STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

SIMPSON Strong-Tie ANCHOR SYSTEMS®

This technical bulletin provides the characteristic design properties for the Strong-Bolt wedge anchor to be used in conjunction with CSA Standard A23.3-04 Annex D.

Introduction to CSA A23.3-04 Annex D

Beginning with the 2005 National Building Code of Canada (NBCC 2005), the building code will provide detailed guidelines for the design and use of post-installed mechanical anchors in cracked and uncracked concrete. The NBCC 2005 references CSA A23.3-04 *Design of Concrete Structures*, which includes Annex D-*Anchorage*.

Annex D provides a Limit States Design (LSD) methodology to calculate factored tension and shear resistances for post-installed mechanical anchors used in cracked or uncracked concrete. This differs from the previous “soft-conversion” approach of the more traditional Working Stress Design (WSD) theory that considers use of post-installed mechanical or adhesive anchors in uncracked concrete only. In the case of the LSD methodology, the designer calculates the factored resistance of an anchor or group of anchors in cracked or uncracked concrete (as applicable), considering each possible failure mode. The “controlling” design value is the lowest calculated factored resistance of each of the possible failure modes.

Note that Annex D is limited in scope. Presently, it covers structural anchors (both cast-in anchors and some types of post-installed mechanical anchors) related to strength, stability or life-safety. These anchor types may be installed and used in normal-weight or lightweight aggregate concrete. Other base materials, such as masonry, are not covered. Only those post-installed mechanical anchors which have been tested and evaluated in accordance with ACI 355.2 *Evaluating the Performance of Post-Installed Anchors in Concrete* may be considered. Other anchor types, such as concrete screws and adhesive anchors are not yet included within the scope of CSA A23.3-04 Annex D or ACI 355.2. Additional limitations based on maximum concrete compressive strength, maximum anchor diameter and maximum embedment depth must also be considered.

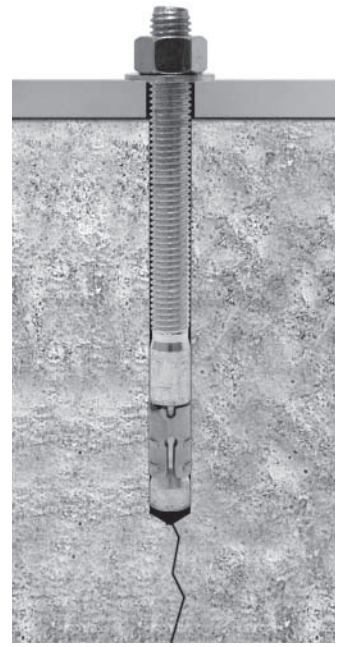
Introduction to ACI 355.2 and ICC ES AC 193

In order to use the design provisions of CSA A23.3-04 Annex D, post-installed mechanical anchors must be tested and qualified under ACI 355.2 *Evaluating the Performance of Post-Installed Anchors in Concrete*. The results of these tests are used to establish such performance values as the effectiveness factor, pullout resistance, axial stiffness, and anchor category. The anchor category is established based on the reliability of an anchor’s performance during testing and is particularly important as it is used to determine the appropriate strength reduction factor.

The performance of post-installed mechanical anchors for use in either uncracked or in both cracked and uncracked concrete can be established under ACI 355.2. In order to qualify a product for use in both cracked and uncracked concrete, and under seismic loading conditions, a series of thirteen separate tests must be conducted. These tests include:

- Tension testing in low and high strength concrete where the anchor has been installed in a 0.3 mm wide crack.
- Tension testing in low strength concrete where the anchor is installed in a crack that is cycled 1,000 times between a width of 0.1 mm and 0.3 mm while simultaneously being subjected to a sustained tension load.
- Tension and shear testing in low strength concrete where the anchor is installed in a 0.5 mm wide crack and subject to a simulated seismic tension or shear load that varies in magnitude over 140 load cycles.

ICC Evaluation Service AC 193 references ACI 355.2 and details additional requirements pertaining to product sampling and testing.



