ICC-ES Evaluation Report

ESR-2502

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DIVISION: 03—CONCRETE
Section: 03151—Concrete Anchoring

REPORT HOLDER:

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EVALUATION SUBJECT:

POWERS POWER-STUD+® SD2 ANCHORS IN CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2009 *International Building Code®* (2009 IBC)
- 2009 *International Residential Code®* (2009 IRC)
- 2006 *International Building Code®* (2006 IBC)
- 2006 *International Residential Code®* (2006 IRC)
- 2003 *International Building Code®* (2003 IBC)
- 2003 *International Residential Code®* (2003 IRC)
- 1997 *Uniform Building Code™* (UBC)

Property evaluated:

Structural

2.0 USES

The Powers Power-Stud+ SD2 anchor is used to resist static, wind and seismic tension and shear loads in cracked and uncracked normal-weight and structural 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); and cracked and uncracked normal-weight or structural sand-lightweight concrete over steel deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa). The anchoring system complies with anchors installed in hardened concrete as described in Section 1912 of the 2009 and 2006 IBC and Section 1913 of the 2003 IBC. The anchoring system is an alternative to cast-in-place anchors described in Section 1911 of the 2009 and 2006 IBC, Section 1912 of the 2003 IBC and Sections 1923.1 and 1923.2 of the UBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the 2009, 2006 and 2003 IRC.

3.0 DESCRIPTION

3.1 Power-Stud+ SD2:

Power-Stud+ SD2 anchors are torque-controlled, mechanical expansion anchors comprised of an anchor body, expansion wedge (clip), washer and hex nut. The anchor body is manufactured from medium carbon steel and has minimum 0.0002-inch (5 μm) zinc plating in accordance with ASTM B 633. The expansion clip is manufactured from AISI Type 316 stainless steel. The washer conforms to ASTM F 844. The hex nuts conform to ASTM A 563, Grade A. The Power-Stud+ SD2 anchor is illustrated in Figure 2.

The anchor body is comprised of a high-strength rod threaded at one end and having a tapered mandrel at the other end. The tapered mandrel is enclosed by a three-section expansion clip which freely moves around the mandrel. The expansion clip movement is restrained by the mandrel taper and by a collar. The anchors are installed in a predrilled hole with a hammer. When torque is applied to the nut of the installed anchor on the threaded end of the anchor body, the mandrel at the other end of the anchor is drawn into the expansion clip, forcing it outward into the sides of the predrilled hole in the base material.

Installation instructions and information are set forth in Section 4.3, Table 1 and Figure 1, and Figures 3 and 4.

3.2 Concrete:

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

3.3 Steel Deck Panels:

Steel deck panels must comply with the configurations in Figure 4 and have a minimum base-metal thickness of 0.035 inch (0.899 mm) [20 gage]. Steel deck must comply with the requirements of ASTM A 653/A 653M SS Grade 36, and have a minimum yield strength of 36 ksi (248 MPa).

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

Design strength of anchors complying with the 2009 and 2003 IBC and 1997 UBC as well as Section 301.1.3 of the 2009 and 2003 IRC must be determined in accordance with ACI 318-08 Appendix D and this report.

Design strength of anchors complying with the 2006 IBC and Section 301.1.3 of 2006 IRC must be in accordance with ACI 318-05 Appendix D and this report.

Design examples according to the 2009 IBC are given in Figures 6 through 8 of this report. Design parameters are based on the 2009 IBC (ACI 318-08) unless noted otherwise in Section 4.1.1 through 4.1.11 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.

Strength reduction factors, ϕ, as given in ACI 318 D.4.4 must be used for load combinations calculated in accordance with Section 1605.2.1 of the IBC and Section 9.2 of ACI 318 or Section 1612.2 of the UBC. Strength reduction factors, ϕ, as given in ACI 318 D.4.5 must be used for load combinations calculated in accordance with ACI 318 Appendix C or Section 1909.2 of the UBC.

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 D.3.5.

Design parameters are provided in Tables 3 and 4 of this report. Strength reduction factors, ϕ, corresponding to ductile steel elements may be used except for $^3/_8$-inch-diameter (9.5 mm) anchors in shear, which have a strength reduction factor corresponding to brittle steel elements.

4.1.1 Requirements for Static Steel Strength in Tension, N_{sa}: The nominal steel strength of a single anchor in tension, N_{sa}, is given in Table 3 of this report. The values of N_{sa} for single anchors given in Table 3 must be used and not be derived by calculation.

4.1.2 Requirements for Static Concrete Breakout Strength in Tension, N_{cb} or N_{cbg}: 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, N_b, must be calculated according to ACI 318 D.5.2, using the values of h_{ef} and k_{cr} as given in Table 3 of this report. The nominal concrete breakout strength in tension in regions where analysis indicates no cracking in accordance with ACI 318 D.5.2.6 must be calculated, with $\psi_{c,N}$ = 1.0 and using the value of k_{uncr} as given in Table 3.

For anchors installed in the soffit of structural sand-lightweight or normal-weight concrete filled steel deck floor and roof assemblies, as shown in Figure 4, calculation of the concrete breakout strength in accordance with ACI 318 D.5.2 is not required.

4.1.3 Requirements for Static Pullout Strength in Tension, N_{pn}: 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 3 of this report. For all design cases, $\psi_{c,P}$ = 1.0. In accordance with ACI 318 D.5.3.2, the nominal pullout strength in cracked concrete must be adjusted by calculation according to Eq-1:

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

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

where f'_c is the specified concrete compressive strength and whereby the exponent $n = {}^1/_2$ for all anchor diameters with the exception of the $^3/_8$-inch-diameter (9.5 mm) anchor size, where $n = {}^1/_3$.

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

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

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

where f'_c is the specified concrete compressive strength and whereby the exponent $n = {}^1/_2$ for all anchors.

Where values for $N_{p,cr}$ or $N_{p,uncr}$ are not provided in Table 3, the pullout strength in tension need not be evaluated.

The nominal pullout strength in tension of the anchors installed in the soffit of structural sand-lightweight or normal-weight concrete filled steel deck floor and roof assemblies, as shown in Figure 4, is provided in Table 3. In accordance with ACI 318 D.5.3.2, the nominal pullout strength in cracked concrete must be calculated according to Eq-1, whereby the value of $N_{p,deck,cr}$ must be substituted for $N_{p,cr}$ and the values of 3,000 psi or 20.7 MPa must substitute for 2,500 psi or 17.2 MPa in the denominator. In regions where analysis indicates no cracking in accordance with ACI 318 5.3.6, the nominal strength in uncracked concrete must be calculated according to Eq-2, whereby the value of $N_{p,deck,uncr}$ must be substituted for $N_{p,uncr}$ and the values of 3,000 psi or 20.7 MPa must substitute for 2,500 psi or 17.2 MPa in the denominator.

4.1.4 Requirements for Static Steel Shear Capacity, V_{sa}: 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 4 of this report and must be used in lieu of the values derived by calculation from ACI 318, Eq. D-20. The shear strength $V_{sa,deck}$ of anchors installed in the soffit of structural sand-lightweight or normal weight concrete filled steel deck floor and roof assemblies, as shown in Figure 4, is given in Table 4.

4.1.5 Requirements for Static Concrete Breakout Strength in Shear, V_{cb} or V_{cbg}: 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 D.6.2, with modifications as described in this section. The basic concrete breakout strength of a single anchor in shear, V_b, must be calculated in accordance with ACI 318 D.6.2.2 using the value of ℓ_e and d_a (d_o) given in Table 4.

