2^1/_4$ (57)
Minimum Hole Depth	h_{hole}	in. (mm)	$2^1/_8$ (54)	$3^1/_2$ (89)	3 (76)	$4^3/_4$ (121)	$3^5/_8$ (92)	$5^7/_8$ (149)	$4^3/_8$ (111)	$2^1/_8$ (54)	3 (76)
Installation Torque	T_{inst}	ft-lbf (N-m)	30 (40.7)		60 (81.3)		90 (122.0)		150 (203.4)	30 (40.7)	60 (81.3)
Pullout Strength, concrete on metal deck (cracked)[3]	$N_{p,deck,cr}$	Lb (kN)	1,040[7] (4.6)[7]	2,615[7] (11.6)[7]	2,040[7] (9.1)[7]	2,730[7] (12.1)[7]	2,615[7] (11.6)[7]	4,990[7] (22.2)[7]	2,815[7] (12.5)[7]	1,340[7] (6.0)[7]	3,785[7] (16.8)[7]
Pullout Strength, concrete on metal deck (uncracked)[3]	$N_{p,deck,uncr}$	Lb (kN)	1,765[7] (7.9)[7]	3,150[7] (14.0)[7]	2,580[7] (11.5)[7]	3,840[7] (17.1)[7]	3,685[7] (16.4)[7]	6,565[7] (29.2)[7]	3,800[7] (16.9)[7]	2,275[7] (10.1)[7]	4,795[7] (21.3)[7]
Pullout Strength, concrete on metal deck (Seismic)[5]	$N_{p,deck,eq}$	Lb (kN)	1,040[7] (4.6)[7]	2,615[7] (11.6)[7]	2,040[7] (9.1)[7]	2,730[7] (12.1)[7]	2,615[7] (11.6)[7]	4,990[7] (22.2)[7]	2,815[7] (12.5)[7]	1,340[7] (6.0)[7]	3,785[7] (16.8)[7]
Steel Strength in Shear, concrete on metal deck[4]	$V_{sa.deck}$	Lb (kN)	1,595 (7.1)	3,490 (15.5)	2,135 (9.5)	4,580 (20.4)	2,640 (11.7)	7,000 (31.1)	4,535 (20.2)	3,545 (15.8)	5,920 (26.3)
Steel Strength in Shear, concrete on metal deck (Seismic)[5]	$V_{sa,deck,eq}$	Lb (kN)	1,595 (7.1)	3,490 (15.5)	1.920 (8.5)	4,120 (18.3)	2,375 (10.6)	6,300 (28.0)	3,690 (16.4)	3,545 (15.8)	5,330 (23.7)

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

[1]Installation must comply with Section 4.3 and Figure 4.
[2]Profile steel deck must comply with Figure 4 and Section 3.3 of this report.
[3]The values must be used in accordance with Section 4.1.4 of this report.
[4]The values must be used in accordance with Section 4.1.5 of this report.
[5]The values must be used in accordance with Section 4.1.8 of this report.
[6]The minimum anchor spacing along the flute must be the greater of $3h_{ef}$ or 1.5 times the flute width.
[7]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying the tabular value by $(f'_c / 3{,}000\text{psi})^{0.5}$ or $(f'_c / 20.7\text{MPa})^{0.5}$.
[8]Concrete shall be normal-weight or sand-lightweight concrete having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa).

