ICC-ES Evaluation Report

ESR-3173

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

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EVALUATION SUBJECT:

MKT SZ CARBON STEEL HIGH LOAD ANCHORS FOR 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)
- 2000 *International Building Code®* (2000 IBC)
- 2000 *International Residential Code®* (2000 IRC)
- 1997 *Uniform Building Code™* (UBC)

Property evaluated:

Structural

2.0 USES

The MKT SZ High Load Anchor is used to resist static, wind, or seismic tension and shear loads in cracked and uncracked normal-weight or 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 anchoring system complies with 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, Sections 1912 and 1913 of the 2000 IBC and Section 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, and Section R301.1.2 of the 2000 IRC.

3.0 DESCRIPTION

3.1 MKT SZ:

3.1.1 General: The MKT SZ Carbon Steel High Load Anchor, designated as the SZ, is a torque-set, sleeve-type mechanical expansion anchor. The SZ is comprised of seven components which vary slightly according to anchor diameter, as shown in Figures 1A and 1B of this report. It is available in two head configurations, illustrated in Figures 1A and 1B.

All carbon steel parts receive a minimum 0.0002-inch-thick (5 μm) galvanized zinc coating according to EN ISO 4042.

Dimensions and installation criteria are set forth in Table 1. This anchor is manufactured using metric units.

3.1.2 SZ-B (Stud Style, Figure 1A): The anchor consists of a threaded rod, hexagon nut, steel washer, distance sleeve, collapsible ring, steel expansion sleeve and threaded cone. This anchor is available in carbon steel only. The material specifications are as follows:

- Threaded rod: steel, strength class 8.8, EN ISO 898-1
- Hexagon nut: steel, strength class 8, EN 20898-2
- Washer: steel, EN 10139
- Distance sleeve: precision steel tubes DIN 2394/2393
- Ring: polyethylene
- Expansion sleeve: steel, EN 10139
- Threaded cone: steel, strength class 8, EN 20898-2

Application of torque at the head of the anchor causes the cone to be drawn into the expansion sleeve. This in turn causes the sleeve to expand against the wall of the drilled hole. Application of the specified installation torque induces a tension force in the stud that is equilibrated by a precompression force in the concrete acting through the component being fastened. Deformation of the collapsible ring prevents buildup of precompression in the distance sleeve in cases where the sleeve is in contact with the washer, and permits the closure of gaps between the concrete and the component being fastened. Application of tension loads that exceed the precompression force in the bolt will cause the cone to displace further into the expansion sleeve (follow-up expansion), generating additional expansion force.

3.1.3 SZ-S (Bolt Style, Figure 1B): The anchor has the same components and material specifications as the SZ-B with the exception that the threaded rod and hexagonal nut are replaced by a hexagon head screw made of carbon steel per EN ISO 898-1, strength class 8.8.

3.2 Concrete:

Normal-weight and sand-lightweight concrete must comply with Sections 1903 and 1905 of the IBC or the UBC, as applicable.

4.0 DESIGN AND INSTALLATION:

4.1 Strength Design:

Design strength of anchors complying with the 2009, 2003 and 2000 IBC and the 1997 UBC, as well as Section 301.1.3 of the 2009, 2003 and 2000 IRC, must be determined in accordance with ACI 318-08 Appendix D and this report.

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

Design parameters provided in Tables 2 and 3 are based on the 2009 IBC (ACI 318-08) unless noted otherwise in Sections 4.1.1 through 4.1.11 and in Tables 2 and 3 of this report. The anchor design must satisfy the requirements in ACI 318 Section 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, Section 9.2 of ACI 318, or Section 1612.1 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. Strength reduction factors, ϕ, corresponding to brittle steel elements must be used. An example calculation is provided in Figure 3 of this report.

4.1.1 Requirements for Static Steel Strength in Tension: The nominal steel strength of a single anchor in tension, N_{sa}, in accordance with ACI 318 D.5.1.2, is provided in Table 2 of this report. Strength reduction factors, ϕ_{sa}, corresponding to brittle steel elements as described in Table 2 must be used.

4.1.2 Requirements for Static Concrete Breakout Strength in Tension: The nominal concrete breakout strength of a single anchor or group of anchors in tension, N_{cb} and N_{cbg}, respectively, must be calculated according to 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.5.2.2 using the values of h_{ef} and k_{cr} as given in Table 2. The value of f'_c used in the calculations must be limited to a maximum of 8,000 psi (5.2 MPa), in accordance with ACI 318 D.3.5. The nominal concrete breakout strength in tension in regions where analysis indicates no cracking at service loads 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 2.