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

4.1.6 Requirements for Static Concrete Pryout Strength in Shear, V_{cp} or V_{cpg}: The nominal concrete pryout strength, V_{cp} or V_{cpg}, must be calculated in accordance with ACI 318 D.6.3, modified by using the value of k_{cp} provided in Table 4 and the value of N_{cb} or N_{cbg} as calculated in accordance with Section 4.1.2 of this report.

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

4.1.7 Requirements for Seismic Design:

4.1.7.1 General: For load combinations including seismic, the design must be performed according to ACI 318 D.3.3, as modified by Section 1908.1.9 of the 2009 IBC, 1908.1.16 of the 2006 IBC or the following:

CODE	ACI 318 SECTION 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
UBC	Moderate or high seismic risk	Seismic Zones 2B, 3 and 4

The nominal steel strength and nominal concrete breakout strength for anchors in tension, and the nominal concrete breakout strength and pryout strength for anchors in shear, must be calculated according to ACI 318 D.5 and D.6, respectively, taking into account the corresponding values in Tables 3 and 4 of this report. The anchors comply with ACI 318 D.1 as ductile steel elements and must be designed in accordance with 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, except for $^{3}/_{8}$-inch-diameter (9.5 mm) anchors in shear, which comply with ACI 318 D.1 as brittle steel elements and must be designed in accordance with ACI 318 D.3.3.5 or D.3.3.6.

4.1.7.2 Seismic Tension: The nominal steel strength and nominal concrete breakout strength for anchors in tension must be calculated according to ACI 318 D.5.1 and D.5.2, as described in Sections 4.1.1 and 4.1.2 of this report and in accordance with ACI 318 D.5.3.2. The appropriate value for pullout strength in tension for seismic loads, N_{eq} or $N_{p,deck,cr}$, described in Table 3 of this report, must be used in lieu of N_p. The values of N_{eq} or $N_{p,deck,cr}$ can be adjusted for concrete strength as follows:

$$N_{eq,f'c} = N_{eq}\left(\frac{f'_c}{2,500}\right)^n \text{ (lb, psi)} \qquad \text{(Eq-3)}$$

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

where f'_c is the specified concrete compressive strength and whereby the exponent $n = {}^{1}/_{2}$ for all anchor diameters with the exception of the $^{3}/_{8}$-inch-diameter (9.5 mm) anchor size where $n = {}^{1}/_{3}$. In addition, for structural sand-lightweight or normal-weight concrete filled steel deck floor and roof assemblies, the value of 3,000 psi or 20.7 MPa must be substituted for the value of 2,500 psi or 17.2 MPa in the denominator.

Where values of N_{eq} are not provided in Table 3 of this report, the pullout strength in tension for seismic loads does not govern and need not be evaluated.

4.1.7.3 Seismic Shear: The nominal concrete breakout strength and pryout strength for anchors in shear must be calculated according to ACI 318 D.6.2 and D.6.3, as described in Sections 4.1.5 and 4.1.6 of this report and in accordance with ACI 318 D.6.1.2. The appropriate value for nominal steel strength in shear for seismic loads, V_{eq} or $V_{sa,deck}$, described in Table 4 of this report must be used in lieu of V_{sa}.

4.1.8 Interaction of Tensile and Shear Forces: For anchors or groups of anchors that are subject to the effects of combined tension and shear forces, the design must be performed in accordance with ACI 318 D.7.

4.1.9 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 the following equation:

$$\psi_{cp,N} = \frac{c}{c_{ac}} \qquad \text{(Eq-4)}$$

whereby 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 Section D.8.6, values of c_{ac} provided in Table 1 of this report must be used.

4.1.10 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: In lieu of ACI 318 D.8.3, values of c_{min} and s_{min} as given in Table 1 of this report must be used. In lieu of ACI 318 D.8.5, minimum member thicknesses, h_{min} as given in Table 1 must be used.

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

4.1.11 Structural Sand-lightweight Concrete: For ACI 318-08, when anchors are used in structural sand-lightweight concrete, the modification factor λ for concrete breakout strength must be taken as 0.6. In addition, the pullout strength $N_{p,cr}$, and N_{eq} must be multiplied by 0.6, as applicable.

For ACI 318-05, the values N_b, N_{eq}, $N_{p,cr}$, *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 soffit of structural sand-lightweight concrete-filled steel deck and floor and roof assemblies, this reduction is not required.

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 and Section 1612.3 of the UBC, shall be established using the following equations:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha} \qquad \text{(Eq-5)}$$

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha} \qquad \text{(Eq-6)}$$

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 Appendix D, Section 4.1 of this report and 2009 IBC Section 1908.1.9 or 2006 IBC Section 1908.1.16, as applicable (lbf or N).

ϕV_n = Lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318 Appendix D, Section 4.1 of this report and 2009 IBC Section 1908.1.9 or 2006 IBC Section 1908.1.16, as applicable (lbf or N).

α = 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 of allowable stress design values for illustrative purposes is shown in Table 5 and Figure 5 of this report.

4.2.2 Interaction of Tensile and Shear Forces: The interaction shall be calculated and consistent with ACI 318 D.7 as follows:

For shear loads $V \leq 0.2V_{allowable,ASD}$, the full allowable load in tension shall be permitted.

For tension loads $T \leq 0.2T_{allowable,ASD}$, the full allowable load in shear shall be permitted.

For all other cases: $$\frac{T}{T_{allowable}} + \frac{V}{V_{allowable}} \leq 1.2 \qquad \text{(Eq-7)}$$

4.3 Installation:

Installation parameters are provided in Table 1, Figure 1 and Figure 4. Anchor locations must comply with this report and the plans and specifications approved by the code official. The Power-Stud+ SD2 must be installed according to manufacturer's published installation instructions and this report. Anchors must be installed in holes drilled into the concrete using carbide-tipped masonry drill bits complying with ANSI B212.15-1994. The nominal drill bit diameter must be equal to that of the anchor size. The minimum drilled hole depth is given in Table 1. The predrilled hole must be cleaned free of dust and debris. The anchor must be hammered into the predrilled hole until the proper nominal embedment depth is achieved. The nut must be tightened against the washer until the torque values specified in Table 1 are achieved.

For installation in the soffit of concrete on steel deck 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). For member thickness and edge distance requirements for installations into the soffit of concrete on steel deck assemblies, see Figure 4A and 4B.

4.4 Special Inspection:

Special inspection is required, in accordance with Section 1704.15 of the 2009 IBC or Section 1704.13 of the 2006 and 2003 IBC and, if applicable, Section 1701.5.2 of the UBC. The special inspector must make periodic inspections during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, hole cleaning procedure, anchor spacing, edge distances, concrete member thickness, anchor embedment, tightening torque and adherence to the Powers Fasteners' printed installation instructions. The special inspector must be present as often as required in accordance with 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 Powers Power-Stud+ SD2 anchors described in this report comply with, or are suitable alternatives 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 Anchors must be installed in cracked and uncracked normal-weight concrete and structural 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); and cracked and uncracked normal weight or structural sand-lightweight concrete over steel deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa).

5.4 The values 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 must be established in accordance with Section 4.2 of this report.

5.7 Anchor spacing(s) and edge distance(s), as well as minimum member thickness, must comply with Table 1 and Figure 4.

5.8 Prior to 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 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 in locations designated as Seismic Design Categories A through F under the IBC, and Seismic Zones 0 to 4 under the UBC, subject to the conditions of this report.

