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DIVISION: 03—CONCRETE
Section: 03151—Concrete Anchoring

REPORT HOLDER:

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EVALUATION SUBJECT:

HILTI KWIK BOLT TZ CARBON AND STAINLESS STEEL ANCHORS IN CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

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

Property evaluated:

Structural

2.0 USES

The Hilti Kwik Bolt TZ anchor (KB-TZ) is used to resist static, wind, and seismic tension and shear loads 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 metal deck having a minimum specified compressive strength, f'_c, of 3,000 psi (20.7 MPa). The anchoring system is an alternative to cast-in-place anchors described in Sections 1911 and 1912 of the 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 IRC.

3.0 DESCRIPTION

KB-TZ anchors are torque-controlled, mechanical expansion anchors. KB-TZ anchors consist of a stud (anchor body), wedge (expansion elements), nut, and washer. The anchor (carbon steel version) is illustrated in Figure 1. The stud is manufactured from carbon or stainless steel materials with corrosion resistance equivalent to Type 304 stainless steel. Carbon steel KB-TZ anchors have a minimum 5 μm (0.00002 inch) zinc plating. The expansion elements for the carbon and stainless steel KB-TZ anchors are fabricated from stainless steel with corrosion resistance equivalent to Type 316 stainless steel. The hex nut for carbon steel conforms to ASTM A 563-04, Grade A, and the hex nut for stainless steel conforms to ASTM F 594.

The anchor body is comprised of a high-strength rod threaded at one end and a tapered mandrel at the other end. The tapered mandrel is enclosed by a three-section expansion element which freely moves around the mandrel. The expansion element movement is restrained by the mandrel taper and by a collar. The anchor is installed in a predrilled hole with a hammer. When torque is applied to the nut of the installed anchor, the mandrel is drawn into the expansion element, which is in turn expanded against the wall of the drilled hole.

Installation information and dimensions are set forth in Section 4.3 and Table 1.

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

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Design strengths must be determined in accordance with ACI 318-05 Appendix D and this report. Design parameters are provided in Tables 3 and 4. 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 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. Strength reduction factors ϕ corresponding to ductile steel elements may be used. An example calculation is provided in Figure 6.

4.1.2 Requirements for Static Steel Strength in Tension: The steel strength in tension must be calculated in accordance with ACI 318 D.5.1. The resulting N_s values are provided in Tables 3 and 4 of this report.

4.1.3 Requirements for Static Concrete Breakout Strength in Tension: The basic concrete breakout strength in tension must be calculated according to ACI 318 Section D.5.2.2, using the values of h_{ef} and k_{cr} as given in Tables 3 and 4 in lieu of h_{ef} and k, respectively. The nominal concrete breakout strength in tension in regions where analysis indicates no cracking in accordance with ACI 318 Section D.5.2.6 must be calculated with $\Psi_{C,N}$ as given in Tables 3 and 4. For carbon steel KB-TZ installed in the soffit of structural sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 5, calculation of the concrete breakout strength may be omitted. (See Section 4.1.5.)

4.1.4 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

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breakout strength in tension for uncracked concrete, calculated according to ACI 318 Section D.5.2, must be further multiplied by the factor $\Psi_{cp,N}$ as given by the following equation:

$$\Psi_{CP,N} = \frac{c}{c_{ac}} \quad (1)$$

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. Values for the critical edge distance c_{ac} must be taken from Table 3 or Table 4.

4.1.5 Requirements for Static Pullout Strength in Tension: The pullout strength of the anchor in cracked and uncracked concrete, where applicable, is given in Tables 3 and 4. In accordance with ACI 318 Section D.5.3.2, the nominal pullout strength in cracked concrete must be calculated according to the following equation:

$$N_{pn,f'c} = N_{p,cr}\sqrt{\frac{f'_c}{2{,}500}} \text{ (lb, psi)} \quad (2)$$

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

In regions where analysis indicates no cracking in accordance with ACI 318 Section D.5.3.6, the nominal pullout strength in tension must be calculated according to the following equation:

$$N_{pn,f'c} = N_{p,uncr}\sqrt{\frac{f'_c}{2{,}500}} \text{ (lb, psi)} \quad (3)$$

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

Where values for $N_{p,cr}$ or $N_{p,uncr}$ are not provided in Table 3 or Table 4, the pullout strength in tension need not be evaluated.