Possible Failure Modes for Post-Installed Mechanical Anchors in Concrete

Tension	Shear
Steel	Steel
Concrete Breakout	Concrete Breakout
Pullout or Pull-through	Concrete Pryout

LIMIT STATES DESIGN

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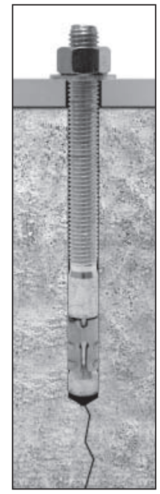
TECHNICAL BULLETIN

STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

The Strong-Bolt is a wedge anchor specifically designed for optimum performance in both cracked and uncracked concrete. Rigorously tested according to the newest industry-wide criteria, the Strong-Bolt anchor is proven to offer increased reliability in the most adverse conditions, including proper functioning in cracked concrete under static and seismic loading. The proprietary tri-segmented clip has dual undercutting embossments on each segment which enable secondary or "follow-up" expansion if a crack forms and intersects the anchor location. This significantly increases the ability of the Strong-Bolt anchor to carry load if the hole opened slightly due to a crack. The Strong-Bolt anchor sets like a standard wedge anchor and is available in Imperial fractional sizes.

Strong-Bolt™

Tri-Segmented Clip



FEATURES:

- Tri-segmented clip: Each segment is able to adjust independently increasing follow-up expansion should the hole increase in size as a result of a crack.
- Dual embossments on each clip segment: Allows the clip to undercut into the concrete increasing follow-up expansion should a crack occur.
- 316 stainless steel clip: In addition to superior corrosion resistance, a stainless steel clip offers better "memory". This memory contributes to the anchor's performance should the hole size increase due to a crack.
- Imperial fractional sized anchor: Fits most fixtures and installs with common drill bits sizes and tools. No need to buy additional tools to install a metric anchor and no special couplers needed.
- Installs like a standard wedge anchor: No complicated installation procedure. No need for special bits or installation tools.
- No equal "≠" sign stamped into the head: Easy identification after installation.

MATERIAL: Carbon steel stud with 316 stainless steel clip

FINISH: Zinc plated

CODES: ICC-ES ESR-1771

TEST CRITERIA: The Strong-Bolt anchor has been tested in accordance with the ICC-ES *Acceptance Criteria for Mechanical Anchors in Concrete Elements* (AC193) and ACI 355.2 for the following:

- Static tension and shear loading in cracked and uncracked concrete
- Seismic and wind loading in cracked and uncracked concrete
- Performance in cracked concrete
- Performance in lightweight concrete over metal deck

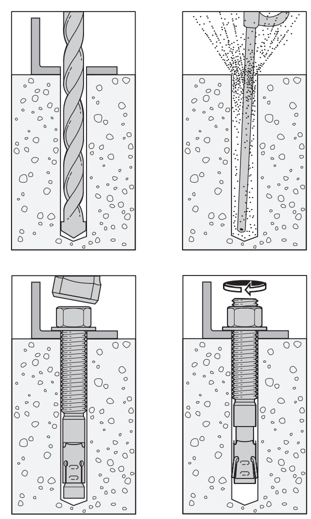
Vibratory Load Testing: A 150 lb. concrete block was suspended from a ½" diameter anchor embedded at 2¼" and vibrated for 12.6 million cycles at a frequency of 30 Hz and an amplitude of 0.025 inches. Subsequent load test showed no reduction in ultimate tension capacity.

INSTALLATION: • Do not use an impact wrench to set or tighten the Strong-Bolt anchor.

⚠ Caution: Oversized holes in the base material will make it difficult to set the anchor and will reduce the anchor's load capacity.

- Drill a hole in the base material using a carbide drill bit the same diameter as the nominal diameter of the anchor to be installed. Drill the hole to the specified embedment depth and blow it clean using compressed air. Overhead installations need not be blown clean. Alternatively, drill the hole deep enough to accommodate embedment depth and dust from drilling.
- Assemble the anchor with nut and washer so that the top of the nut is flush with the top of the anchor. Place the anchor in the fixture and drive into the hole until washer and nut are tight against the fixture.
- Tighten to the required installation torque.

Installation Sequence



APPLICATION:

- Interior environment where low levels of moisture and corrosive chemicals are present.

SUGGESTED SPECIFICATIONS:

Strong-Bolt anchors shall be an imperial-sized steel threaded stud with an integral cone expander and a three-segment expansion clip. The stud shall be manufactured from carbon steel and the expansion clip shall have two undercutting embossments per segment and be manufactured from 316 stainless steel. The anchor shall have been tested and qualified for performance in cracked concrete per ACI 355.2 and ICC-ES AC193. Anchors shall be Strong-Bolt wedge anchors from Simpson Strong-Tie Company Inc., Pleasanton, CA, and be installed following instructions by Simpson Strong-Tie.