4.1.3 Requirements for Static Pullout Strength in Tension: Since there are no values for $N_{p,cr}$ or $N_{p,uncr}$ provided in Table 2, the pullout strength in tension does not need to be considered.

4.1.4 Requirements for Static Steel Shear Capacity: The nominal steel strength in shear, V_{sa}, of a single anchor in accordance with ACI 318 D.6.1.2, is given in Table 3 of this report and must be used in lieu of values derived by calculation from ACI 318, Eq. D-20. Strength reduction factors, ϕ_{sa}, corresponding to brittle steel elements as described in Table 3 must be used.

4.1.5 Requirements for Static Concrete Breakout Strength of Anchors in Shear, V_{cb} or V_{cbg}: The nominal concrete breakout strength for a single anchor or group of anchors in shear, V_{cb} and V_{cbg}, respectively, must be calculated in accordance with ACI 318 D.6.2, with modifications as described in this section. The basic concrete breakout strength in shear, V_b, must be calculated in accordance with ACI 318 D.6.2.2 using the values of l_e and d_a described in Table 3 of this report. The value of f'_c used for calculation purposes must not exceed 8,000 psi (55.2 MPa) in accordance with ACI 318 D.3.5.

4.1.6 Requirements for Static Concrete Pryout Strength of Anchor in Shear, V_{cp} or V_{cpg}: Static nominal concrete pryout shear strength for a single anchor or group of anchors, V_{cb} and V_{cbg}, respectively, must be calculated in accordance with ACI 318 Section D.6.3, modified by using the value of k_{cp} described in Table 3 of this report and the value of N_{cb} or N_{cbg} as calculated in accordance with Section 4.1.2 of this report.

4.1.7 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 of this report must be used. Intermediate values between s_{min} and c_{min} can be calculated by linear interpolation. Figure A of this report provides more detail.

4.1.8 Requirements for Critical Edge Distance: In applications where $c < c_{ac}$ and supplemental reinforcement to control splitting of the concrete is not present, the concrete breakout strength in tension for uncracked concrete, calculated according to ACI 318 D.5.2, must be further multiplied by the factor $\psi_{cp,N}$ given by Eq-1:

$$\Psi_{cp,N}=\frac{c}{c_{ac}} \quad \text{(Eq-1)}$$

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 using ACI 318 D.8.6, values of c_{ac} provided in Table 2 must be used.

In lieu of ACI 318 D.8.6, the critical edge distance, c_{ac}, required to develop the basic concrete breakout strength of a post-installed anchor in uncracked concrete without supplementary reinforcement, given in Table 2, must be used.

4.1.9 Requirements for Seismic Design: 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, Section 1908.1.16 of the 2006 IBC, or the following:

CODE	ACI 318 D.3.3 SEISMIC REGION	CODE EQUIVALENT DESIGNATION
2003 and 2000 IBC and 2003 and 2000 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 the nominal concrete breakout strength for anchors in tension, and the nominal concrete breakout strength and pryout strengths for anchors in shear, must be calculated according to ACI 318 D.5 and D.6, respectively, taking into account the corresponding values given in Table 2 or 3 of this report. The nominal steel strength for anchors in shear, $V_{sa,eq}$, must be evaluated with the values given in Table 3. Since there are no values for $N_{p,eq}$ given in Table 2, the pullout strength in tension does not need to be considered.

The anchors comply with ACI 318 D.1 as brittle steel elements and must be designed in accordance with ACI 318-08 D.3.3.5 or D.3.3.6 or ACI 318-05 D.3.3.5, as applicable. If no values for $N_{pn,eq}$ are given in Table 2, the static design strength values govern. (See Section 4.1.3 of this report.)

4.1.10 Sand-lightweight Concrete: For ACI 318-08, when anchors are used in sand-lightweight concrete, the modification factor λ for concrete breakout strength must be taken as 0.6.

For ACI 318-05, the values N_b, and V_b determined in accordance with this report must be multiplied by 0.60, in lieu of ACI 318 D.3.4.

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

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, must be established using the following relationships:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha} \qquad \text{(Eq-2)}$$

and

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha} \qquad \text{(Eq-3)}$$

where:

$T_{allowable,\ ASD}$ = Allowable tension load (lbf or N).

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

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

ϕV_n = The lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318 Appendix 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 kN).

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

The requirements for member thickness, edge distance and spacing, as described in this report, must apply. Allowable stress design loads for selected cases are provided in Table 4. An example calculation is provided in Figure 3.