The pullout strength in cracked concrete of the carbon steel KB-TZ installed in the soffit of sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 5, is given in Table 3. In accordance with ACI 318 Section D.5.3.2, the nominal pullout strength in cracked concrete must be calculated according to Eq. (2), whereby the value of $N_{p,deck,cr}$ must be substituted for $N_{p,cr}$. The use of stainless steel KB-TZ anchors installed in the soffit of concrete on steel deck assemblies is beyond the scope of this report. In regions where analysis indicates no cracking in accordance with ACI 318 Section D.5.3.6, the nominal pullout strength in tension may be increased by $\Psi_{C,N}$ as given in Table 3. $\Psi_{C,P}$ is 1.0 for all cases. Minimum anchor spacing along the flute for this condition must be the greater of $3.0h_{ef}$ or $1^1/_2$ times the flute width.

4.1.6 Requirements for Static Steel Shear Capacity V_s: In lieu of the value of V_s as given in ACI 318 Section D.6.1.2(c), the values of V_s given in Tables 3 and 4 of this report must be used. The shear strength $V_{s,deck}$ as governed by steel failure of the KB-TZ installed in the soffit of structural sand lightweight or normal-weight concrete on steel deck floor and roof assemblies, as shown in Figure 5, is given in Table 3.

4.1.7 Requirements for Static Concrete Breakout Strength of Anchor in Shear, V_{cb} or V_{cbg}: Static concrete breakout strength shear capacity must be calculated in accordance with ACI 318 Section D.6.2 based on the values provided in Tables 3 and 4. The value of l_e used in ACI 318 Equation (D-24) must taken as no greater than h_{ef}.

4.1.8 Requirements for Static Concrete Pryout Strength of Anchor in Shear, V_{cp} or V_{cpg}: Static concrete pryout strength shear capacity must be calculated in accordance with ACI 318 Section D.6.3, modified by using the value of k_{cp} provided in Tables 3 and 4 of this report and the value of N_{cb} or N_{cbg} as calculated in Section 4.1.3 of this report. For anchors installed in the soffit of structural sand lightweight or normal-weight concrete over profile steel deck floor and roof assemblies, as shown in Figure 5, calculation of the concrete pry-out strength in accordance with ACI 318 Section D.6.3 is not required.

4.1.9 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: In lieu of ACI 318 Section D.8.3, values of c_{min} and s_{min} as given in Tables 2 and 3 of this report must be used. In lieu of ACI 318 Section D.8.5, minimum member thicknesses h_{min} as given in Tables 3 and 4 of this report must be used. Additional combinations for minimum edge distance c_{min} and spacing s_{min} may be derived by linear interpolation between the given boundary values. (See Figure 4.) The critical edge distance at corners must be minimum $4h_{ef}$ in accordance with ACI 318 Section D.8.6.

4.1.10 Requirements for Seismic Design: For load combinations including earthquake, the design must be performed according to ACI 318 Section D.3.3 as modified by Section 1908.1.16 of the IBC, as follows:

CODE	ACI 318 D.3.3. SEISMIC REGION	CODE EQUIVALENT DESIGNATION
IBC and 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 strength for anchors in shear, must be calculated according to ACI 318 Sections D.5 and D.6, respectively, taking into account the corresponding values given in Tables 3 and 4. The anchors comply with ACI 318 D.1 as ductile steel elements and must be designed in accordance with ACI 318 Section D.3.3.4 or D.3.3.5. The nominal pullout strength $N_{p,seis}$ and the nominal steel strength for anchors in shear $V_{s,seis}$ must be evaluated with the values given in Tables 3 and 4. The values of $N_{p,seis}$ must be adjusted for concrete strength as follows:

$$N_{p,seis,f'c} = N_{p,seis}\sqrt{\frac{f'_c}{2{,}500}} \text{ (lb, psi)} \quad (4)$$

$$N_{p,seis,f'c} = N_{p,seis}\sqrt{\frac{f'_c}{17.2}} \text{ (N, MPa)}$$

If no values for $N_{p,seis}$ or $V_{s,seis}$ are given in Table 3 or Table 4, the static design strength values govern. (See Sections 4.1.5 and 4.1.6.)

4.1.11 Structural Sand Lightweight Concrete: When structural lightweight concrete is used, values determined in accordance with ACI 318 Appendix D and this report must be modified by a factor of 0.60.

4.1.12 Structural Sand Lightweight Concrete over Metal Deck: Use of structural sand lightweight concrete is allowed in accordance with values presented in Table 3 and installation details as show in Figure 5.

4.2 Allowable Stress Design:

4.2.1 General: Design resistances 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 as follows:

$$R_{allow,ASD} = \frac{R_d}{\alpha} \qquad (5)$$

where $R_d = \phi \cdot R_k$ represents the limiting design strength in tension (ϕN_n) or shear (ϕV_n) as calculated according to ACI 318 Sections D.4.1.1 and D.4.1.2 and Section 4.1 of this report. For load combinations including earthquake, the value R_d in Equation (5) must be multiplied by 0.75 in accordance with ACI 318 Section D.3.3.3. Limits on edge distance, anchor spacing and member thickness, as given in Tables 3 and 4 of this report, must apply. Allowable service loads for single anchors in tension and shear with no edge distance or spacing reduction are provided in Tables 6 through 9, for illustration. These values have been derived per Equation (5) using the appropriate strength reduction factors ϕ from Tables 3 and 4 and the α factors provided in Section 4.2 of this report.