Strong-Bolt Installation Data

Strong-Bolt Dia	Units	½ in.	⅝ in.	¾ in.	1 in.
Bit Size	in	½	⅝	¾	1
Min. Fixture Hole	in (mm)	9⁄16 (14.3)	11⁄16 (17.5)	⅞ (22.2)	1⅛ (28.6)
Wrench Size	in	¾	15⁄16	1⅛	1½

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

Mark	Units	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
From	in (mm)	1½ (38)	2 (51)	2½ (64)	3 (76)	3 ½ (89)	4 (102)	4½ (114)	5 (127)	5½ (140)	6 (152)	6½ (165)	7 (178)	7½ (191)	8 (203)	8½ (216)	9 (229)	9½ (241)	10 (254)	11 (279)	12 (305)	13 (330)	14 (356)	15 (381)	16 (406)	17 (432)	18 (457)
Up To But Not Including	in (mm)	2 (51)	2½ (64)	3 (76)	3½ (89)	4 (102)	4½ (114)	5 (127)	5½ (140)	6 (152)	6½ (165)	7 (178)	7½ (191)	8 (203)	8½ (216)	9 (229)	9½ (241)	10 (254)	11 (279)	12 (305)	13 (330)	14 (356)	15 (381)	16 (406)	17 (432)	18 (457)	19 (483)

STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

Strong-Bolt Anchor Product Data[1]

Size (in)	Model No.	Drill Bit Dia (in)	Thread Length[1] (in)	Quantity: Box	Quantity: Carton
½ x 3¾	STB50334	½	2 5/16	25	125
½ x 4¼	STB50414		2 13/16	25	100
½ x 5½	STB50512		4 1/16	25	100
½ x 7	STB50700		5 9/16	25	100
½ x 8½	STB50812		6	25	50
½ x 10	STB50100		6	25	50
⅝ x 4½	STB62412	⅝	2⅞	20	80
⅝ x 5	STB62500		3⅜	20	80
⅝ x 6	STB62600		4⅜	20	80
⅝ x 7	STB62700		5⅜	20	80
⅝ x 8½	STB62812		6	20	40
⅝ x 10	STB62100		6	10	20
¾ x 5½	STB75512	¾	3⅝	10	40
¾ x 6¼	STB75614		4⅜	10	40
¾ x 7	STB75700		5⅛	10	40
¾ x 8½	STB75812		6	10	20
¾ x 10	STB75100		6	10	20
1 x 7	STB100700	1	2¼	5	20
1 x 10	STB1001000		2¼	5	10
1 x 13	STB1001300		2¼	5	10

1. The published length is the overall length of the anchor. Allow one anchor diameter for the nut and washer thickness plus the fixture thickness when selecting a length.

Material Specifications

Carbon Steel – Zinc Plated[1]			
Component Materials			
Anchor Body	Nut	Washer	Clip
Carbon Steel SAE J403, Grade 1030-1035 SAE J403, Grade 12L14	Carbon Steel ASTM A 563, Grade A	Carbon Steel ASTM F844	316 Stainless Steel

1. Zinc meets ASTM B 633, Class SC 1 (Fe / Zn 5), Type I.

Table 1 - Strong-Bolt Anchor Installation Information and Additional Data[1]

Characteristic	Symbol	Units	Nominal Anchor Diameter: ½ inch (12.7 mm)			⅝ inch (15.9 mm)			¾ inch (19.1 mm)			1 inch (25.4 mm)	
Installation Information													
Drill Bit Diameter	d	in.	½			⅝			¾			1	
Minimum Baseplate Clearance Hole Diameter	d_c	mm	14.3			17.5			22.2			28.6	
Installation Torque	T_{inst}	N-m	68			115			244			312	
Embedment Depth	—	mm	70	98	127	86	130	156	105	146	191	133	248
Critical Edge Distance	C_{ac}	mm	229	200	171	279	244	210	343	298	257	457	343
Minimum Edge Distance	C_{min}	mm	102			127			152			203	
Minimum Spacing	S_{min}	mm	102			159			159			203	
Minimum Concrete Thickness	h_{min}	mm	114	152	171	140	200	210	171	222	257	229	343
Additional Data													
Anchor Category	1, 2 or 3	—	1						2				
Yield Strength	f_{ya}	MPa	745									414	
Tensile Strength	f_{uta}	MPa	862									538	
Minimum Tensile and Shear Stress Area	A_{se}	mm^2	70			108			176			305	
Axial Stiffness in Service Load Range	ß	N/mm	21,891			24,693			39,404			52,468	

1. The information presented in this table is to be used in conjunction with with the design criteria of CSA A23.3-04 Annex D.

STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

SIMPSON Strong-Tie ANCHOR SYSTEMS®

Table 2 - Strong-Bolt Anchor Tension Design Data[1]

Characteristic	Symbol	Units	Nominal Anchor Diameter										
			½ inch (12.7 mm)			⅝ inch (15.9 mm)			¾ inch (19.1 mm)			1 inch (25.4 mm)	
Embedment Depth	—	mm	70	98	127	86	130	156	105	146	191	133	248
Steel Resistance of Anchor in Tension													
Tensile Resistance of Steel	N_{sa}[6]	kN	60.1			92.9			151.8			163.8	
Resistance Modification Factor—Steel Failure	R	—	0.80[2]			0.80[2]			0.70[2]			0.80[2]	
Concrete Breakout Resistance of Anchor in Tension[10]													
Effective Embedment Depth	h_{ef}	mm	57	86	114	70	114	140	86	127	171	114	229
Critical Edge Distance[7]	C_{ac}	mm	229	200	171	279	244	210	343	298	257	457	343
Effectiveness Factor—Uncracked Concrete	k_{uncr}	—	10										
Effectiveness Factor—Cracked Concrete	k_{cr}	—	7										
Ratio of k_{uncr}/k_{cr}	$\psi_{c,N}$[9]	—	1.41										
Resistance Modification Factor—Concrete Breakout Failure	R	—	1.00[8]						0.85[8]				
Pull-Out Resistance of Anchor in Tension[11]													
Pull-Out Resistance Cracked Concrete (f'_c = 17.25 MPa)	$N_{pr,cr}$[12]	kN	—[3]	13.3[5]	13.3[5]	—[3]	23.1[4]	23.4[4]	—[3]	—[3]	43.8[5]	34.3[5]	49.8[5]
Pull-Out Resistance Uncracked Concrete (f'_c = 17.25 MPa)	$N_{pr,uncr}$[12]	kN	—[3]	18.3[5]	20.5[5]	—[3]	32.2[4]	32.5[4]	—[3]	41.9[5]	53.9[5]	37.2[5]	43.1[5]
Resistance Modification Factor—Pullout Failure	R	—	1.00						0.85				
Pull-Out Resistance of Anchor in Tension for Seismic Applications[11]													
Pull-Out Resistance of Single Anchor for Seismic Loads (f'_c = 17.25 MPa)	$N_{pr,eq}$[13]	kN	—[3]	13.3[5]	13.3[5]	—[3]	23.1[4]	23.4[4]	—[3]	—[3]	43.8[5]	34.3[5]	49.8[5]
Resistance Modification Factor—Pullout Failure	R	—	1.00						0.85				

1. The information presented in this table is to be used in conjunction with the design criteria of CSA A23.3-04 Annex D, except as modified below.
2. Refer to Clause D.5.4 to determine the appropriate value of R. The ¾ inch diameter is considered as a brittle steel element. The ½ inch, ⅝ inch, and 1 inch diameters are considered as ductile steel elements.
3. Pull-out strength is not reported since concrete breakout controls.
4. Adjust the characteristic pull-out resistance for other concrete compressive strengths by multiplying the tabular value by $(f'_{c,specified} / 17.25\ \text{MPa})^{0.7}$.
5. Adjust the characteristic pull-out resistance for other concrete compressive strengths by multiplying the tabular value by $(f'_{c,specified} / 17.25\ \text{MPa})^{0.5}$.
6. Calculate steel resistance of anchor in tension per Clause D.6.1.2. $N_{sr} = nA_{se}\phi_s f_{ut} R = nN_{sa}\phi_s R$.
7. The modification factor $\Psi_{cp,N} = 1.0$ for cracked concrete. Otherwise, the modification factor for uncracked concrete without supplementary reinforcement to control splitting is either: (1) $\Psi_{cp,N} = 1.0$ if $C_{min} \geq c_{ac}$ or (2) $\Psi_{cp,N} = \frac{C_{min}}{c_{ac}} \geq \frac{1.5h_{ef}}{c_{ac}}$ if $C_{min} < c_{ac}$. The modification factor, $\Psi_{cp,N}$ is applied to the nominal concrete breakout strength, N_{cbr} or N_{cbgr}.
8. Resistance modification factor, R, applies when the requirements of Clause D.5.4(c) for Condition B are met. If the requirements of Clause D.5.4(c) for Condition A are met, refer to Clause D.5.4 to determine the appropriate value of R.
9. Per Clause D.6.2.6, when analysis indicates cracking at service load levels, $\Psi_{c,N}$ shall be taken as 1.0.
10. For sand-lightweight concrete, in lieu of CSA A23.3-04 Clause D4.4, modify the value of N_r by multiplying all values of $\sqrt{f'_c}$ affecting N_r by 0.60. All-lightweight concrete is beyond the scope of this table.
11. For sand-lightweight concrete, modify the value of $N_{pr,cr}$ $N_{pr,uncr}$ and $N_{pr.eq}$ by 0.60. All-lightweight concrete is beyond the scope of this table.
12. The pullout resistance of anchor in tension is based on the 5% fractile result of tests performed in accordance with ACI 355.2/355.2R as per Clause D.6.3.2 of CSA A23.3-04. To ensure proper reliability, equation D-15 of CSA A23.3-04 must be multiplied by ϕ_c and R and should read as follows: $N_{cpr} = \Psi_{c,P} N_{pr} \phi_c R$
13. For seismic applications, equation D-15 of CSA A23.3-04 mustbe multiplied by ϕ_c and R and should read as follows: $N_{cpr} = \Psi_{c,P} N_{pr.eq} \phi_c R$