TABLE 4B—STAINLESS STEEL STRONG-BOLT® 2 ANCHOR TENSION AND SHEAR STRENGTH DESIGN DATA FOR THE SOFFIT OF CONCRETE OVER PROFILE STEEL DECK, FLOOR AND ROOF ASSEMBLIES[1,2,6,10]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER								
			Lower Flute							Upper Flute	
			3/8 inch		1/2 inch		5/8 inch		3/4 inch	3/8 inch	1/2 inch
Nominal Embedment Depth	h_{nom}	in.	2	3 3/8	2 3/4	4 1/2	3 3/8	5 5/8	4 1/8	2	2 3/4
		(mm)	(51)	(86)	(70)	(114)	(86)	(143)	(105)	(51)	(70)
Effective Embedment Depth	h_{ef}	in.	1 5/8	3	2 1/4	4	2 3/4	5	3 3/8	1 5/8	2 1/4
		(mm)	(41)	(76)	(57)	(102)	(70)	(127)	(86)	(41)	(57)
Minimum Hole Depth	h_{hole}	in.	2 1/8	3 1/2	3	4 3/4	3 5/8	5 7/8	4 3/8	2 1/8	3
		(mm)	(54)	(89)	(76)	(121)	(92)	(149)	(111)	(54)	(76)
Installation Torque	T_{inst}	ft-lbf	30		60		80		150	30	60
		(N-m)	(40.7)		(81.3)		(108.5)		(203.4)	(40.7)	(81.3)
Pullout Strength, concrete on metal deck (cracked)[3]	$N_{p,deck,cr}$	Lb	1,230[8]	2,605[8]	1,990[7]	2,550[7]	1,750[9]	4,020[9]	3,030[7]	1,550[8]	2,055[7]
		(kN)	(5.5)[8]	(11.6)[8]	(8.9)[7]	(11.3)[7]	(7.8)[9]	(17.9)[9]	(13.5)[7]	(6.9)[8]	(9.1)[7]
Pullout Strength, concrete on metal deck (uncracked)[3]	$N_{p,deck,uncr}$	Lb	1,580[8]	3,950[8]	2,475[7]	2,660[7]	2,470[7]	5,000[7]	4,275[9]	1,990[8]	2,560[7]
		(kN)	(7.0)[8]	(17.6)[8]	(11.0)[7]	(11.8)[7]	(11.0)[7]	(22.2)[7]	(19.0)[9]	(8.9)[8]	(11.4)[7]
Pullout Strength, concrete on metal deck (seismic)[5]	$N_{p,deck,eq}$	Lb	1,230[8]	2,345[8]	1,990[7]	2,550[7]	1,750[9]	4,020[9]	3,030[7]	1,550[8]	2,055[7]
		(kN)	(5.5)[8]	(10.4)[8]	(8.9)[7]	(11.3)[7]	(7.8)[9]	(17.9)[9]	(13.5)[7]	(6.9)[8]	(9.1)[7]
Steel Strength in Shear, concrete on metal deck[4]	$V_{sa.deck}$	lb	2,285	3,085	3,430	4,680	3,235	5,430	6,135	3,085	5,955
		(kN)	(10.2)	(13.7)	(15.3)	(20.8)	(14.4)	(24.2)	(27.3)	(13.7)	(26.5)
Steel Strength in Shear, concrete on metal deck (seismic)[5]	$V_{sa.deck,eq}$	Lb	2,285	3,085	2,400	3,275	3,235	5,430	5,520	3,085	4,170
		(kN)	(10.2)	(13.7)	(10.7)	(14.6)	(14.4)	(24.2)	(24.6)	(13.7)	(18.5)

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

[1]Installation must comply with Section 4.3 and Figure 4.
[2]Profile steel deck must comply with Figure 4 and Section 3.3 of this report.
[3]The values must be used in accordance with Section 4.1.4 of this report.
[4]The values must be used in accordance with Section 4.1.5 of this report.
[5]The values must be used in accordance with Section 4.1.8 of this report.
[6]The minimum anchor spacing along the flute must be the greater of $3h_{ef}$ or 1.5 times the flute width.
[7]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying the tabular value by $(f'_c / 3{,}000 \text{ psi})^{0.5}$ or $(f'_c / 20.7\text{MPa})^{0.5}$.
[8]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying the tabular value by $(f'_c / 3{,}000\text{psi})^{0.3}$ or $(f'_c / 20.7\text{MPa})^{0.3}$.
[9]The characteristic pull-out strength for greater concrete compressive strengths must be increased by multiplying the tabular value by $(f'_c / 3{,}000 \text{ psi})^{0.4}$ or $(f'_c / 20.7\text{MPa})^{0.4}$.
[10]Concrete shall be normal-weight or sand-lightweight concrete having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa).