The value of α must be taken as follows:

REFERENCE FOR STRENGTH REDUCTION FACTORS	α	
	Including Seismic	**Excluding Seismic**
ACI 318 Section D.4.4	1.1	1.4
ACI 318 Section D.4.5	1.2	1.55

4.2.2 Interaction: In lieu of ACI 318 D.7.1, D.7.2 and D.7.3, interaction must be calculated as follows:

For shear loads $V \leq 0.2 \cdot V_{allow,ASD}$, the full allowable load in tension $T_{allow,ASD}$ may be taken.

For tension loads $T \leq 0.2 \cdot T_{allow,ASD}$, the full allowable load in shear $V_{allow,ASD}$ may be taken.

For all other cases:

$$\frac{T}{T_{allow,ASD}} + \frac{V}{V_{allow,ASD}} \leq 1.2 \qquad (6)$$

4.3 Installation:

Installation parameters are provided in Table 1 and in Figure 2. The Hilti KB-TZ must be installed according to manufacturer's published 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. The drilled hole must exceed the depth of anchor embedment by at least one anchor diameter to permit over-driving of anchors and to provide a dust collection area as required. The anchor must be hammered into the predrilled hole until at least four threads are below the fixture surface. 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 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 restrictions for installations into the soffit of concrete on steel deck assemblies, see Figure 5.

4.4 Special Inspection:

Special inspection is required, in accordance with Section 1704.13 of the IBC and Section 1701.5.2 of the UBC. The special inspector must be on the jobsite continuously during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, hole cleaning procedures, anchor spacing, edge distances, concrete thickness, anchor embedment, and tightening torque.

5.0 CONDITIONS OF USE

The Hilti KB-TZ anchors described in this report comply with the codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 Anchor sizes, dimensions and minimum embedment depths 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 conflict, this report governs.

5.3 Anchors must be limited to use 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 metal 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 (55.1 MPa).

5.5 Loads applied to the anchors must be adjusted in accordance with Section 1605.2 of the IBC and Sections1612.2 or 1909.2 of the UBC for strength design, and in accordance with Section 1605.3 of the IBC and Section 1612.3 of the UBC for allowable stress design.

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

5.7 Allowable design values are established in accordance with Section 4.2.

5.8 Anchor spacing and edge distance as well as minimum member thickness must comply with Tables 3 and 4.

5.9 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.

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

5.11 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.

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

5.13 Where not otherwise prohibited in the code, KB-TZ 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.

5.14 Use of zinc-coated carbon steel anchors is limited to dry, interior locations.

5.15 Special inspection must be provided in accordance with Section 4.4.

5.16 Anchors are manufactured by Hilti AG, in Schaan, Liechtenstein, under a quality control program with inspections by Underwriters Laboratories Inc. (AA-637).

6.0 EVIDENCE SUBMITTED

6.1 Data in accordance with the ICC-ES Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193), dated January 2007 (ACI 355.2).

6.2 A quality control manual.

7.0 IDENTIFICATION

The anchors are identified by packaging labeled with the manufacturer's name (Hilti, Inc.) and contact information, anchor name, anchor size, evaluation report number (ICC-ES ESR-1917), and the name of the inspection agency (Underwriters Laboratories Inc.). The anchors have the letters KB-TZ embossed on the anchor stud and four notches embossed into the anchor head, and these are visible after installation for verification.

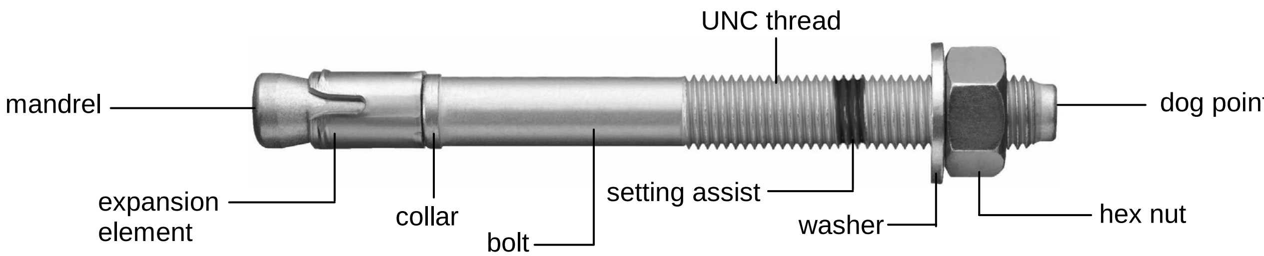


FIGURE 1—HILTI CARBON STEEL KWIK BOLT TZ (KB-TZ)