5.12 Where not otherwise prohibited in the code, Power-Stud+ SD2 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-coated carbon steel anchors is limited to dry, interior locations.

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

5.15 Anchors are manufactured 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 February 2010, which incorporates requirements in ACI 355.2-07 / ACI 355.2-04, for use in cracked and uncracked concrete; including optional suitability Test 12 and 13 (AC193, Table 4.2) for seismic tension and shear; and quality control documentation.

7.0 IDENTIFICATION

The Power-Stud+ SD2 anchors are identified by dimensional characteristics and packaging. A length letter code head marking is stamped on each anchor on the exposed threaded stud end, along with a plus sign "+" and the number "2" which are visible after installation. Table 2 shows the length code identification system. Packages are identified with the anchor name, type and size; the manufacturer's name; the name of the inspection agency (CEL); and the evaluation report number (ICC-ES ESR-2502).

TABLE A—MEAN AXIAL STIFFNESS VALUES, β, FOR POWER-STUD+ SD2 EXPANSION ANCHORS IN NORMAL-WEIGHT CONCRETE[1]

Concrete State	Units	Nominal Anchor Size (inch)			
		$^3/_8$	$^1/_2$	$^5/_8$	$^3/_4$
Uncracked concrete	lbf/in. (kN/mm)	8,650 (1,517)	7,170 (1,258)	5,690 (998)	4,200 (737)
Cracked concrete	lbf/in. (kN/mm)	495 (87)	570 (100)	645 (113)	720 (126)

[1]Mean values shown; actual stiffness varies considerably depending on concrete strength, loading and geometry of application.

TABLE 1—POWER-STUD+ SD2 ANCHOR INSTALLATION SPECIFICATIONS

ANCHOR PROPERTY AND SETTING INFORMATION	NOTATION	UNITS	NOMINAL ANCHOR SIZE (inch)									
			$^3/_8$	$^1/_2$				$^5/_8$			$^3/_4$	
Outside diameter of anchor	d_a [d_o][3]	in.	0.375	0.500				0.625			0.750	
		(mm)	(9.5)	(12.7)				(15.9)			(19.1)	
Minimum diameter of hole clearance in fixture	d_h	in.	$^7/_{16}$	$^9/_{16}$				$^{11}/_{16}$			$^{13}/_{16}$	
		(mm)	(11.1)	(14.3)				(17.5)			(20.6)	
Nominal drill bit diameter	d_{bit}	in.	$^3/_8$	$^1/_2$				$^5/_8$			$^3/_4$	
			ANSI	ANSI				ANSI			ANSI	
Minimum nominal embedment depth[1]	h_{nom}	in.	$2^3/_8$	$2^1/_2$		$3^3/_4$		$3^7/_8$	$4^7/_8$		$4^1/_2$	$5^3/_4$
		(mm)	(60)	(64)		(83)		(98)	(124)		(114)	(146)
Effective embedment	h_{ef}	in.	2.00	2.00		3.25		3.25	4.25		3.75	5.00
		(mm)	(51)	(51)		(83)		(83)	(108)		(95)	(127)
Minimum concrete member thickness[1]	h_{min}	in.	4	$4^1/_2$	6	$5^3/_4$	$5^3/_4$	$5^3/_4$	$6^1/_2$	8	7	10
		(mm)	(102)	(114)	(152)	(146)	(146)	(146)	(165)	(203)	(178)	(254)
Critical edge distance[2]	c_{ac}	in.	$6^1/_2$	8		10		8	$15^3/_4$	10	12	12
		(mm)	(165)	(203)		(254)		(203)	(400)	(254)	(305)	(305)
Minimum edge distance[2]	c_{min}	in.	$2^1/_2$	4	$2^3/_4$	4	$2^3/_4$	$4^1/_4$	$4^1/_4$		5	$4^1/_2$
		(mm)	(64)	(102)	(70)	(102)	(70)	(108)	(108)		(127)	(114)
Minimum spacing distance[2]	s_{min}	in.	$3^1/_2$	6	6	4	6	$4^1/_4$	$4^1/_4$		6	6
		(mm)	(89)	(152)	(152)	(102)	(152)	(108)	(108)		(152)	(152)
Minimum hole depth[2]	h_o	in.	$2^5/_8$	$2^3/_4$		4		$4^1/_4$	$5^1/_4$		5	$6^1/_4$
		(mm)	(67)	(70)		(102)		(108)	(133)		(127)	(159)
Minimum overall anchor length	ℓ_{anch}	in.	3	$3^3/_4$		$4^1/_2$		$4^3/_4$	6		$6^1/_4$	7
		(mm)	(76)	(95)		(114)		(121)	(152)		(159)	(178)
Installation torque	T_{inst}	ft.-lb.	20	40				60			110	
		(N-m)	(27)	(54)				(81)			(149)	
Torque wrench / socket size	-	in.	$^9/_{16}$	$^3/_4$				$^{15}/_{16}$			$1^1/_8$	
Nut height	-	In.	$^{21}/_{64}$	$^7/_{16}$				$^{35}/_{64}$			$^{41}/_{64}$	

For **SI:** 1 inch = 25.4 mm, 1 ft-lbf = 1.356 N-m.

[1]The embedment depth, h_{nom}, is measured from the outside surface of the concrete member to the embedded end of the anchor prior to tightening.
[2]For installations through the soffit of steel deck into concrete see the installation details in Figure 4A and 4B of this report. In addition, anchors shall have an axial spacing along the flute equal to the greater of $3h_{ef}$ or 1.5 times the flute width.
[3]The notation in brackets is for the 2006 IBC.

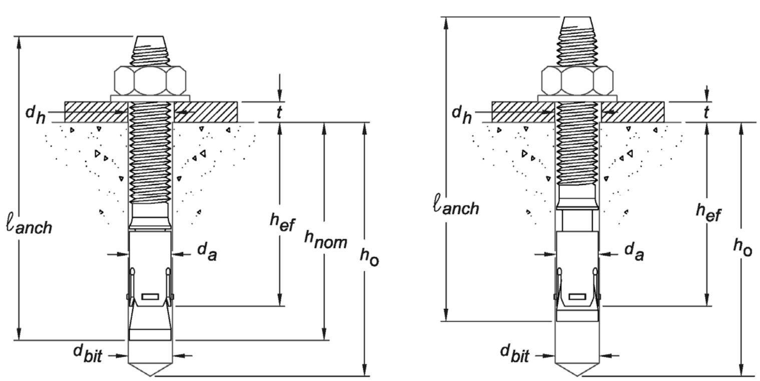


FIGURE 1—POWER-STUD+ SD2 ANCHOR DETAIL
Before (Left Picture) and After (Right Picture) Application of Installation Torque