TABLE 5A—CARBON STEEL STRONG-BOLT® 2 ANCHOR INSTALLATION INFORMATION IN THE TOPSIDE OF CONCRETE-FILLED PROFILE STEEL DECK FLOOR AND ROOF ASSEMBLIES[1,2,3,4]

Design Information	Symbol	Units	Nominal Anchor Diameter (inch)		
			$^{3}/_{8}$		$^{1}/_{2}$
Nominal Embedment Depth	h_{nom}	in.	$1^{7}/_{8}$	$1^{7}/_{8}$	$2\ ^{3}/_{4}$
Effective Embedment Depth	h_{ef}	in.	$1^{1}/_{2}$	$1^{1}/_{2}$	$2^{1}/_{4}$
Minimum Concrete Thickness[5]	$h_{min,deck}$	in.	$2^{1}/_{2}$	$3^{1}/_{4}$	$3^{1}/_{4}$
Critical Edge Distance	$c_{ac,deck,top}$	in.	$4^{3}/_{4}$	4	4
Minimum Edge Distance	$c_{min,deck,top}$	in.	$4^{3}/_{4}$	$4^{1}/_{2}$	$4^{3}/_{4}$
Minimum Spacing	$s_{min,deck,top}$	in.	7	$6^{1}/_{2}$	8

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

[1]Installation must comply with Sections 4.1.6, 4.1.11 and 4.3 and Figure 5 of this report.
[2]Design capacity shall be based on calculations according to values in Tables 2A and 3A of this report.
[3]Minimum flute depth (distance from top of flute to bottom of flute) is 1 ½-inch, see Figure 5.
[4]Steel deck thickness shall be minimum 20 gauge.
[5]Minimum concrete thickness ($h_{min,deck}$) refers to concrete thickness above upper flute, see Figure 5.

TABLE 5B—STAINLESS STEEL STRONG-BOLT® 2 ANCHOR INSTALLATION INFORMATION IN THE TOPSIDE OF CONCRETE-FILLED PROFILE STEEL DECK FLOOR AND ROOF ASSEMBLIES[1,2,3,4]

Design Information	Symbol	Units	Nominal Anchor Diameter (inch)		
			$^{3}/_{8}$		$^{1}/_{2}$
Nominal Embedment Depth	h_{nom}	in.	$1^{7}/_{8}$	$1^{7}/_{8}$	$2\ ^{3}/_{4}$
Effective Embedment Depth	h_{ef}	in.	$1^{1}/_{2}$	$1^{1}/_{2}$	$2^{1}/_{4}$
Minimum Concrete Thickness[5]	$h_{min,deck}$	in.	$2^{1}/_{2}$	$3^{1}/_{4}$	$3^{1}/_{4}$
Critical Edge Distance	$c_{ac,deck,top}$	in.	$4^{3}/_{4}$	4	4
Minimum Edge Distance	$c_{min,deck,top}$	in.	$4^{3}/_{4}$	$4^{3}/_{4}$	6
Minimum Spacing	$s_{min,deck,top}$	in.	$6^{1}/_{2}$	$6^{1}/_{2}$	8

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

[1]Installation must comply with Sections 4.1.6, 4.1.11 and 4.3 and Figure 5 of this report.
[2]Design capacity shall be based on calculations according to values in Tables 2B and 3B of this report.
[3] Minimum flute depth (distance from top of flute to bottom of flute) is 1½ inch, see Figure 5.
[4]Steel deck thickness shall be minimum 20 gauge.
[5]Minimum concrete thickness ($h_{min,deck}$) refers to concrete thickness above upper flute, see Figure 5.

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

Nominal Anchor Diameter (in.)	Nominal Embedment Depth, h_{nom} (in.)	Effective Embedment Depth, h_{ef} (in.)	Allowable Tension Load, $T_{allowable}$ (lbs.)
Carbon Steel			
1/4	1 3/4	1 1/2	970
3/8	1 7/8	1 1/2	970
	2 7/8	2 1/2	1,465
1/2	2 3/4	2 1/4	1,585
	3 7/8	3 3/8	2,305*
5/8	3 3/8	2 3/4	2,400
	5 1/8	4 1/2	3,965
3/4	4 1/8	3 3/8	3,125
	5 3/4	5	3,895
1	5 1/4	4 1/2	3,110
	9 3/4	9	3,600
Stainless Steel			
1/4	1 3/4	1 1/2	845
3/8	1 7/8	1 1/2	970
	2 7/8	2 1/2	2,080
1/2	2 3/4	2 1/4	1,420
	3 7/8	3 3/8	1,975
5/8	3 3/8	2 3/4	2,405
	5 1/8	4 1/2	3,345
3/4	4 1/8	3 3/8	3,270
	5 3/4	5	4,225