Table 3 - Strong-Bolt Anchor Shear Design Data[1]

Characteristic	Symbol	Units	Nominal Anchor Diameter										
			½ inch (12.7 mm)			⅝ inch (15.9 mm)			¾ inch (19.1 mm)			1 inch (25.4 mm)	
Embedment Depth	—	mm	70	98	127	86	130	156	105	146	191	133	248
Steel Resistance of Anchor in Shear													
Shear Resistance (f'_c = 17.25 MPa)	V_{sa}[4]	kN	29.2			46.6			85.9			66.8	
Resistance Modification Factor—Steel Failure	R	—	0.75[2]			0.75[2]			0.65[2]			0.75[2]	
Concrete Breakout Resistance of Anchor in Shear[5]													
Outside Diameter	d_o	mm	12.7			15.9			19.1			25.4	
Load Bearing Length of Anchor in Shear	ℓ	mm	57	86	102	70	114	127	86	127	152	114	203
Resistance Modification Factor—Concrete Breakout Failure	R	—	1.00[3]										
Concrete Pryout Resistance of Anchor in Shear[6]													
Coefficient for Pryout Strength	k_{cp}	—	1.0	2.0									
Resistance Modification Factor—Concrete Pryout Failure	R	—	1.00										
Steel Resistance of Anchor in Shear for Seismic Applications													
Shear Resistance of Single Anchor for Seismic Loads (f'_c = 17.25 MPa)	$V_{sa.eq}$[7]	kN	29.2			37.3	43.2	46.6	68.7	77.0	85.9	66.8	
Resistance Modification Factor—Steel Failure	R	—	0.75[2]			0.75[2]			0.65[2]			0.75[2]	

1. The information presented in this table is to be used in conjunction with the design criteria of CSA A23.3-04 Annex D, except as modified below.
2. Refer to Clause D.5.4 to determined the appropriate value of R. The ¾ inch diameter is considered as a brittle steel element. The ½ inch, ⅝ inch, and 1 inch diameters are considered as ductile steel elements.
3. Resistance modification factor, R, applies when the requirements of Clause D.5.4(c) for Condition B are met. If the requirements of Clause D.5.4(c) for Condition A are met, refer to Clause D.5.4 to determine the appropriate value of R.
4. Calculate steel resistance of anchor in shear per Clause D.7.1.2. $V_{sr} = nA_{se}\phi_s 0.6 f_{ut} R = nV_{sa}\phi_s R$.
5. For sand-lightweight concrete, in lieu of CSA A23.3-04 Clause D4.4, modify the value of V_r by multiplying all values of $\sqrt{f'_c}$ affecting V_r by 0.60. All-lightweight concrete is beyond the scope of this table.
6. When calculating concrete pryout resistance of anchor in shear per CSA A23.3-04 Clause D.7.3, the value of N_{cbr} or N_{cbgr} in equation D-31 or D-32 must be calculated using equation D-7 and applying the resistance modification factor, R, for shear loads.
7. For seismic applications, calculate steel resistance of anchor in shear per CSA A23.3-04 Clause D.7.1.2. $V_{sr} = nV_{sa.eq}\phi_s R$

STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

Table 4 - Strong-Bolt Anchor Tension and Shear Design Data for Normal-Weight or Sand-Lightweight Concrete Over Metal Deck[1,2]

Characteristic	Symbol	Units	Nominal Anchor Diameter			
			½ inch (12.7 mm)		⅝ inch (15.9 mm)	
Embedment Depth	—	mm	70	114	86	143
Effective Embedment Depth	h_{ef}	mm	57	102	70	127
Installation Torque	T_{inst}	N-m	54	54	54	68
Pullout Resistance, concrete on metal deck (cracked) [3,4]	$N_{pr,deck,cr}$	kN	5.9[6]	8.5	12.6	16.3
Pullout Resistance, concrete on metal deck (uncracked) [3,4]	$N_{pr,deck,uncr}$	kN	8.1[6]	11.6	16.8	21.7
Steel Strength in Shear, concrete on metal deck [5]	$V_{st.deck}$	kN	19.6[6]	29.8	27.9	39.4

1. The information presented in this table is to be used in conjunction with the design criteria of CSA A23.3-04 Annex D, except as modified below.
2. Concrete compressive strength (f'_c) shall be 20.7 MPa minimum.
3. For anchors installed in the soffit of sand-lightweight or normal-weight concrete over metal deck floor and roof assemblies, as shown in Figure A, calculation of the concrete breakout strength may be omitted.
4. In accordance with CSA A23.3-04 Clause D6.3.2, the nominal pullout strength in cracked concrete for anchors installed in the soffit of sand lightweight or normal-weight concrete over metal deck floor and roof assemblies $N_{pr,deck,cr}$ shall be substituted for $N_{pr,cr}$. Where analysis indicates no cracking at service loads, the normal pullout strength in uncracked concrete $N_{pr,deck,uncr}$ shall be substituted for $N_{pr,uncr}$.
5. In accordance with CSA A23.3-04 Clause D7.1.2 (c), the shear strength for anchors installed in the soffit of sand-lightweight or normal-weight concrete over metal deck floor and roof assemblies $V_{st,deck}$ shall be substituted for V_{sa}.
6. Values applicable to both the lower and the upper flute, see Figure A.

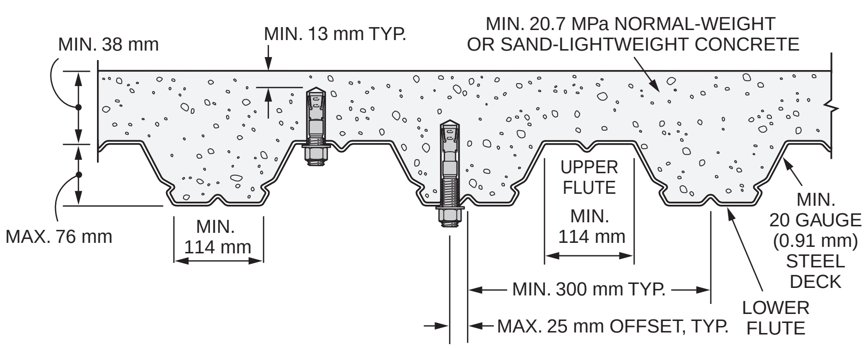
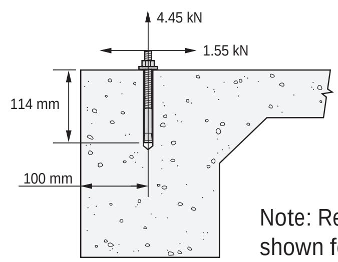


Figure A
Installation in Concrete over Metal Deck

STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

SIMPSON Strong-Tie ANCHOR SYSTEMS®

Determine if a single ½ inch diameter Strong-Bolt torque-controlled expansion anchor with a minimum 127 mm embedment (h_{ef} = 114 mm) installed 100 mm from the edge of a 300 mm deep spandrel beam is adequate for a specified tension load of 4.45 kN for wind and a reversible specified shear load of 1.55 kN for wind. The anchor will be in the tension zone, away from other anchors in f'_c = 20 MPa normal-weight concrete.



Note: Rebar not shown for clarity.