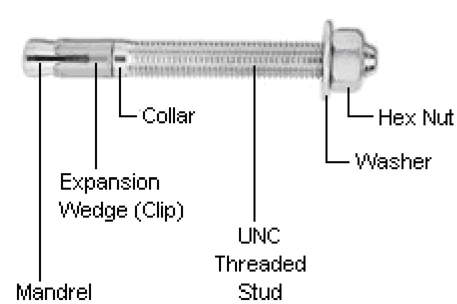
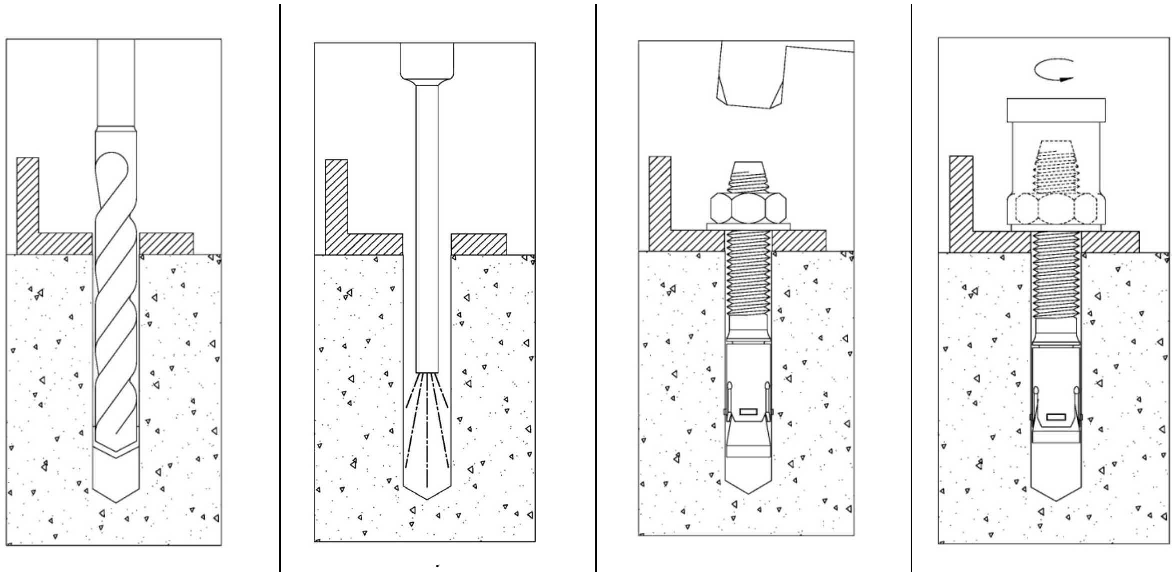


FIGURE 2—POWER-STUD+ SD2 ANCHOR ASSEMBLY

TABLE 2—POWER-STUD+ SD2 LENGTH CODE IDENTIFICATION SYSTEM

Length ID marking on threaded stud head		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Overall anchor length, ℓ_{anch}, (inches)	From	$1^1/_2$	2	$2^1/_2$	3	$3^1/_2$	4	$4^1/_2$	5	$5^1/_2$	6	$6^1/_2$	7	$7^1/_2$	8	$8^1/_2$	9
	Up to but not including	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	$8^1/_2$	9	$9^1/_2$



1.) Using the proper drill bit size, drill a hole into the base material to the required depth. The tolerances of the drill bit used should meet the requirements of ANSI Standard B212.15.

2.) Remove dust and debris from hole using a hand pump, compressed air or a vacuum to remove loose particles left from drilling.

3.) Position the washer on the anchor and thread on the nut. If installing through a fixture, drive the anchor through the fixture into the hole. Be sure the anchor is driven to the minimum required embedment depth, h_{nom}.

4.) Tighten the anchor with a torque wrench by applying the required installation torque, T_{inst}. Note: the threaded stud will draw up during tightening of the nut; the expansion wedge (clip) remains in original position.

FIGURE 3—POWER-STUD+ SD2 INSTALLATION INSTRUCTIONS

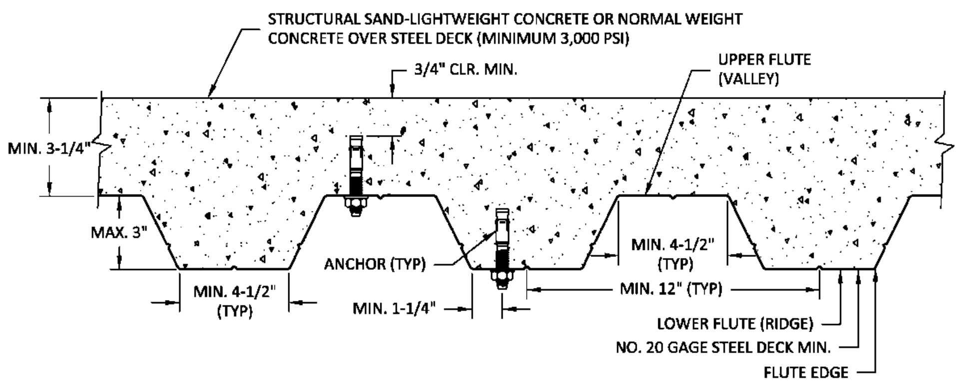


FIGURE 4A—POWER-STUD+ SD2 INSTALLATION DETAIL FOR ANCHORS IN THE SOFFIT OF CONCRETE OVER STEEL DECK FLOOR AND ROOF ASSEMBLIES (SEE DIMENSIONAL PROFILE REQUIREMENTS)[1]

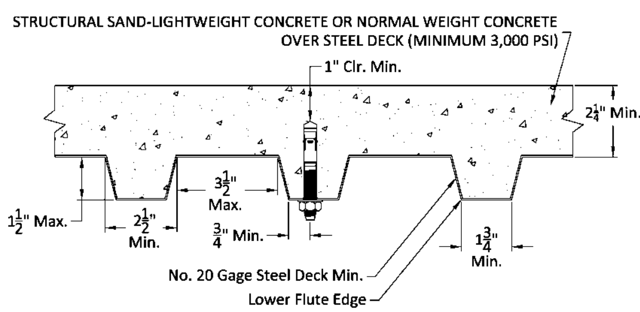


FIGURE 4B —POWER-STUD+ SD2 INSTALLATION DETAIL FOR ANCHORS IN THE SOFFIT OF CONCRETE OVER STEEL DECK FLOOR AND ROOF ASSEMBLIES (SEE DIMENSIONAL PROFILE REQUIREMENTS)[2,3]

[1]Anchors may be placed in the upper flute or lower flute of the steel deck profiles in accordance with Figure 4A provided the minimum hole clearance is satisfied. Anchors in the lower flute of Figure 4A profiles may be installed with a maximum 1-inch offset in either direction from the center of the flute. The offset distance may be increased proportionally for profiles with lower flute widths greater than those shown provided the minimum lower flute edge distance is also satisfied.

[2]Anchors may be placed in the lower flute of the steel deck profiles in accordance with Figure 4B provided the minimum hole clearance is satisfied. Anchors in the lower flute of Figure 4B profiles may be installed with a maximum $^1/_8$-inch offset in either direction from the center of the flute. The offset distance may be increased proportionally for profiles with lower flute widths greater than those shown provided the minimum lower flute edge distance is also satisfied.

[3]Anchors may be placed in the upper flute of the steel deck profiles in accordance with Figure 4B provided the concrete thickness above the upper flute is minimum $3^1/_4$-inch a minimum hole clearance $^3/_4$-inch is satisfied.