TABLE 1—SETTING INFORMATION (CARBON STEEL AND STAINLESS STEEL ANCHORS)

SETTING INFORMATION	Symbol	Units	Nominal anchor diameter (in.)													
			3/8			1/2				5/8				3/4		
Anchor O.D.	d_o	In.	0.375			0.5				0.625				0.75		
		(mm)	(9.5)			(12.7)				(15.9)				(19.1)		
Nominal bit diameter	d_{bit}	In.	3/8			1/2				5/8				3/4		
Effective min. embedment	h_{ef}	In.	2			2	3-1/4			3-1/8	4			3-3/4	4-3/4	
		(mm)	(51)			(51)	(83)			(79)	(102)			(95)	(121)	
Min. hole depth	h_o	In.	2-5/8			2-5/8	4			3-7/8	4-3/4			4-5/8	5-3/4	
		(mm)	(67)			(67)	(102)			(98)	(121)			(117)	(146)	
Min. thickness of fastened part[1]	t_{min}	In.	1/4			3/4	1/4			3/8	3/4			1/8	1-5/8	
		(mm)	(6)			(19)	(6)			(9)	(19)			(3)	(41)	
Installation torque	T_{inst}	ft-lb	25			40				60				110		
		(Nm)	(34)			(54)				(81)				(149)		
Min. dia. of hole in fastened part	d_h	In.	7/16			9/16				11/16				13/16		
		(mm)	(11.1)			(14.3)				(17.5)				(20.6)		
Standard anchor lengths	ℓ_{anch}	In.	3	3-3/4	5	3-3/4	4-1/2	5-1/2	7	4-3/4	6	8-1/2	10	5-1/2	8	10
		(mm)	(76)	(95)	(127)	(95)	(114)	(140)	(178)	(121)	(152)	(216)	(254)	(140)	(203)	(254)
Threaded length (incl. dog point)	ℓ_{thread}	In.	7/8	1-5/8	2-7/8	1-5/8	2-3/8	3-3/8	4-7/8	1-1/2	2-3/4	5-1/4	6-3/4	1-1/2	4	6
		(mm)	(22)	(41)	(73)	(41)	(60)	(86)	(124)	(38)	(70)	(133)	(171)	(38)	(102)	(152)
Unthreaded length	ℓ_{unthr}	In.	2-1/8			2-1/8				3-1/4				4		
		(mm)	(54)			(54)				(83)				(102)		

[1]The minimum thickness of the fastened part is based on use of the anchor at minimum embedment and is controlled by the length of thread. If a thinner fastening thickness is required, increase the anchor embedment to suit.

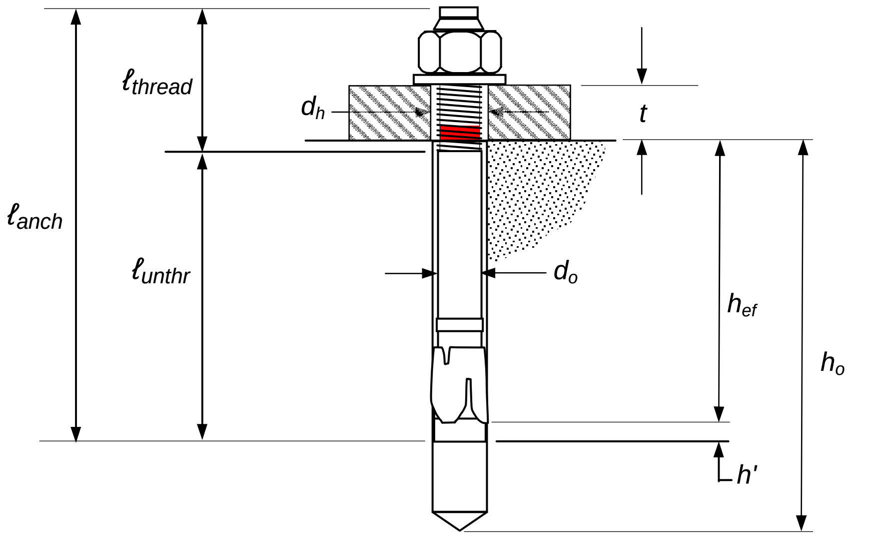


FIGURE 2—KB-TZ INSTALLED

TABLE 2—LENGTH IDENTIFICATION SYSTEM (CARBON STEEL AND STAINLESS STEEL ANCHORS)