Design Assumptions:

1. Single Anchor.
2. Tension load only.
3. Concrete determined to remain uncracked for the life of the anchorage.
4. Load combinations taken from ACI 318-14 Section 5.3 or ACI 318-11 Section 9.2, as applicable (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 a based on weighted average: α = 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. Concrete thickness, $h \geq h_{min}$
9. Values are for Condition B (supplementary reinforcement in accordance with ACI 318-14 17.3.3 or ACI 318-11 D.4.3 is not provided.)

*Illustrative Procedure (reference Table 2A of this report for design data):

Strong-Bolt® 2 carbon steel: 1/2-inch diameter anchor with an effective embedment depth, h_{ef} = 3 3/8".

Step 1: Calculate steel strength in tension in accordance with ACI 318-14 17.4.1 or ACI 318-11 D.5.1, as applicable;

$\phi_{sa}N_{sa}$ = 0.75 x 12,100 = 9,075 lbs.

Step 2: Calculate concrete breakout strength in tension in accordance with ACI 318-14 17.4.1.1 or ACI 318-11 D.5.2, as applicable;

$\phi_{cb}N_{cb}$ = 0.65 x 7,440 = 4,836 lbs.

Step 3: Calculate pullout strength in tension in accordance with ACI 318-14 17.4.1.1 or ACI 318-11 D.5.3, as applicable;

$\phi_{p}N_{p,uncr}$ = 0.65 x 5,255 = 3,416 lbs.

Step 4: The controlling value from Steps 1, 2, and 3 above in accordance with ACI 318-14 17.3.1.2 or ACI 318-11 D.4.1.2, as applicable;

ϕN_n = 3,416 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;

$T_{allowable,ASD} = \phi N_n/\alpha$ = 3,416 / 1.48 = 2,305 lbs.

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

TABLE 7—LENGTH IDENTIFICATION HEAD MARKS ON STRONG-BOLT® 2 ANCHORS (CORRESPONDS TO LENGTH OF ANCHOR – INCHES)

Mark	Units	A	B	C	D	E	F	G	H	I	J	K	L	M
From	in	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2
Up To But Not Including	in	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	8

Mark	Units	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
From	in	8	8 1/2	9	9 1/2	10	11	12	13	14	15	16	17	18
Up To But Not Including	in	8 1/2	9	9 1/2	10	11	12	13	14	15	16	17	18	19

FIGURE 1—STRONG-BOLT® 2 WEDGE ANCHOR (CARBON STEEL VERSION)