4.2.2 Interaction of Tensile and Shear Forces: Interaction of tensile and shear loads must be calculated as follows:

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

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

For all other cases:

$$\frac{T_{applied}}{T_{allowable,ASD}} + \frac{V_{applied}}{V_{allowable,ASD}} \leq 1.2 \qquad \text{(Eq-4)}$$

4.3 Installation:

Installation parameters are provided in Table 1 and in Figure 2 of this report. Anchors must be installed per the manufacturer's published instructions and this report. Anchor locations must comply with this report and plans and specifications approved by the code official. Anchors must be installed in holes drilled using carbide-tipped drill bits given in Table 1. The nominal bit diameter must be equal to the nominal anchor size. The minimum drilled hole depth is given in Table 1. Prior to anchor installation, dust and debris must be removed from the hole using a hand pump, compressed air or a vacuum. The anchor must be driven into the predrilled hole until the proper nominal embedment depth is achieved. The anchor is tightened until the installation torque, T_{inst}, specified in Table 1 is achieved.

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, 2003 and 2000 IBC, or Section 1701.5.2 of UBC, as applicable. 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 procedures, edge distance(s), anchor spacing(s), concrete thickness, embedment depth, tightening torque and adherence to the manufacturer's 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 and 1706 must be observed, where applicable.

5.0 CONDITIONS OF USE

The MKT SZ Carbon Steel High Load 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 Anchor sizes, dimensions, and installation parameters are as set forth in this report.

5.2 The anchors must be installed in accordance with the manufacturer's published instructions and this report. In case of conflicts, this report governs.

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

5.4 The values of f'_c used for calculation purposes must not exceed 8,000 psi (55.1 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, edge distance, and minimum member thickness must comply with Table 1.

5.8 Prior to installation, calculations and details justifying that the applied loads comply with this report must be submitted to the code official for approval. 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 ICC-ES acceptance criteria for evaluating data to determine the performance of expansion anchors subjected to fatigue or shock loading is unavailable at this time, the use of these anchors under such conditions is beyond the scope of this report.

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

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

5.12 Where not otherwise prohibited in the code, MKT SZ 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 inspections are provided in accordance with Section 4.4 of this report.

5.15 Anchors are manufactured in Weilerbach, Germany, under a quality control program with inspections by Underwriters Laboratories Inc. (AA-668).

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193), dated February 2010, for use in cracked and uncracked concrete; and quality control documentation.

7.0 IDENTIFICATION

Anchors are identified by packaging labeled with the anchor name and size, the manufacturer's name (MKT) and contact information, the evaluation report number (ICC-ES ESR-3173), and the name of the inspection agency (Underwriters Laboratories). The MKT SZ anchors have the letters SZ embossed on the distance sleeve.

TABLE 1—SZ INSTALLATION INFORMATION[1]

SETTING INFORMATION	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER	
			M16	M20
Anchor Outside Diameter	$d_a(d_o)$[5]	in. (mm)	0.93 (23,5)	1.08 (27,5)
Drill Bit Diameter	d_{bit}	in. (mm)	0.95 (24)	1.10 (28)
Cutting Diameter of Drill Bit	$d_{bit,min}$	in. (mm)	0.949 (24.10)	1.106 (28.10)
	$d_{bit,max}$	in. (mm)	0.967 (24.55)	1.124 (28.55)
Minimum Hole Depth	h_0	in. (mm)	5.12 (130)	6.3 (160)
Minimum Base Plate Clearance Hole Diameter [2]	d_c	in. (mm)	1.02 (26)	1.22 (31)
Installation Torque (Carbon Steel)	T_{inst}	ft-lbf (N-m)	118 (160)	207 (280)
Embedment Depth	h_{nom}	in. (mm)	4.65 (118)	5.83 (148)
Effective Embedment Depth	h_{ef}	in. (mm)	3.94 (100)	4.92 (125)
Minimum Edge Distance	c_{min1}	in. (mm)	4.7 (120)	7.1 (180)
Minimum Spacing[3]	s_{min1}	in. (mm)	12.6 (320)	21.3 (540)
Minimum Edge Distance	c_{min2}	in. (mm)	7.1 (180)	11.8 (300)
Minimum Spacing[4]	s_{min2}	in. (mm)	3.9 (100)	4.9 (125)
Minimum Concrete Thickness	h_{min}	in. (mm)	7.9 (200)	9.8 (250)

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

[1]The information presented in this table must be used in conjunction with the design requirements of ACI 318 Appendix D.
[2]The clearance must comply with applicable code requirements for the connected element.
[3]s_{min1} applies when c_{min1} is provided.
[4]s_{min2} applies when c_{min2} is provided.
[5]The notation in parenthesis is for the 2006 IBC.