Length ID marking on bolt head		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**
Length of anchor, ℓ_{anch} (inches)	From	1 ½	2	2 ½	3	3 ½	4	4 ½	5	5 ½	6	6 ½	7	7 ½	8	8 ½	9	9 ½	10	11	12	13	14	15
	Up to but not including	2	2 ½	3	3 ½	4	4 ½	5	5 ½	6	6 ½	7	7 ½	8	8 ½	9	9 ½	10	11	12	13	14	15	16

FIGURE 3—BOLT HEAD WITH LENGTH IDENTIFICATION CODE AND KB-TZ HEAD NOTCH EMBOSSMENT

TABLE 3—DESIGN INFORMATION, CARBON STEEL KB-TZ

DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter											
			3/8		1/2				5/8			3/4		
Anchor O.D.	d_o	In. (mm)	0.375 (9.5)		0.5 (12.7)				0.625 (15.9)			0.75 (19.1)		
Effective min. embedment[1]	h_{ef}	In. (mm)	2 (51)		2 (51)		3-1/4 (83)		3-1/8 (79)	4 (102)		3-3/4 (95)		4-3/4 (121)
Min. member thickness[2]	h_{min}	In. (mm)	4 (102)	5 (127)	4 (102)	6 (152)	6 (152)	8 (203)	5 (127)	6 (152)	8 (203)	6 (152)	8 (203)	8 (203)
Critical edge distance	c_{ac}	In. (mm)	4-3/8 (111)	4 (102)	5-1/2 (140)	4-1/2 (114)	7-1/2 (191)	6 (152)	6-1/2 (165)	8-3/4 (222)	6-3/4 (171)	10 (254)	8 (203)	9 (229)
Min. edge distance	c_{min}	In. (mm)	2-1/2 (64)		2-3/4 (70)		2-3/8 (60)		3-5/8 (92)	3-1/4 (83)		4-3/4 (121)		4-1/8 (105)
	for $s \geq$	In. (mm)	5 (127)		5-3/4 (146)		5-3/4 (146)		6-1/8 (156)	5-7/8 (149)		10-1/2 (267)		8-7/8 (225)
Min. anchor spacing	s_{min}	In. (mm)	2-1/2 (64)		2-3/4 (70)		2-3/8 (60)		3-1/2 (89)	3 (76)		5 (127)		4 (102)
	for $c \geq$	In. (mm)	3-5/8 (92)		4-1/8 (105)		3-1/2 (89)		4-3/4 (121)	4-1/4 (108)		9-1/2 (241)		7-3/4 (197)
Min. hole depth in concrete	h_o	In. (mm)	2-5/8 (67)		2-5/8 (67)		4 (102)		3-7/8 (98)	4-3/4 (121)		4-5/8 (117)		5-3/4 (146)
Min. specified yield strength	f_y	lb/in^2 (N/mm^2)	100,000 (690)		84,800 (585)				84,800 (585)			84,800 (585)		
Min. specified ult. strength	f_u	lb/in^2 (N/mm^2)	125,000 (862)		106,000 (731)				106,000 (731)			106,000 (731)		
Effective tensile stress area	A_{se}	In^2 (mm^2)	0.052 (33.6)		0.101 (65.0)				0.162 (104.6)			0.237 (152.8)		
Steel strength in tension	N_s	lb (kN)	6,500 (28.9)		10,705 (47.6)				17,170 (76.4)			25,120 (111.8)		
Steel strength in shear	V_s	lb (kN)	3,595 (16.0)		6,405 (28.5)				10,555 (47.0)			15,930 (70.9)		
Steel strength in shear, seismic[3]	V_{seis}	lb (kN)	2,255 (10.0)		6,405 (28.5)				10,555 (47.0)			14,245 (63.4)		
Steel strength in shear, concrete on metal deck[4]	$V_{s,deck}$	lb (kN)	2130 (9.5)		3,000 (13.3)		4,945 (22)		4,600 (20.5)	6,040 (26.9)		NP		NP
Pullout strength uncracked concrete[5]	$N_{p,uncr}$	lb (kN)	2,515 (11.2)		NA		5,515 (24.5)		NA	9,145 (40.7)		8,280 (36.8)		10,680 (47.5)
Pullout strength cracked concrete[5]	$N_{p,cr}$	lb (kN)	2,270 (10.1)		NA		4,915 (21.9)		NA	NA		NA		NA
Pullout strength concrete on metal deck[6]	$N_{p,deck,cr}$	lb (kN)	1,460 (6.5)		1,460 (6.5)		2,620 (11.7)		2,000 (8.9)	4,645 (20.7)		NP		NP
Anchor category[7]			1											
Effectiveness factor k_{uncr} uncracked concrete			24											
Effectiveness factor k_{cr} cracked concrete[8]			17											
$\Psi_{C,N} = k_{uncr}/k_{cr}$ [9]			1.41											
Coefficient for pryout strength, k_{cp}			1.0				2.0							
Strength reduction factor ϕ for tension, steel failure modes[10]			0.75											
Strength reduction factor ϕ for shear, steel failure modes[10]			0.65											
Strength reduction ϕ factor for tension, concrete failure modes or pullout, Condition B[11]			0.65											
Strength reduction ϕ factor for shear, concrete failure modes, Condition B[11]			0.70											

For **SI:** 1 inch = 25.4 mm, 1 lbf = 4.45 N, 1 psi = 0.006895 MPa For pound-inch units: 1 mm = 0.03937 inches.