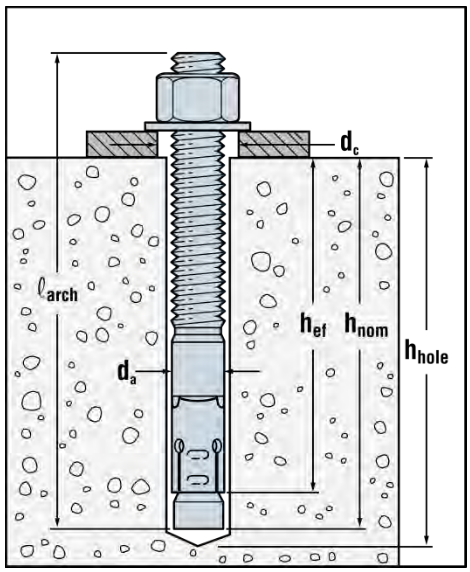


FIGURE 2—STRONG-BOLT® 2 WEDGE ANCHOR INSTALLATION

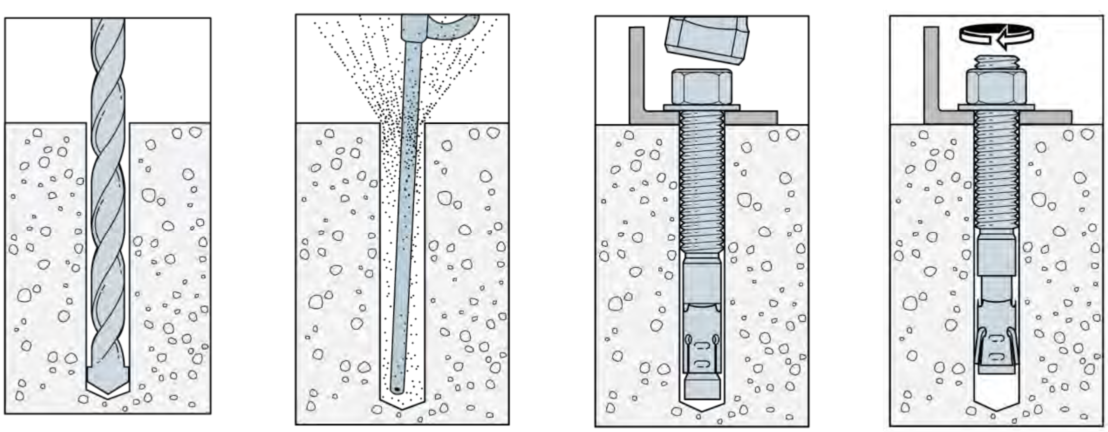


FIGURE 3—STRONG-BOLT® 2 WEDGE ANCHOR INSTALLATION SEQUENCE

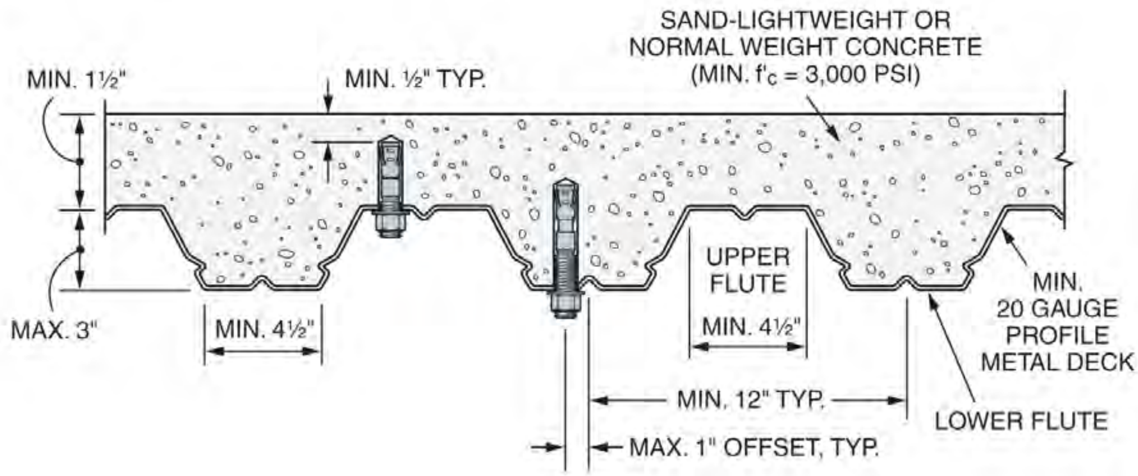


FIGURE 4—INSTALLATION IN THE SOFFIT OF CONCRETE OVER PROFILE STEEL DECK FLOOR AND ROOF ASSEMBLIES[1]

[1]Anchors may be placed in the upper flute or lower flute of the steel deck assembly provided a minimum $^1/_2$-inch concrete cover beyond the end of the anchor is provided. Anchors in the lower flute of Figure 4 may be installed with a maximum1-inch offset in either direction from the centerline of the flute.