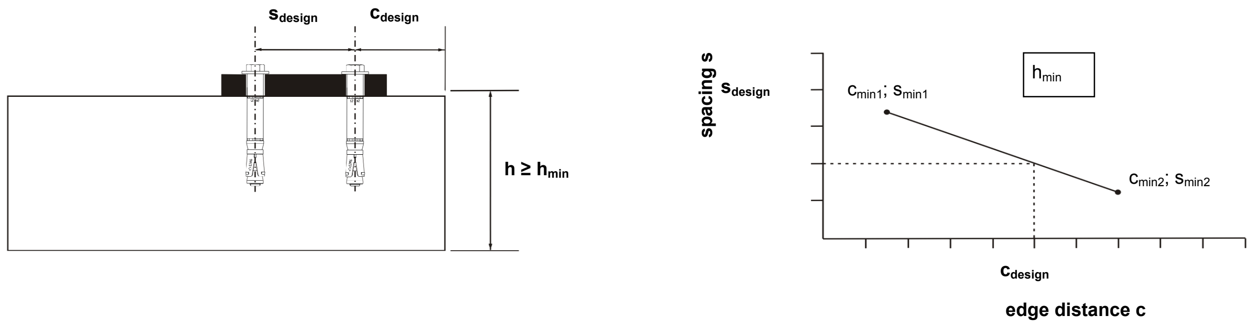


FIGURE A—EXAMPLE OF ALLOWABLE INTERPOLATION OF MINIMUM EDGE DISTANCE AND MINIMUM SPACING

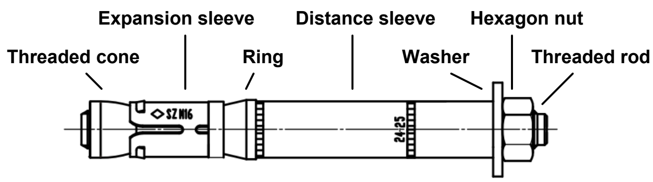


FIGURE 1A—MKT SZ-B

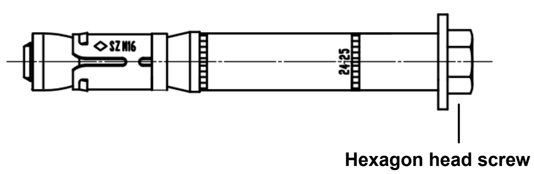
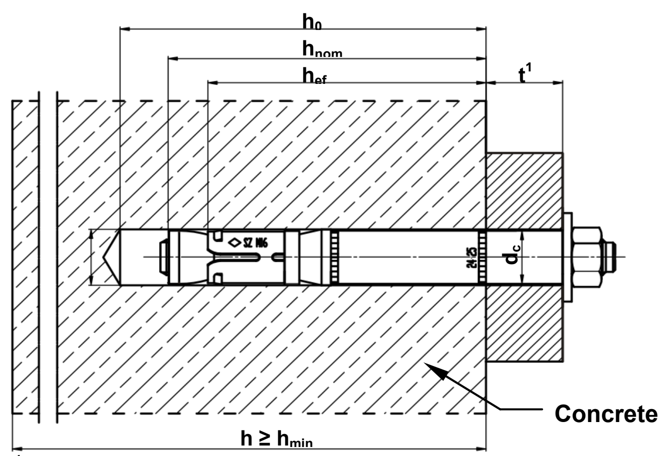


FIGURE 1B—MKT SZ-S



[1] Thickness of base plate

FIGURE 2—MKT SZ ANCHOR (INSTALLED)