TABLE 3—TENSION DESIGN INFORMATION FOR POWER-STUD+ SD2 ANCHOR IN CONCRETE
(For use with load combinations taken from ACI 318, Section 9.2)[1,2]

Design Characteristic	Notation	Units	Nominal Anchor Size (inch)						
			3/8	1/2		5/8		3/4	
Anchor category	1, 2 or 3	-	1	1		1		1	
STEEL STRENGTH IN TENSION[4]									
Minimum specified yield strength (neck)	f_y	ksi	96.0	85.0		85.0		70.0	
		(N/mm^2)	(662)	(586)		(586)		(483)	
Minimum specified ultimate strength (neck)	f_{uta}[11]	ksi	120.0	106.0		106.0		90.0	
		(N/mm^2)	(827)	(731)		(731)		(620)	
Effective tensile stress area (neck)	$A_{se,N}$ [A_{se}][12]	in^2	0.0552	0.1007		0.1619		0.2359	
		(mm^2)	(35.6)	(65.0)		(104.5)		(153.2)	
Steel strength in tension	N_{sa}[11]	lbf	6,625	10,445		13,080		21,230	
		(kN)	(29.5)	(46.5)		(58.2)		(94.4)	
Reduction factor for steel strength[3]	ϕ	-	0.75						
CONCRETE BREAKOUT STRENGTH IN TENSION[8]									
Effective embedment	h_{ef}	in.	2.00	2.00	3.25	3.25	4.25	3.75	5.00
		(mm)	(51)	(51)	(83)	(83)	(108)	(95)	(127)
Effectiveness factor for uncracked concrete	k_{uncr}	-	24	24		24		24	
Effectiveness factor for cracked concrete	k_{cr}	-	17	17		17		17	
Modification factor for cracked and uncracked concrete[5]	$\Psi_{c,N}$[11]	-	1.0 See note 5	1.0 See note 5		1.0 See note 5		1.0 See note 5	
Critical edge distance	c_{ac}	in. (mm)	See Table 1						
Reduction factor for concrete breakout strength in tension[3]	ϕ	-	0.65 (Condition B)						
PULLOUT STRENGTH IN TENSION (NON-SEISMIC APPLICATIONS)[8]									
Characteristic pullout strength, uncracked concrete (2,500 psi)[6]	$N_{p,uncr}$	lbf	2,775	See note 7	6,615	See note 7	See note 7	See note 7	See note 7
		(kN)	(12.3)		(29.4)				
Characteristic pullout strength, cracked concrete (2,500 psi)[6]	$N_{p,cr}$	lbf	2,165	See note 7	4,375	See note 7	4,980	See note 7	7,795
		(kN)	(9.6)		(19.5)		(22.4)		(35.1)
Reduction factor for pullout strength[3]	ϕ	-	0.65 (Condition B)						
PULLOUT STRENGTH IN TENSION FOR SEISMIC APPLICATIONS[8]									
Characteristic pullout strength, seismic (2,500 psi)[6,9]	N_{eq}[11]	lbf	2,165	See note 7	4,375	See note 7	4,980	See note 7	7,795
		(kN)	(9.6)		(19.5)		(22.4)		(35.1)
Reduction factor for pullout strength[3]	ϕ	-	0.65 (Condition B)						
PULLOUT STRENGTH IN TENSION FOR STRUCTURAL SAND LIGHTWEIGHT AND NORMAL-WEIGHT CONCRETE OVER STEEL DECK									
Characteristic pullout strength, uncracked concrete over steel deck, according to Figure 4A[6,10]	$N_{p,deck,uncr}$	lbf	1,855	2,065	3,930	4,665	7,365	4,900 (21.8)	
		(kN)	(8.3)	(9.2)	(17.5)	(20.8)	(32.8)		
Characteristic pullout strength, cracked concrete over steel deck, according to Figure 4A[6,10]	$N_{p,deck,cr}$	lbf	1,445	1,465	2,600	3,305	3,490	3,470 (15.4)	
		(kN)	(6.4)	(6.5)	(11.6)	(14.7)	(15.5)		
Characteristic pullout strength, uncracked concrete over steel deck, according to Figure 4B[6,10]	$N_{p,deck,uncr}$	lbf (kN)	1,600 (7.1)	2,025 (9.0)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	
Characteristic pullout strength, cracked concrete over steel deck, according to Figure 4B[6,10]	$N_{p,deck,cr}$	lbf (kN)	1,250 (5.6)	1,435 (6.4)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	
Reduction factor for pullout strength[3]	ϕ	-	0.65 (Condition B)						

For **SI:** 1 inch = 25.4 mm, 1 ft-lbf = 1.356 N-m, 1 ksi = 6.895 N/mm^2, 1 lbf = 0.0044 kN

[1]The data in this table is intended to be used with the design provisions of ACI 318 Appendix D; for anchors resisting seismic load combinations the additional requirements of ACI 318 D.3.3 shall apply.

[2]Installation must comply with published instructions and details.

[3]All values of ϕ were determined from the load combinations of IBC Section 1605.2, ACI 318 Section 9.2 or UBC Section 1612.2. If the load combinations of ACI 318 Appendix C or IBC Section 1909.2 are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.5. For reinforcement that meets ACI 318 Appendix D requirements for Condition A, see ACI 318 D.4.4 for the appropriate ϕ factor.

[4]The Power-Stud+ SD2 is considered a ductile steel element in tension as defined by ACI 318 D.1. Tabulated values for steel strength in tension are based on test results per ACI 355.2 and must be used for design.

[5]For all design cases $\Psi_{c,N}$=1.0. The appropriate effectiveness factor for cracked concrete (k_{cr}) or uncracked concrete (k_{uncr}) must be used.

[6]For all design cases $\Psi_{c,P}$=1.0. For the calculation of N_{pn}, see Section 4.1.3 of this report.

[7]Pullout strength does not control design of indicated anchors. Do not calculate pullout strength for indicated anchor size and embedment.

[8]Anchors are permitted to be used in structural sand-lightweight concrete in accordance with Section 4.1.11 of this report.

[9]Tabulated values for characteristic pullout strength in tension are for seismic applications are based on test results per ACI 355.2, Section 9.5.

[10]Values for $N_{p,deck}$ are for structural sand-lightweight concrete ($f'_{c,\,min}$ = 3,000 psi) and additional lightweight concrete reduction factors need not be applied. In addition, evaluation for the concrete breakout capacity in accordance with ACI 318 D.5.2 is not required for anchors installed in the deck soffit (flute).

[11]For 2003 IBC code basis, f_{uta} replaces f_{ut} ; N_{sa} replaces N_s ; $\Psi_{c,N}$ replaces Ψ_3 ; and N_{eq} replaces $N_{p,seis}$.

[12]The notation in brackets is for the 2006 IBC.

TABLE 4—SHEAR DESIGN INFORMATION FOR POWER-STUD+ SD2 ANCHOR IN CONCRETE
(For use with load combinations taken from ACI 318, Section 9.2)[1,2]