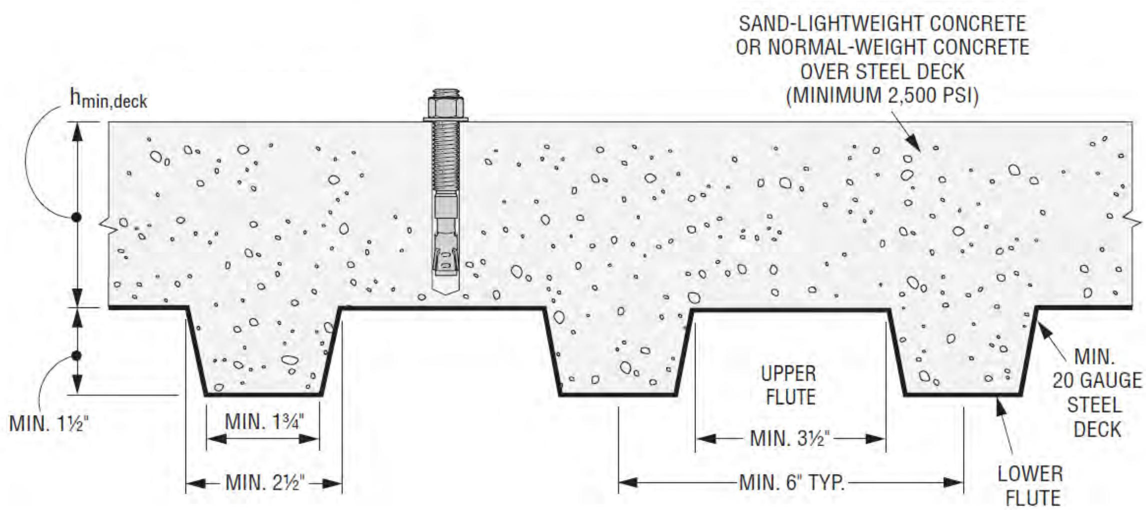


FIGURE 5—INSTALLATION ON THE TOP OF CONCRETE-FILLED PROFILE STEEL DECK FLOOR AND ROOF ASSEMBLIES

(1 in = 25.4 mm)

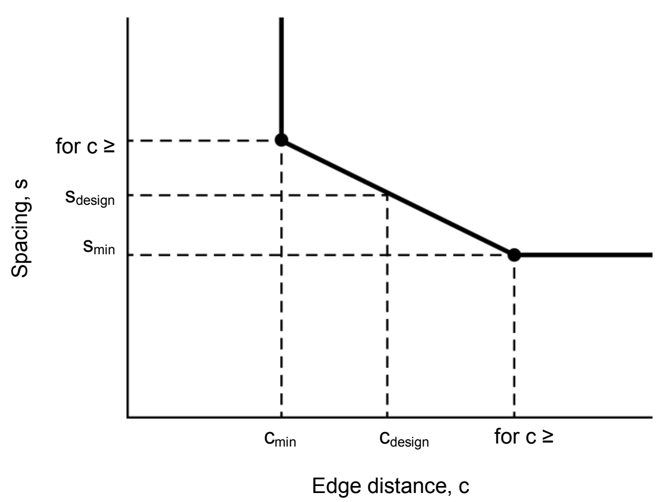
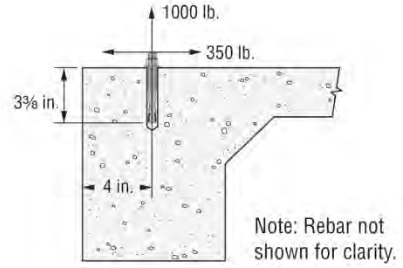


FIGURE 6—INTERPOLATION OF MINIMUM EDGE DISTANCE AND ANCHOR SPACING[1]

[1]Interpolation only valid for $^3/_4$- inch diameter carbon steel and $^3/_8$-, $^1/_2$- and $^5/_8$-inch-diameter stainless-steel anchors. Spacing and edge distance combinations must fall on or above and to the right of the diagonal line.

Determine if a single ½ inch diameter carbon steel Strong-Bolt® 2 torque-controlled expansion anchor with a minimum 3⅞ inch embedment (h_{ef} = 3⅜ 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	
$N_{sa} = 12{,}100$		Table 2A
$\phi = 0.75$		Table 2A
$n = 1$ (single anchor)		
Calculating for ϕN_{sa}:		
$\phi N_{sa} = 0.75 \times 1 \times 12{,}100 = 9{,}075$ 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 2A
λ = 1.0 for normal-weight concrete	8.6.1	
$\Psi_{cp,N} = 1.0$	D.5.2.7	
$\Psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,min}}{1.5h_{ef}}$ when $c_{a,min} < 1.5\,h_{ef}$	Eq. (D-11)	
by observation, $c_{a,min} = 4 < 1.5h_{ef}$		
$\Psi_{ed,N} = 0.7 + 0.3 \frac{(4)}{1.5(3.375)} = 0.94$		
$\Psi_{c,N}$ = 1.0 assuming cracking at service loads ($f_t > f_r$)	D.5.2.6	
ϕ = 0.65 for Condition B (no supplementary reinforcement provided)		Table 2A
$A_{Nco} = 9h_{ef}^2 = 9(3.375)^2 = 102.52$ in.^{2}	Eq. (D-6)	
$A_{Nc} = (c_{a1} + 1.5h_{ef})(2 \times 1.5h_{ef}) = (4 + 1.5(3.375))(2 \times 1.5(3.375)) = 91.76$ in.^{2}	Fig. RD.5.2.1(a)	
$\frac{A_{Nc}}{A_{Nco}} = \frac{91.76}{102.52} = 0.90$		
Calculating for ϕN_{cb}:		
$\phi N_{cb} = 0.65 \times 0.90 \times 0.94 \times 1.0 \times 1.0 \times 17 \times 1.0 \times \sqrt{3{,}000} \times (3.375)^{1.5} = 3{,}175$ lb.		