TABLE 2—SZ CHARACTERISTIC TENSION STRENGTH DESIGN INFORMATION[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER	
			M16	**M20**
Anchor Category	1,2 or 3	-	1	1
Embedment Depth	h_{nom}	in. (mm)	4.65 (118)	5.83 (148)
Steel Strength in Tension (ACI 318 D.5.1)				
Specified Yield Strength	f_{ya}	psi (N/mm²)	92,888 (640)	92,888 (640)
Specified Tensile Strength	f_{uta}	psi (N/mm²)	116,110 (800)	116,110 (800)
Effective Tensile Stress Area	$A_{se,N}$ (A_{se})[7]	in^2 (mm²)	0.2429 (156,7)	0.3794(244,8)
Tension Resistance of Steel	N_{sa}	lbf (kN)	28,171(125.4)	44,009 (195,8)
Strength Reduction Factor-Steel Failure[2]	ϕ_{sa}	-	0.65	0.65
Concrete Breakout Strength in Tension (ACI 318 D.5.2)				
Effective Embedment Depth	h_{ef}	in. (mm)	3.94 (100)	4.92 (125)
Critical Edge Distance	c_{ac}	in. (mm)	9.1 (230)	11.3 (288)
Effectiveness Factor-Uncracked Concrete	k_{uncr}	-	27 (11.3)	27 (11.3)
Effectiveness Factor-Cracked Concrete	k_{cr}	-	21 (8.8)	21 (8.8)
Modification Factor for Cracked and Uncracked Concrete	$\Psi_{c,N}$[6]	-	1.0	1.0
Strength Reduction Factor-Concrete Breakout Failure[3]	ϕ_{cb}	-	0.65	0.65
Pull-Out Strength in Tension (ACI 318 D.5.3)				
Pull-Out Resistance Cracked Concrete (f'_c = 2,500 psi)	$N_{pn,cr}$	lbf (kN)	N/A[4]	N/A[4]
Pull-Out Resistance Uncracked Concrete (f'_c = 2,500 psi)	$N_{pn,uncr}$	lbf (kN)	N/A[4]	N/A[4]
Tension Strength for Seismic Applications (ACI 318 D.3.3.3)				
Tension Resistance of Single Anchor for Seismic Loads (f'_c = 2,500 psi)	$N_{pn,eq}$	lbf (kN)	N/A[4]	N/A[4]
Axial Stiffness in Service Load Range, Cracked Concrete[5]	β_{cr}	lb/in. (kN/mm)	57,102 (10)	142,754 (25)
Axial Stiffness in Service Load Range, Uncracked Concrete[5]	β_{uncr}	lb/in. (kN/mm)	114,203 (20)	485,364 (85)

For **SI:** 1 inch = 25.4mm, 1lbf = 0.00445kN, 1 lb/in = 0.175 N/mm, 1 psi = 0.00689 N/mm², 1 in^2 = 645 mm^2.

[1]The information presented in this table must be used in conjunction with the design requirements of ACI 318 Appendix D.
[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 18 9.2 are used. If the load combinations of Section 1909.2 of the UBC or ACI 318 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318 D.4.5. The M16 and M20 diameter anchors are brittle steel elements as defined in ACI 318 D.1.
[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used and the requirements of ACI 318 D.4.4(c) for Condition B are satisfied. For installations where complying supplementary reinforcement can be verified, the ϕ_{cb} factors described in ACI 318 D.4.4 for Condition A are allowed. If the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used and the requirements of ACI 318 D.4.4 for Condition A are satisfied, the appropriate value of ϕ_{cb} must be determined in accordance with ACI 318 D.4.4(c). If the load combinations of ACI 318 Appendix C or Section 1902. 2 of the UBC are used, the appropriate value of ϕ_{cb} must be determined in accordance with ACI 318 D.4.5.
[4]As described in Section 4.1.3 of this report, N/A (Not Applicable) denotes that pullout resistance is not critical and does not need to be considered.
[5]Minimum axial stiffness value, maximum values may be larger (e.g., due to high-strength concrete).
[6]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.
[7]The notation in parentheses is for the 2006 IBC.

TABLE 3—SZ CHARACTERISTIC SHEAR STRENGTH DESIGN INFORMATION[1]

CHARACTERISTIC	SYMBOL	UNITS	NOMINAL ANCHOR DIAMETER			
			M16		M20	
Anchor type			SZ-B	SZ-S	SZ-B	SZ-S
Anchor Category	1,2 or 3	-	1		1	
Embedment Depth	h_{nom}	in. (mm)	4.65 (118)		5.83 (148)	
Steel Strength in Shear (ACI 318 D.6.1)						
Shear Resistance of Steel	V_{sa}	lb (kN)	19,100 (85)	21,600 (96)	22,400 (100)	27,600 (123)
Strength Reduction Factor-Steel Failure[2]	ϕ_{sa}	-	0.60		0.60	
Concrete Breakout Strength in Shear (ACI 318 D.6.2)						
Anchor Outside Diameter	d_a	in. (mm)	0.93 (23.5)		1.08 (27.5)	
Load Bearing Length of Anchor in Shear	l_e	in. (mm)	1.85 (47)		2.17 (55)	
Strength Reduction Factor-Concrete Breakout Failure[3]	ϕ_{cb}	-	0.70		0.70	
Concrete Pryout Strength in Shear (ACI 318 D.6.3)						
Coefficient for Pryout Strength	k_{cp}	-	2		2	
Strength Reduction Factor-Concrete Pryout Failure[4]	ϕ_{cp}	-	0.70		0.70	
Shear Strength for Seismic Applications (ACI 318 D.3.3.3)						
Shear Resistance of Single Anchor for Seismic Loads (f'_c = 2,500 psi)	$V_{sa,eq}$	lb (kN)	13,488 (60)		22,480 (100)	
Strength Reduction Factor-Steel Failure	ϕ_{eq}	-	0.60		0.60	