[1]See Fig. 2.
[2] For structural light-weight concrete over metal deck, see Figure 5.
[3] See Section 4.1.10 of this report.
[4]See Section 4.1.6. NP (not permitted) denotes that the condition is not supported by this report.
[5]See Section 4.1.5 of this report. NA (not applicable) denotes that this value does not control for design.
[6]See Section 4.1.5 of this report. NP (not permitted) denotes that the condition is not supported by this report. Values are for cracked concrete. Values are applicable to both static and seismic load combinations.
[7]See ACI 318-05 Section D.4.4.
[8]See ACI 318-05 Section D.5.2.2.
[9]See ACI 318-05 Section D.5.2.6.
[10]The KB-TZ is a ductile steel element as defined by ACI 318 Section D.1.
[11]For use with the load combinations of ACI 318 Section 9.2. Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pullout or pryout strength governs. For cases where the presence of supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 4—DESIGN INFORMATION, STAINLESS STEEL KB-TZ

DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter											
			3/8		1/2				5/8			3/4		
Anchor O.D.	d_o	in. (mm)	0.375 (9.5)		0.5 (12.7)				0.625 (15.9)			0.75 (19.1)		
Effective min. embedment[1]	h_{ef}	in. (mm)	2 (51)		2 (51)		3-1/4 (83)		3-1/8 (79)	4 (102)		3-3/4 (95)		4-3/4 (121)
Min. member thickness	h_{min}	in. (mm)	4 (102)	5 (127)	4 (102)	6 (152)	6 (152)	8 (203)	5 (127)	6 (152)	8 (203)	6 (152)	8 (203)	8 (203)
Critical edge distance	c_{ac}	in. (mm)	4-3/8 (111)	3-7/8 (98)	5-1/2 (140)	4-1/2 (114)	7-1/2 (191)	6 (152)	7 (178)	8-7/8 (225)	6 (152)	10 (254)	7 (178)	9 (229)
Min. edge distance	c_{min}	in. (mm)	2-1/2 (64)		2-7/8 (73)		2-1/8 (54)		3-1/4 (83)	2-3/8 (60)		4-1/4 (108)		4 (102)
	for $s \geq$	in. (mm)	5 (127)		5-3/4 (146)		5-1/4 (133)		5-1/2 (140)	5-1/2 (140)		10 (254)		8-1/2 (216)
Min. anchor spacing	s_{min}	in. (mm)	2-1/4 (57)		2-7/8 (73)		2 (51)		2-3/4 (70)	2-3/8 (60)		5 (127)		4 (102)
	for $c \geq$	in. (mm)	3-1/2 (89)		4-1/2 (114)		3-1/4 (83)		4-1/8 (105)	4-1/4 (108)		9-1/2 (241)		7 (178)
Min. hole depth in concrete	h_o	in. (mm)	2-5/8 (67)		2-5/8 (67)		4 (102)		3-7/8 (98)	4-3/4 (121)		4-5/8 (117)		5-3/4 (146)
Min. specified yield strength	f_y	lb/in^2 (N/mm^2)	92,000 (634)		92,000 (634)				92,000 (634)			76,125 (525)		
Min. specified ult. Strength	f_u	lb/in^2 (N/mm^2)	115,000 (793)		115,000 (793)				115,000 (793)			101,500 (700)		
Effective tensile stress area	A_{se}	in^2 (mm^2)	0.052 (33.6)		0.101 (65.0)				0.162 (104.6)			0.237 (152.8)		
Steel strength in tension	N_s	lb (kN)	5,968 (26.6)		11,554 (51.7)				17,880 (82.9)			24,055 (107.0)		
Steel strength in shear	V_s	lb (kN)	4,870 (21.7)		6,880 (30.6)				11,835 (52.6)			20,050 (89.2)		
Pullout strength in tension, seismic[2]	N_{seis}	lb (kN)	NA		2,735 (12.2)		NA		NA			NA		
Steel strength in shear, seismic[2]	V_{seis}	lb (kN)	2,825 (12.6)		6,880 (30.6)				11,835 (52.6)			14,615 (65.0)		
Pullout strength uncracked concrete[3]	$N_{p,uncr}$	lb (kN)	2,630 (11.7)		NA		5,760 (25.6)		NA			NA		12,040 (53.6)
Pullout strength cracked concrete[3]	$N_{p,cr}$	lb (kN)	2,340 (10.4)		3,180 (14.1)		NA		NA	5,840 (26.0)		8,110 (36.1)		NA
Anchor category[4]			1											
Effectiveness factor k_{uncr} uncracked concrete			24											
Effectiveness factor k_{cr} cracked concrete[5]			17		24		17		17	17		24		17
$\Psi_{C,N} = k_{uncr}/k_{cr}$ [6]			1.41		1.00		1.41		1.41	1.41		1.00		1.41
Strength reduction factor ϕ for tension, steel failure modes[7]			0.75											
Strength reduction factor ϕ for shear, steel failure modes[7]			0.65											
Strength reduction ϕ factor for tension, concrete failure modes, Condition B[8]			0.65											
Coefficient for pryout strength, k_{cp}			1.0				2.0							
Strength reduction ϕ factor for shear, concrete failure modes, Condition B[8]			0.70											