Design Characteristic	Notation	Units	Nominal Anchor Diameter						
			3/8	1/2		5/8		3/4	
Anchor category	1, 2 or 3	-	1	1		1		1	
STEEL STRENGTH IN SHEAR[4]									
Minimum specified yield strength (threads)	f_y	ksi	76.8	68.0		68.0		56.0	
		(N/mm^2)	(530)	(469)		(469)		(386)	
Minimum specified ultimate strength (threads)	f_{uta}[10]	ksi	96.0	84.8		84.8		72.0	
		(N/mm^2)	(662)	(585)		(585)		(496)	
Effective tensile stress area (threads)	$A_{se,V}$ [A_{se}][11]	in^2	0.0775	0.1419		0.2260		0.3345	
		(mm^2)	(50.0)	(65.7)		(104.9)		(215.8)	
Steel strength in shear[5]	V_{sa}[10]	lbf	2,190	4,640		9,800		10,175	
		(kN)	(9.7)	(20.6)		(44.1)		(45.3)	
Reduction factor for steel strength[3]	ϕ	-	0.60	0.65					
CONCRETE BREAKOUT STRENGTH IN SHEAR[6]									
Load-bearing length of anchor (h_{ef} or $8d_o$, whichever is less)	ℓ_e[10]	in.	2.00	2.00	3.25	3.25	4.25	3.75	5.00
		(mm)	(51)	(51)	(83)	(83)	(108)	(95)	(127)
Nominal anchor diameter	d_a [d_o][11]	in. (mm)	0.375 (9.5)	0.500 (12.7)		0.625 (15.9)		0.750 (19.1)	
Reduction factor for concrete breakout strength in shear[3]	ϕ	-	0.70 (Condition B)						
PRYOUT STRENGTH IN SHEAR[6]									
Coefficient for pryout strength (1.0 for h_{ef} < 2.5 in., 2.0 for $h_{ef} \geq$ 2.5 in.)	k_{cp}	-	1.0	1.0	2.0	2.0	2.0	2.0	2.0
Effective embedment	h_{ef}	in. (mm)	2.00 (51)	2.00	3.25	3.25	4.25	3.75	5.00
				(51)	(83)	(83)	(108)	(95)	(127)
Reduction factor for pryout strength[3]	ϕ	-	0.70 (Condition B)						
STEEL STRENGTH IN SHEAR FOR SEISMIC APPLICATIONS									
Steel strength in shear, seismic[7]	V_{eq}[10]	lbf	1,955	4,640		6,530		6,635	
		(kN)	(8.7)	(20.6)		(29.0)		(29.5)	
Reduction factor for steel strength in shear, seismic[3]	ϕ	-	0.60	0.65					
STEEL STRENGTH IN SHEAR FOR STRUCTURAL SAND-LIGHTWEIGHT AND NORMAL-WEIGHT CONCRETE OVER STEEL DECK[9]									
Steel strength in shear, concrete over steel deck, according to Figure 4A[8]	$V_{sa,deck}$	lbf	2,170	3,815	5,040	4,015	6,670	4,325 (19.2)	
		(kN)	(9.7)	(17.0)	(22.4)	(17.9)	(29.7)		
Steel strength in shear, concrete over steel deck, according to Figure 4B[8]	$V_{sa,deck}$	lbf (kN)	2,170 (9.7)	2,880 (12.8)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	
Reduction factor for steel strength in shear, concrete over steel deck[3]	ϕ	-	0.60	0.65					

For **SI:** 1 inch = 25.4 mm, 1 ft-lbf = 1.356 N-m, 1 ksi = 6.895 N/mm^2, 1 lbf = 0.0044 kN.

[1]The data in this table is intended to be used with the design provisions of ACI 318 Appendix D; for anchors resisting seismic load combinations the additional requirements of ACI 318 D.3.3 shall apply.
[2]Installation must comply with published instructions and details.
[3]All values of ϕ were determined from the load combinations of IBC Section 1605.2, ACI 318 Section 9.2 or UBC Section 1612.2. If the load combinations of Appendix C or UBC Section 1909.2 are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.5. For reinforcement that meets ACI 318 Appendix D requirements for Condition A, see ACI 318 D.4.4 for the appropriate ϕ factor.
[4]The Power-Stud+ SD2 is considered a ductile steel element as defined by ACI 318 D.1 except for the 3/8-inch-diameter anchors in shear.
[5]Tabulated values for steel strength in shear are based on test results per ACI 355.2, Section 9.4 and must be used for design. These tabulated values are lower than calculated results using equation D-20 in ACI 318-08 (318-05) and ACI 318 D.6.1.2.
[6]Anchors are permitted to be used in structural sand-lightweight concrete in accordance with Section 4.1.11 of this report.
[7]Tabulated values for steel strength in shear are for seismic applications are based on test results per ACI 355.2, Section 9.6.
[8]Values for $V_{sa,deck}$ are for structural sand-lightweight concrete ($f'_{c,\,min}$ = 3,000 psi) and additional lightweight concrete reduction factors need not be applied. In addition, evaluation for the concrete breakout capacity in accordance with ACI 318 D.6.2 and the pryout capacity in accordance with Section D.6.3 is not required for anchors installed in the deck soffit (flute).
[9]Shear loads for anchors installed through steel deck into concrete may be applied in any direction.
[10]For 2003 IBC code basis, f_{uta} replaces f_{ut} ; V_{sa} replaces V_s ; ℓ_e replaces ℓ ; and V_{eq} replaces $V_{sa,seis}$.
[11]The notation in brackets is for the 2006 IBC.

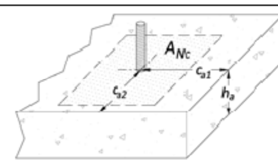
TABLE 5—EXAMPLE ALLOWABLE STRESS DESIGN VALUES FOR ILLUSTRATIVE PURPOSES[1,2,3,4,5,6,7,8,9]

Nominal Anchor Diameter (in.)	Nominal Embedment Depth (in.)	Effective Embedment (in.)	Allowable Tension Load (pounds)
$^3/_8$	$2^3/_8$	2.00	1,220
$^1/_2$	$2^1/_2$	2.00	1,490
	$3^3/_4$	3.25	2,905
$^5/_8$	$3^7/_8$	3.25	3,090
	$4^7/_8$	4.25	4,615
$^3/_4$	$4^1/_2$	3.75	3,825
	$5^3/_4$	5.00	5,890

For **SI:** 1 inch = 25.4 mm, 1 ft-lbf = 1.356 N-m.

[1] Single anchor with static tension load only.
[2] Concrete determined to remain uncracked for the life of the anchorage.
[3] Load combinations from ACI 318 Section 9.2 (no seismic loading considered).
[4] 30% dead load and 70% live load, controlling load combination 1.2*D* + 1.6*L*.
[5] Calculation of weighted average for α = 1.2(0.3) + 1.6(0.7) = 1.48.
[6] f'_c = 2,500 psi (normal weight concrete).
[7] $c_{a1} = c_{a2} \geq c_{ac}$.
[8] $h \geq h_{min}$.
[9] Values are for Condition B where supplementary reinforcement in accordance with ACI 318 D.4.4 is not provided.

Given: Calculate the factored resistance strength, $\boldsymbol{\phi N_n}$, and the allowable stress design value, $\boldsymbol{T_{allowable,ASD}}$, for a $^3/_8$-inch-diameter Power-Stud+ SD2 anchor assuming the given conditions in Table 5.