For **SI:** 1 inch = 25.4mm, 1 lbf = 0.00445 kN, 1 psi = 0.00689 N/mm², 1 in^2 = 645 mm^2.

[1]The information presented in this table must be used in conjunction with the design criteria of ACI 318 Appendix D.
[2]The tabulated value of ϕ_{sa} applies when the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used and the requirements of ACI 318 D.4.4(c) for Condition B are satisfied. If the load combinations of Section 1909.2 of the UBC or ACI 318 Appendix C are used, the appropriate value of ϕ_{sa} must be determined in accordance with ACI 318 D.4.5. The M16 and M20 diameter anchors are brittle steel elements as defined in ACI 318 D.1.1.
[3]The tabulated value of ϕ_{cb} applies when both the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used and the requirements of ACI 318 D.4.4(c) for Condition B are satisfied. Condition B applies where supplementary reinforcement is not provided or where pryout strength governs. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318 D.4.4 for Condition A are allowed. If the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used and the requirements of ACI 318 D.4.4 for Condition A are satisfied, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4(c). If the load combinations of ACI 318 Appendix C or Section 1909.2 of the UBC are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.5.
[4]The tabulated value of ϕ_{cp} applies when both the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used and the requirements of ACI 318 D.4.4(c) for Condition B are satisfied. Condition B applies where supplementary reinforcement is not provided or where pryout strength governs. For installations where complying supplementary reinforcement can be verified, the ϕ factors described in ACI 318 D.4.4 for Condition A are allowed. If the load combinations of ACI 318 Appendix C or Section 1909.2 of the UBC are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.5.

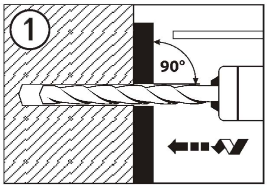
TABLE 4—EXAMPLE ALLOWABLE STRESS DESIGN VALUES FOR ILLUSTRATIVE PURPOSES[1,2,3,4,5,6,7]

Nominal Anchor Diameter	Embedment Depth, h_{nom}	Effective Embedment Depth, h_{ef}	Allowable Tension Load, $\phi N_n / \alpha$
	in (mm)	in (mm)	lbf (kN)
M16	4.65 (118)	3.94 (100)	4,117 (18.3)
M20	5.83 (148)	4.92 (125)	5,753 (25.6)

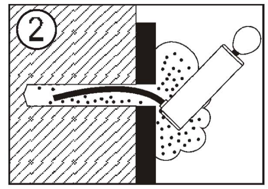
For **SI:** 1 inch = 25.4 mm, 1 lbf = 0.00445 kN.

[1]Single anchor with static tension load only
[2]Concrete determined to remain uncracked for the life of the anchorage
[3]Load combination from ACI 318 Section 9.2 (no seismic loading) with ϕ_{sa} = 0.75, ϕ_{cb} = 0.65, and ϕ_p = 0.65.
[4]30% dead load and 70 % live load. Controlling load combination is 1.2D + 1.6L. Calculation of α based on weighted average: α = 0.3*1.2 + 0.7*1.6 = 1.48
[5]f'_c = 2,500 psi (normal weight concrete)
[6]$c_{a1} = c_{a2} \geq c_{ac}$
[7]$h \geq h_{min}$

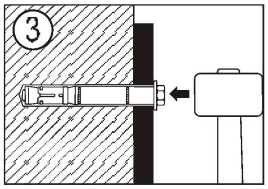
INSTALLATION INSTRUCTIONS



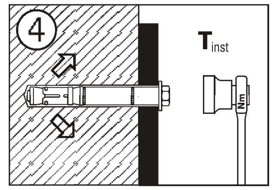
Step1: Select the correct diameter Metric bit, drill hole to minimum required hole depth or deeper.