	CSA A23.3-04 Code Ref.	Tech Bulletin Table Ref.
1. Determine the Factored Tension and Shear Design Loads for Ultimate Limit States:	*8.3*	
$N_f = 1.4W = 1.4 \times 4.45 = 6.23$ kN		
$V_f = 1.4W = 1.4 \times 1.55 = 2.17$ kN		
2. Steel Resistance of Anchor in Tension:	*D.6.1*	
$N_{sa} = 60.1$ kN		*Table 2*
$\phi_s = 0.85$	8.4.3	
R = 0.80	D.5.4	*Table 2*
n = 1 (single anchor)		
Calculating for N_{sr}:		
$N_{sr} = 1 \times 0.85 \times 60.1 \times 0.80 = 40.8$ kN	Eq (D-3)	
3. Concrete Breakout Resistance of Anchor in Tension:	*D.6.2*	
$N_{cbr} = \frac{A_N}{A_{No}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_{br}$	*Eq. (D-4)*	
where:		
$N_{br} = k\phi_c\sqrt{f'_c}\, h_{ef}^{1.5} R$	*Eq. (D-7)*	
substituting:		
$N_{cbr} = \frac{A_N}{A_{No}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N}\, k\, \phi_c \sqrt{f'_c}\, h_{ef}^{1.5} R$		

	CSA A23.3-04 Code Ref.	Tech Bulletin Table Ref.
where:		
$k = k_{cr} = 7.0$	*D.6.2.2*	*Table 2*
$\Psi_{cp,N} = 1.0$	*D.6.2.7*	
$\Psi_{ed,N} = 0.7 + 0.3 \frac{c_{min}}{1.5h_{ef}}$ when $c_{min} < 1.5\, h_{ef}$	*Eq. (D-12)*	
by observation, c_{min} = 100 mm < 1.5 h_{ef}		
$\Psi_{ed,N} = 0.7 + 0.3 \frac{100}{1.5\,(114)} = 0.88$		
$\Psi_{c,N}$ = 1.0 assuming cracking at service loads ($f_t > f_r$)	*D.6.2.6*	
R = 1.00 for Condition B, Category 1 (no supplementary reinforcement provided)	*D.5.4*	*Table 2*
$\phi_c = 0.65$	*8.4.2*	
$A_{No} = 9h_{ef}^2 = 9(114)^2 = 116964$ mm^2	*Eq. (D-6)*	
c_1 = 100 mm		
$A_N = (c_1 + 1.5h_{ef})(2 \times 1.5h_{ef}) = 92682$ mm^2	*Fig. D.6*	
$\frac{A_N}{A_{No}} = \frac{92682}{116964} = 0.79$		
Calculating for N_{cbr}:		
$N_{cbr} = 0.79 \times 0.88 \times 1.0 \times 1.0 \times 7.0 \times 0.65 \times \sqrt{20} \times (114)^{1.5} \times 1.00 = 17218$ N = 17.2 kN		
4. Pullout Resistance of Anchor in Tension:	*D.6.3*	
$N_{pr} = 13.3 \times \left(\frac{20}{17.25}\right)^{0.5} = 14.3$ kN		*Table 2*
R = 1.00	*D.5.4*	*Table 2*
$\phi_c = 0.65$	*8.4.2*	
$\Psi_{c,p} = 1.0$	*D.6.3.6*	
$N_{cpr} = \Psi_{c,p} N_{pr} \phi_c R = 1.0 \times 14.3 \times 0.65 \times 1.00 = 9.3$ kN		
5. Check All Failure Modes under Tension Loading:	*D.5.1.2*	

Summary:

Steel Resistance	=	40.8 kN
Concrete Breakout Resistance	=	17.2 kN
Pullout Resistance	=	9.3 kN ← **Controls**

∴ N_r = 9.3 kN as Pullout Resistance controls > N_f = 6.23 kN – OK

	CSA A23.3-04 Code Ref.	Tech Bulletin Table Ref.
6. Steel Resistance of Anchor in Shear:	*D.7.1*	
$V_{sa} = 29.2$ kN		*Table 3*
$\phi_s = 0.85$	*8.4.3*	
R = 0.75	*D.5.4*	*Table 3*
Calculating for V_{sr}:		
$V_{sr} = 1 \times 0.85 \times 29.2 \times 0.75 = 18.6$ kN	*Eq. (D-20)*	

STRONG-BOLT™ Wedge Anchor for Cracked and Uncracked Concrete (for use with CSA A23.3-04 Annex D)