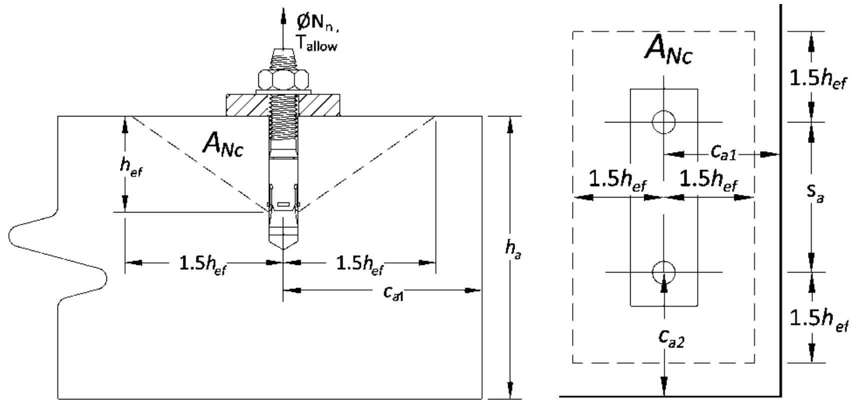


Calculation in accordance with ACI 318-08 (ACI 318-05) Appendix D and this report:	Code Ref.	Report Ref.
Step 1. Calculate steel strength of a single anchor in tension: $\boldsymbol{\phi N_{sa}} = (0.75)(6{,}625) = 4{,}969\ lbs.$	D.5.1.2	Table 3
Step 2. Calculate concrete breakout strength of a single anchor in tension: $\phi N_{cb} = \phi \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$ $N_b = k_c \sqrt{f'_c} (h_{ef})^{1.5}$ $N_b = (24)\sqrt{2{,}500}(2.0)^{1.5} = 3{,}394\ lbs.$ $\boldsymbol{\phi N_{cb}} = (0.65)\frac{(36.0)}{(36.0)}(1.0)(1.0)(1.0)(3{,}394) = 2{,}206\ lbs.$	D.5.2.1	Table 3
Step 3. Calculate pullout strength of a single anchor: $\phi N_{pn} = \phi N_{p,uncr} \psi_{c,P} \left(\frac{f'_{c,act}}{2{,}500}\right)^n$ $\boldsymbol{\phi N_{pn}} = (0.65)(2{,}775)(1.0)(1.0)^{0.5} = 1{,}804\ lbs.$	D.5.2.2	Table 3
Step 4. Determine controlling factored resistance strength in tension: $\boldsymbol{\phi N_n} = \min\lvert \phi N_{sa}, \phi N_{cb}, \phi N_{pn} \rvert = \phi N_{pn} = 1{,}804\ lbs.$	D.4.1.1	
Step 5. Calculate allowable stress design conversion factor for loading condition: Controlling load combination: 1.2*D* + 1.6*L* $\boldsymbol{\alpha}$ = 1.2(30%) + 1.6(70%) = 1.48	9.2	
Step 6. Calculate the converted allowable stress design value: $\boldsymbol{T_{allowable,ASD}} = \frac{\phi N_n}{\alpha} = \frac{1{,}804}{1.48} = 1{,}219\ lbs.$		Section 4.2

FIGURE 5—EXAMPLE STRENGTH DESIGN CALCULATION INCLUDING ASD CONVERSION FOR ILLUSTRATIVE PURPOSES

Given:
Two $^{3}/_{8}$" Power-Stud+ SD2 anchors
Concrete compressive strength:
(f'_c) = 4,000 psi
No supplemental reinforcement:
(Condition B per ACI 318-08 D.4.4 c)
Assume cracked concrete, no seismic, no loading eccentricity and a rigid plate

h_a = 5.0 in.
h_{ef} = 2.0 in.
s_a = 4.5 in.
c_{a1} = $c_{a,min}$ = 6.0 in.
$c_{a2} \geq 1.5c_{a1}$



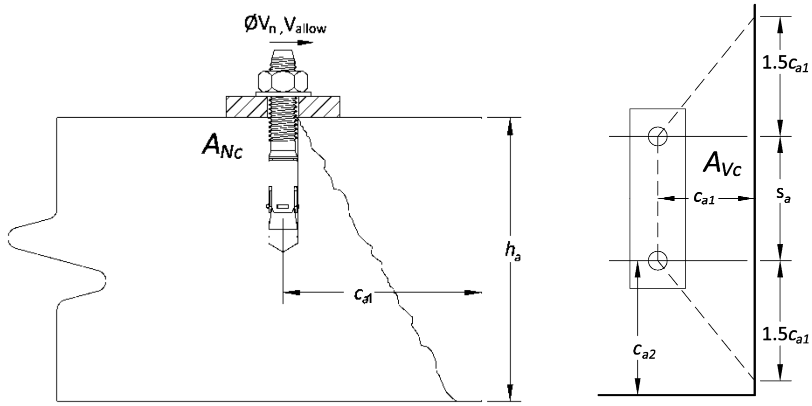
Calculate the factored resistance design strength in <u>tension</u> and equivalent allowable stress design load for the configuration.

Calculation in accordance with ACI 318-08 (ACI 318-05) and this report:	Code Ref.	Report Ref.
Step 1. Verify minimum member thickness, spacing and edge distance: h_a = 5.0 in. ≥ h_{min} = 4.0 in. ∴ OK s_a = 4.5 in. ≥ s_{min} = 3.5 in. ∴ OK $c_{a,min}$ = 6.0 in. ≥ c_{min} = 2.5 in. ∴ OK	D.8	Table 1
Step 2. Calculate steel strength of anchor group in tension: $N_{sag} = n \bullet N_{sa}$ = 2•6,625 lbs. = 13,250 lbs. Calculate steel capacity: ϕN_{sag} = 0.75 • 13,250 lbs. = **9,937 lbs**.	D.5.1.2	§4.1.1 Table 3
Step 3. Calculate concrete breakout strength of anchor group in tension: $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$	D.5.2.1 (b)	§4.1.2
Step 3a. Calculate A_{Nco} and A_{Nc} $A_{Nco} = 9h_{ef}^{2} = 9 \bullet (2.0)^2$ = **36.0 in.²** $A_{nc} = (3.0\ h_{ef}) \bullet (3.0\ h_{ef} + s_a) = (3.0 \bullet 2.0) \bullet ((3.0 \bullet 2.0) + 4.5)$ = **63.0 in.²** ∴ A_{Nc} = **63.0 in.²**	D.5.2.1 (b)	Table 1
Step 3b. Calculate $\psi_{ec,N} = \frac{1}{(1+\frac{2e'_N}{3h_{ef}})} \leq 1.0$; $e'_N = 0$ ∴ $\psi_{ec,N}$ = **1.0**	D.5.2.4	-
Step 3c. Calculate $\psi_{ed,N}$ = 1.0 if $c_{a,min} \geq 1.5h_{ef}$; $\psi_{ed,N} = 0.7 + 0.3\frac{c_{a,min}}{1.5h_{ef}}$ if $c_{a,min} < 1.5h_{ef}$ $c_{a,min}$ = 6.0 in. ≥ $1.5h_{ef}$ = 3.0 in. ∴ $\psi_{ed,N}$ = **1.0**	D.5.2.5	Table 1
Step 3d. Calculate $\psi_{c,N}$ = **1.0**	D.5.2.6	Table 3
Step 3e. Calculate $\psi_{cp,N}$ = **1.0** (cracked concrete)	D.5.2.7	-
Step 3f. Calculate $N_b = k_{cr} \lambda \sqrt{f'_c}\, h_{ef}^{1.5} = 17\ (1.0)\sqrt{4{,}000} \bullet 2.0^{1.5}$ = **3,041 lbs.**	D.5.2.2	Table 3
Step 3g. Calculate concrete breakout strength of anchor group in tension: N_{cbg} = (63.0/36.0) • 1.0 • 1.0 • 1.0 • 1.0 • 3,041 = 5,321 lbs. Calculate concrete breakout capacity = ϕN_{cbg} = 0.65 • 5,321 = **3,459 lbs.**	D.5.2.1 (b)	§4.1.2
Step 4. Calculate nominal pullout strength of a single anchor in tension: $N_{pn} = \psi_{c,P} \bullet N_{pn,f'c}$	D.5.3.1	§4.1.3 Table 3
Step 4a. Calculate $\psi_{c,P}$ = **1.0** (cracked concrete)	D.5.3.6	§4.1.9 Table 3
Step 4b. Calculate $N_{pn,f'c} = N_{p,cr} \left(\frac{f'c}{2500}\right)^{0.33} = 2{,}165\left(\frac{4000}{2500}\right)^{0.33}$ = 2,528 lbs. Calculate pullout capacity: ϕN_{pn} = 0.65 • 2,528 • 1.0 = **1,643 lbs.**	D.5.3.2	§4.1.3 Table 3
Step 5. Determine controlling resistance strength of the anchor group in tension: $\phi N_n = \min\left\|\phi N_{sag}, \phi N_{cbg}, n\phi N_{pn}\right\| = n\phi N_{pn}$ = **3,287 lbs.**	D.4.1.1 D.4.1.2	§4.1
Step 6. Calculate allowable stress design conversion factor for loading condition: Assume controlling load combination: 1.2*D* + 1.6*L* ; 50% Dead Load, 50% Live Load α = 1.2(50%) + 1.6(50%) = **1.40**	9.2	§4.2.1
Step 7. Calculate allowable stress design value: $T_{allowable,ASD} = \frac{\phi N_n}{\alpha} = \frac{3{,}287}{1.40}$ = **2,347 lbs.**	9.2	§4.2.1