Step 2:
Remove drilling debris with a blowout bulb or with compressed air.

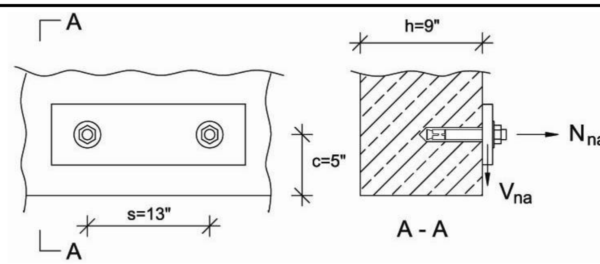


Step 3:
Using a hammer, tap the anchor through the part being fastened into the drilled hole until the washer is in contact with the fastened part. Do not expand Anchor by hand prior to installation.



Step 4:
Using a torque wrench, apply the specified installation torque.

Determine if two M16 diameter SZ-B (Stud) carbon steel High Load anchors with an effective embedment depth h_{ef} = 3.94 inches installed 13 inches from center to center and 5 inches from the edge of a 9 inch deep slab is adequate for a service tension load of 4,000 lb. (live load) and a reversible service shear load of 2,000 lb. (live load). The anchor group will be in the tension zone, away from other anchors in f'_c = 3,000 psi normal–weight concrete.



	ACI318-08 Code Ref.	Report Ref.

1. Verify minimum Member Thickness, Spacing and Edge Distance:

h = 9 in. ≥ h_{min} = 7.9 in. o.k. — Table 1

s = 13 in. ≥ s_{min} = 12.6 in. o.k. — Table 1

$c_{a,\,min}$ = 5 in. ≥ c_{min} = 4.7 in. o.k. — Table 1

2. Determine the Factored Tension and Shear Design Loads: — 9.2.1

N_{ua} = 1.6 L = 1.6 x 4,000 = 6,400 lb.

V_{ua} = 1.6 L = 1.6 x 2,000 = 3,200 lb.

3. Steel Capacity under Tension Loading: — D.5.1

N_{sa} = 28,171 — Table 2

ϕ = 0.65 — Table 2

n = 2 (double anchor group)

Calculating for ϕN_{sa} :

ϕN_{sa} = 0.65 x 2 x 28,171 = 36,622 lb.

4. Concrete Breakout Capacity under Tension Loading — D.5.2

$$N_{cbg}=\frac{A_{Nc}}{A_{Nco}}\Psi_{ec,N}\Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}N_b$$ Eq.(D-5)

where:

$$N_b=k_c\lambda\sqrt{f'_c}h_{ef}^{1.5}$$ Eq.(D-7)

with $k_c = k_{cr}$ = 21 — Table 2

$\lambda = 1.0$ for normal-weight concrete

$\Psi_{ec,N}$=1.0 since eccentrically e'_N= 0 — Eq.(D-9)

$$\Psi_{ed,N}=0.7+0.3\frac{C_{a,min}}{1.5h_{ef}} \text{ when } C_{a,min}\le 1.5h_{ef}$$ Eq.(D-11)

$\Psi_{ed,N}$=0.7+0.3$\frac{c_{a,min}}{1.5h_{ef}}$ when $c_{a,min}$≤1.5h_{ef}

by observation $c_{a,min}$=3<1.5h_{ef} = 5.91 in.

$$\Psi_{ed,N}=0.7+0.3\frac{(5)}{1.5(3.94)}=0.95$$

$\Psi_{c,N}$ = 1.0 assuming cracking at service loads ($f_t > f_r$) — D.5.2.6

$\Psi_{cp,N}$ = 1.0 designed for cracked concrete — D.5.2.7

calculating for $\frac{A_{Nc}}{A_{Nco}}$

$A_{Nco} = 9h_{ef}^2 = 9(3.94)^2$ = 139.71 In.^{2} — Eq. (D-6)

A_{Nc} = (c_{a1}+1.5 h_{ef}) (2x 1.5 h_{ef} + s_1)
= (5 + 1.5x 3.94) (2x 1.5 x 3.94 +13)
= 270.8 in.^{2} — Fig. RD.5.2.1 b

$$\frac{A_{Nc}}{A_{Nco}}=\frac{270.8\text{ in.}^2}{139.71\text{ in.}^2}=1.94$$

FIGURE 3—SZ EXAMPLE CALCULATION

	ACI318-08 Code Ref.	Report Ref.