For **SI**: 1 inch = 25.4 mm, 1 lbf = 4.45 N, 1 psi = 0.006895 MPa For pound-inch units: 1 mm = 0.03937 inches

[1]See Fig. 2.
[2]See Section 4.1.10 of this report. NA (not applicable) denotes that this value does not control for design.
[3]See Section 4.1.5 of this report. NA (not applicable) denotes that this value does not control for design.
[4]See ACI 318-05 Section D.4.4.
[5]See ACI 318-05 Section D.5.2.2.
[6]See ACI 318-05 Section D.5.2.6.
[7]The KB-TZ is a ductile steel element as defined by ACI 318 Section D.1.
[8]For use with the load combinations of ACI 318-05 Section 9.2. Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pullout or pryout strength governs. For cases where the presence of supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

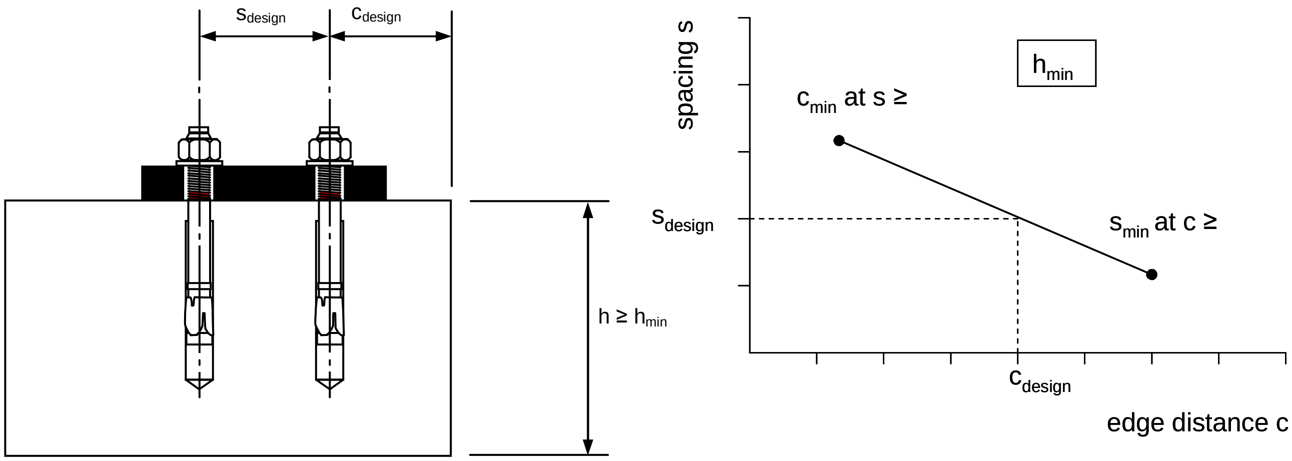


FIGURE 4—INTERPOLATION OF MINIMUM EDGE DISTANCE AND ANCHOR SPACING

TABLE 5—MEAN AXIAL STIFFNESS VALUES β FOR KB-TZ CARBON AND STAINLESS STEEL ANCHORS IN NORMAL-WEIGHT CONCRETE (10^3 pounds/in.)[1]

Concrete condition	carbon steel KB-TZ, all diameters	stainless steel KB-TZ, all diameters
uncracked concrete	700	120
cracked concrete	500	90

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

TABLE 6—KB-TZ CARBON AND STAINLESS STEEL ALLOWABLE STATIC TENSION (ASD), NORMAL-WEIGHT UNCRACKED CONCRETE, CONDITION B (pounds)[1,2, 3]