FIGURE 6 — EXAMPLE STRENGTH DESIGN CALCULATION FOR TENSION CAPACITY

Given:
Two $^3/_8$" Power-Stud+ SD2 anchors
Concrete compressive strength:
(f'_c) = 4,000 psi
No supplemental reinforcement:
(Condition B per ACI 318-08 D.4.4 c)
Assume cracked concrete, no seismic, no loading eccentricity and a rigid plate

h_a = 5.0 in.
h_{ef} = 2.0 in.
s_a = 4.5 in.
$c_{a1} = c_{a,min}$ = 6.0 in.
$c_{a2} \geq 1.5c_{a1}$



Calculate the factored resistance design strength in shear and equivalent allowable stress design load for the configuration.

Calculation in accordance with ACI 318-08 (ACI 318-05) and this report:	**Code Ref.**	**Report Ref.**
Step 1. Verify minimum member thickness, spacing and edge distance: h_a = 5.0 in. ≥ h_{min} = 4.0 in. ∴ OK s_a = 4.5 in. ≥ s_{min} = 3.5 in. ∴ OK $c_{a,min}$ = 6.0 in. ≥ c_{min} = 2.5 in. ∴ OK	D.8	Table 1
Step 2. Calculate steel strength of anchor group in shear: $V_{sag} = n \cdot V_{sa}$ = 2 • 2,190 lbs. = 4,380 lbs. Calculate steel capacity: ϕV_{sag} = 0.60 • 4,380 lbs. = **2,625 lbs**.	D.6.1.2	§4.1.4 Table 4
Step 3. Calculate concrete breakout strength of anchor group in shear: $V_{cbg} = \frac{A_{Vc}}{A_{Vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b$	D.6.2.1 (b)	§4.1.5
Step 3a. Calculate A_{Vco} and A_{Vc} $A_{Vco} = 4.5\,(c_{a1})^2 = 4.5 \cdot (6.0)^2$ = **162.0 in.^{2}** $A_{Vc} = (h_a) \cdot (3\,c_{a1} + s_a) = (5.0)((3 \cdot 6.0) + 4.5)$ = **112.5 in.^{2}**	D.6.2.1	Table 1
Step 3b. Calculate $\psi_{ec,V} = \frac{1}{(1+\frac{2e'_N}{3c_{a1}})} \leq 1.0$; $e'_V = 0$ ∴ $\psi_{ec,V}$ = **1.0**	D.6.2.5	-
Step 3c. Calculate $\psi_{ed,V}$ = 1.0 if $c_{a2} \geq 1.5c_{a1}$; $\psi_{ed,V} = 0.7 + 0.3\frac{c_{a2}}{1.5c_{a1}}$ if $c_{a2} < 1.5c_{a1}$ $c_{a2} \geq 1.5\,c_{a1}$ ∴ $\psi_{ed,V}$ = **1.0**	D.6.2.6	Table 1
Step 3d. Calculate $\psi_{c,V}$ = **1.0** (cracked concrete, no supplemental or edge reinforcement)	D.6.2.7	-
Step 3e. Calculate $\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}}$; for members where $h_a < 1.5c_{a1}$ $h_a = 5.0 < 1.5c_{a1} = 9.0$ ∴ $\psi_{h,V} = \sqrt{\frac{9.0}{5.0}}$ = **1.34**	D.6.2.8 (*ACI 318-08 only*)	-
Step 3f. Calculate $V_b = \left(7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right)\lambda\sqrt{f'_c}(c_{a1})^{1.5} = 7\left(\frac{2.0}{0.375}\right)^{0.2}\sqrt{0.375}\,(1.0)\sqrt{4000}(6.0)^{1.5}$ = **5,569 lbs.**	D.6.2.2	Table 4
Step 3g. Calculate concrete breakout strength of anchor group in shear: V_{cbg} = (112.5/162.0) • 1.0 • 1.0 • 1.0 • 1.34 • 5,569 = 5,182 lbs. Calculate concrete breakout capacity = ϕV_{cbg} = 0.70 • 5,182 = **3,627 lbs.**	D.6.2.1 (b)	§4.1.5
Step 4. Calculate nominal pryout strength of an anchor group in shear: $V_{cpg} = k_{cp} N_{cbg}$ = 1.0 • 5,321 lbs = 5,321 lbs. Calculate pryout capacity: ϕV_{cpg} = 0.70 • 5,321 lbs. = **3,724 lbs**.	D.6.3.1 (b)	§4.1.6 Table 4
Step 5. Determine controlling resistance strength in shear: $\phi V_n = \min\left\vert \phi V_{sag}, \phi V_{cbg}, \phi V_{cpg} \right\vert = \phi V_{sag}$ = **2,625 lbs.**	D.4.1.1 D.4.1.2	§4.1
Step 6. Calculate allowable stress design conversion factor for loading condition: Assume controlling load combination: 1.2D + 1.6L ; 50% Dead Load, 50% Live Load α = 1.2(30%) + 1.6(70%) = **1.40**	9.2	§4.2.1
Step 7. Calculate allowable stress design value: $V_{allowable,ASD} = \frac{\phi V_n}{\alpha} = \frac{2,625}{1.40}$ = **1,875 lbs.**	9.2	§4.2.1

FIGURE 7 — EXAMPLE STRENGTH DESIGN CALCULATION FOR SHEAR CAPACITY

ICC-ES Evaluation Report

ESR-2502 Supplement

Reissued May 1, 2010

This report is subject to re-examination in two years.

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DIVISION: 03—CONCRETE
Section: 03151—Concrete Anchoring

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EVALUATION SUBJECT:

POWERS POWER-STUD™+ SD2 ANCHORS IN CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2007 *Florida Building Code—Building*
- 2007 *Florida Building Code—Residential*

Property evaluated:

Structural

2.0 PURPOSE OF THIS SUPPLEMENT

This supplement is issued to indicate that the Powers Power-Stud™+ SD2 Anchors in Cracked and Uncracked Concrete described in the master report comply with the 2007 *Florida Building Code—Building* and the 2007 *Florida Building Code—Residential*, when designed and installed in accordance with the master evaluation report.

Use of the Powers Power-Stud™+ SD2 Anchors in Cracked and Uncracked Concrete as described in the master evaluation report to comply with the High Velocity Hurricane Zone Provisions of the 2007 *Florida Building Code—Building* has not been evaluated, and is outside the scope of this supplement.

For products falling under Florida Rule 9B-72, verification that the report holder's quality assurance program is audited by a quality assurance entity approved by the Florida Building Commission for the type of inspections being conducted is the responsibility of an approved validation entity (or the code official when the report holder does not possess an approval by the Commission).

This supplement expires concurrently with the master report reissued on May 1, 2010.