Calculating for N_b and N_{cbg}:

$N_b = 21 \times 1.0 \times \sqrt{3{,}000} \times (3.94)^{1.5}$
$= 8{,}995$ lb.

$N_{cbg} = 1.94 \times 1.0 \times 0.95 \times 1.0 \times 1.0 \times 8{,}995$
$= 16{,}579$ lb.

ϕ = 0.65 for Condition B

(no supplementary reinforcement provided) — Table 2

$\phi N_{cb} = 0.65 \times 16{,}579 = 10{,}776$ lb.

5. Pullout Capacity — D.5.3

not decisive — Table 2

6. Check all Failure Modes under Tension Loading: — D.4.1.2

Summary:

Steel Capacity	=	36,622 lb
Concrete Breakout Capacity	=	10,776 lb. ← **Controls**
Pullout Capacity	=	not decisive

ϕN_n = 10,776 lb. as Concrete Breakout Capacity controls
> N_{ua} = 6,400 lb. - OK

7. Steel Capacity under Shear Loading: — D.6.1

Calculating for ϕV_{sa}:

V_{sa} = 2 x 19,100= 38,200 lb. — Table 3
ϕ = 0.65 — Table 3
ϕV_{sa} = 0.65 x 38,200 = 24,830 lb.

8. Concrete Breakout Capacity under Shear Loading: — D.6.2

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \Psi_{ec,V} \Psi_{ed,V} \Psi_{c,V} V_b$$ — Eq. (D-24)

where:

$$V_b = 7\left(\frac{l_e}{d_a}\right)^{0.2} \sqrt{d_a}\sqrt{f'_c}\, c_{a1}^{1.5}$$ — Eq. (D-24)

$\Psi_{ec,V}$ = 1.0 since eccentricity $e'_V = 0$ — Eq. (D-26)

$\Psi_{ed,V}$ = 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

calculating for $\frac{A_{Vc}}{A_{Vc0}}$

h = 9 > 1.5 c_{a1} = 1.5 x 5 = 7.5 in.

A_{Vc} = (2(1.5c_{a1}) + s_1) 1.5c_{a1}
= (2 x 1.5 x 5 + 13) x 1.5 x 5
= 210 in.^{2} — Fig. RD.6.2.1 b

A_{Vc0} = 4.5 $(c_{a1})^2$ = 4.5 x 5^2 = 112.5 in.^{2} — Eq. (D-23)

$$\frac{A_{Vc}}{A_{Vc0}} = \frac{210}{112.5} = 1.87$$ — D.6.2.1

calculating for V_b and ϕV_{cbg}

d_a = 0.93 in. — Table 3

$l_e = 2d_a$ = 1.85 in. — D.6.2.2

c_{a1} = 5 in.

ϕ = 0.70 for Condition B — Table 3

(no supplementary reinforcement provided)

$V_b = 7 \times \left(\frac{1.85}{0.93}\right)^{0.2} \times \sqrt{0.93} \times \sqrt{3{,}000} \times 5^{1.5}$ = 4,749lb.

$\phi V_{cbg} = 0.70 \times 1.87 \times 1.0 \times 1.0 \times 1.0 \times 4{,}479$
$= 6{,}216$ lb

9. Concrete Pryout Strength: — D.6.3

$V_{cpg} = k_{cp} N_{cbg}$

Where:
$k_{cp} = 2.0$ for $h_{ef} \geq 2.0$
$\phi = 0.70$ for condition B — Table 3
$\phi V_{cpg} = 0.70 \times 2.0 \times 16{,}579 = 23{,}211$ lb.

10. Check all Failure Modes under Shear Loading: — D.4.1.2

Summary:

Steel Capacity	=	24,830 lb.
Concrete Breakout Capacity	=	6,216 lb. ← **Controls**
Pryout Capacity	=	23,211 lb.

ϕV_n = 6,216 lb. as Concrete Breakout Capacity controls
> V_{ua} = 3,000 lb. – OK

11. 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

$$\frac{N_{ua}}{\Phi N_n} + \frac{V_{ua}}{\Phi V_n} \leq 1.2$$

$$\frac{6{,}400}{10{,}776} + \frac{3{,}200}{6{,}216} = 0.59 + 0.51 = 1.10 \leq 1.2\text{-OK}$$

12. Summary
Two M16 diameter SZ High Load anchors at 3.94 in. effective embedment depth are adequate to resist the applied service tension and shear loads of 4,000 lb. and 2,000 lb., respectively.

FIGURE 3—SZ EXAMPLE CALCULATION (Continued)