SIMPSON Strong-Tie ANCHOR SYSTEMS®

	CSA A23.3-04 Code Ref.	Tech Bulletin Table Ref.
7. Concrete breakout Resistance of Anchor in Shear:	D.7.2	
$V_{cbr} = \frac{A_V}{A_{Vo}} \Psi_{ed,V} \Psi_{c,V} V_{br}$	*Eq. (D-22)*	
where:		
$V_{br} = 0.58\left(\frac{\ell}{d_o}\right)^{0.2} \sqrt{d_o}\, \phi_c \sqrt{f'_c}\, c_1^{1.5} R$	*Eq. (D-25)*	
substituting:		
$V_{cbr} = \frac{A_V}{A_{Vo}} \Psi_{ed,V} \Psi_{c,V}\, 0.58\left(\frac{\ell}{d_o}\right)^{0.2} \sqrt{d_o}\, \phi_c \sqrt{f'_c}\, c_1^{1.5} R$		
where:		
R = 1.00 for Condition B (no supplementary reinforcement provided)	*D.5.4*	*Table 3*
$A_{Vo} = 4.5c_1^2 = 4.5(100)^2 = 45000\ mm^2$	*Eq. (D-24)*	
$A_V = 2(1.5c_1)(1.5c_1) = 2(1.5(100))(1.5(100)) = 45000\ mm^2$		*Fig.D.9*
$\frac{A_V}{A_{Vo}} = \frac{45000}{45000} = 1$		
$\Psi_{ed,V} = 1.0$ since $c_2 > 1.5c_1$	*Eq. (D-29)*	
$\Psi_{c,V} = 1.0$ assuming cracking at service loads ($f_t > f_r$)	*D.7.2.7*	
$d_o = 12.7$ mm		*Table 1*
$\ell = h_{ef}$ for anchors with a constant stiffness over the full length of the embedded section.		
However, in no case shall ℓ exceed $8d_0$.		
$h_{ef} = 114.3$ mm		
$\ell = 8d_0 = 8\ (12.7) = 102$ mm	*D.3*	*Table 3*
$c_1 = 100$ mm		

$$V_{cbr} = 1 \times 1.0 \times 1.0 \times 0.58 \times \left(\frac{102}{12.7}\right)^{0.2} \times \sqrt{12.7} \times 0.65 \times \sqrt{20} \times (100)^{1.5} \times 1.0 = 9107\ N = 9.1\ kN$$

	CSA A23.3-04 Code Ref.	Tech Bulletin Table Ref.
8. Concrete Pryout Resistance of Anchor in Shear:	D.7.3	
$V_{cpr} = k_{cp} N_{cbr}$	*Eq. (D-31)*	
where:		
$N_{cbr} = 17.2$ kN		
R = 1.00	*D.5.4.*	*Table 3*
$k_{cp} = 2.0$	*D.7.3*	*Table 3*
$k_{cp} N_{cbr} = 2.0 \times 17.2 \times \frac{1.00}{1.00} = 34.4$ kN	*D.7.3*	
$V_{cpr} = 34.4 \times 1.0 = 34.4$ kN		
9. Check All Failure Modes under Shear Loading:	*D.5.1.2*	

Summary:

Steel Resistance = 18.6 kN

Concrete Breakout Resistance = 9.1 kN ⟵ **Controls**

Pryout Resistance = 34.4 kN

∴ V_r = 9.1 kN as Concrete Breakout Resistance controls > V_f = 2.17 kN – OK

	CSA A23.3-04 Code Ref.
10. Check Interaction of Tension and Shear Forces:	*D.8*
If $0.2\ V_r \geq V_f$, then the full tension design strength is permitted.	*D.8.2*
By observation, this is not the case.	
If $0.2\ N_r \geq N_f$, then the full shear design strength is permitted	*D.8.3*
By observation, this is not the case.	
Therefore:	
$\frac{N_f}{N_r} + \frac{V_f}{V_r} \leq 1.2$	*Eq. (D-35)*

$$\frac{6.23}{9.3} + \frac{2.17}{9.1} = 0.67 + 0.24 = 0.91 < 1.2 \text{ – OK}$$

11. Summary

A single ½ in. diameter Strong-Bolt anchor at a 127 mm embedment depth is adequate to resist the applied specified tension and shear loads of 4.45 kN and 1.55 kN, respectively.

This technical bulletin is effective until June 30, 2010, and reflects information available as of April 1, 2008. This information is updated periodically and should not be relied upon after June 30, 2010; contact Simpson Strong-Tie for current information and limited warranty or see www.strongtie.com.

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