	ACI 318-08 Code Ref.	Report Ref.
4. Pullout Capacity:	D.5.3	
$N_{pn,cr} = 3{,}735 \times \left(\frac{3{,}000}{2{,}500}\right)^{0.5} = 4{,}091$ lb.		Table 2A
$\phi = 0.65$		Table 2A
$\phi N_{pn} = 0.65 \times 4{,}091 = 2{,}659$		
5. Check All Failure Modes under Tension Loading:	D.4.1.2	
Summary:		
Steel Capacity = 9,075 lb.		
Concrete Breakout Capacity = 3,175 lb.		
Pullout Capacity = 2,659 lb. ← **Controls**		
∴ **ϕN_n = 2,659 lb. as Pullout Capacity controls > N_{ua} = 1,600 lb. – OK**		
6. Steel Capacity under Shear Loading:	D.6.1	
$V_{sa} = 7{,}235$ lb.		Table 3A
$\phi = 0.65$		Table 3A
Calculating for ϕV_{sa}:		
$\phi V_{sa} = 0.65 \times 7{,}235 = 4{,}703$ 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:		
$\phi V_{cb} = \phi \frac{A_{Vc}}{A_{Vco}} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} 7\left(\frac{\ell_e}{d_a}\right)^{0.2} \sqrt{d_a} \lambda \sqrt{f'_c} c_{a1}^{1.5}$		
where:		
ϕ = 0.70 for Condition B (no supplementary reinforcement provided)		Table 3A
$A_{Vco} = 4.5c_{a1}^2 = 4.5(4)^2 = 72$ 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.		
ℓ_e = 3.375 in.	D.6.2.2	
λ = 1.0 for normal-weight concrete	8.6.1	
c_{a1} = 4 in.		
$\phi V_{cb} = 0.70 \times 1 \times 1.0 \times 1.0 \times 1.0 \times 7 \times \left(\frac{3.375}{0.5}\right)^{0.2} \times \sqrt{0.5} \times 1.0 \times \sqrt{3{,}000} \times (4)^{1.5} = 2{,}224$ lb.		

FIGURE 7—STRONG-BOLT® 2 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 3A*
$k_{cp} = 2.0$	*D.6.3.1*	
$k_{cp} N_{cb} = 2.0 \times \frac{3{,}175}{0.65} = 9{,}769$ lb.	*D.6.3.1*	
$\phi n V_{cp} = 0.70 \times 1 \times 9{,}769 = 6{,}838$ lb.		
9. Check All Failure Modes under Shear Loading:	*D.4.1.2*	
Summary:		
Steel Capacity = 4,703 lb.		
Concrete Breakout Capacity = 2,224 lb. ← **Controls**		
Pryout Capacity = 6,838 lb.		
∴ **ϕV_n = 2,224 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)*	
$\frac{1{,}600}{2{,}659} + \frac{560}{2{,}224} = 0.60 + 0.25 = 0.85 < 1.2$ – OK		

11. Summary

A single ½ in. diameter carbon steel Strong-Bolt® 2 anchor at a 3⅞ in. embedment depth is adequate to resist the applied service tension and shear loads of 1,000 lb. and 350 lb., respectively.

FIGURE 7—STRONG-BOLT® 2 ANCHOR EXAMPLE CALCULATION (Continued)