Nominal Anchor Diameter	Embedment Depth h_{ef} (in.)	Concrete Compressive Strength[2]							
		f'c = 2,500 psi		f'c = 3,000 psi		f'c = 4,000 psi		f'c = 6,000 psi	
		Carbon steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Stainless steel
3/8	2	1,168	1,221	1,279	1,338	1,477	1,545	1,809	1,892
1/2	2	1,576	1,576	1,726	1,726	1,993	1,993	2,441	2,441
	3 1/4	2,561	2,674	2,805	2,930	3,239	3,383	3,967	4,143
5/8	3 1/8	3,078	3,078	3,372	3,372	3,893	3,893	4,768	4,768
	4	4,246	4,457	4,651	4,883	5,371	5,638	6,578	6,905
3/4	3 3/4	3,844	4,046	4,211	4,432	4,863	5,118	5,956	6,268
	4 3/4	4,959	5,590	5,432	6,124	6,272	7,071	7,682	8,660

For **SI**: 1 lbf = 4.45 N, 1 psi = 0.00689 MPa For pound-inch units: 1 mm = 0.03937 inches

[1]Values are for single anchors with no edge distance or spacing reduction. For other cases, calculation of R_d as per ACI 318-05 and conversion to ASD in accordance with Section 4.2.1 Eq. (5) of this report is required.

[2]Values are for normal weight concrete. For sand-lightweight concrete, multiply values by 0.60.

[3]Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pullout or pryout strength governs. For cases where the presence of supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 7—KB-TZ CARBON AND STAINLESS STEEL ALLOWABLE STATIC TENSION (ASD), NORMAL-WEIGHT CRACKED CONCRETE, CONDITION B (pounds)[1,2, 3]

Nominal Anchor Diameter	Embedment Depth h_{ef} (in.)	Concrete Compressive Strength[2]							
		f'c = 2,500 psi		f'c = 3,000 psi		f'c = 4,000 psi		f'c = 6,000 psi	
		Carbon steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Stainless steel
3/8	2	1,054	1,086	1,155	1,190	1,333	1,374	1,633	1,683
1/2	2	1,116	1,476	1,223	1,617	1,412	1,868	1,729	2,287
	3 1/4	2,282	2,312	2,500	2,533	2,886	2,925	3,535	3,582
5/8	3 1/8	2,180	2,180	2,388	2,388	2,758	2,758	3,377	3,377
	4	3,157	2,711	3,458	2,970	3,994	3,430	4,891	4,201
3/4	3 3/4	2,866	3,765	3,139	4,125	3,625	4,763	4,440	5,833
	4 3/4	4,085	4,085	4,475	4,475	5,168	5,168	6,329	6,329

For **SI**: 1 lbf = 4.45 N, 1 psi = 0.00689 MPa For pound-inch units: 1 mm = 0.03937 inches

[1]Values are for single anchors with no edge distance or spacing reduction. For other cases, calculation of R_d as per ACI 318-05 and conversion to ASD in accordance with Section 4.2.1 Eq. (5) is required.
[2]Values are for normal weight concrete. For sand-lightweight concrete, multiply values by 0.60.
[3]Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pullout or pryout strength governs. For cases where the presence of supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 8—KB-TZ CARBON AND STAINLESS STEEL ALLOWABLE STATIC SHEAR LOAD (ASD), (pounds)[1]

Nominal Anchor Diameter	**Allowable Steel Capacity, Static Shear**	
	Carbon Steel	**Stainless Steel**
3/8	1,669	2,661
1/2	2,974	3,194
5/8	4,901	5,495
3/4	7,396	9,309

For **SI**: 1 lbf = 4.45 N
[1]Values are for single anchors with no edge distance or spacing reduction due to concrete failure.

TABLE 9—KB-TZ CARBON AND STAINLESS STEEL ALLOWABLE SEISMIC TENSION (ASD), NORMAL-WEIGHT CRACKED CONCRETE, CONDITION B (pounds)[1,2, 3]

Nominal Anchor Diameter	Embedment Depth h_{ef} (in.)	Concrete Compressive Strength[2]							
		f'c = 2,500 psi		f'c = 3,000 psi		f'c = 4,000 psi		f'c = 6,000 psi	
		Carbon steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Stainless steel	Carbon steel	Stainless steel
3/8	2	1,006	1,037	1,102	1,136	1,273	1,312	1,559	1,607
1/2	2	1,065	1,212	1,167	1,328	1,348	1,533	1,651	1,878
	3 1/4	2,178	2,207	2,386	2,418	2,755	2,792	3,375	3,419
5/8	3 1/8	2,081	2,081	2,280	2,280	2,632	2,632	3,224	3,224
	4	3,014	2,588	3,301	2,835	3,812	3,274	4,669	4,010
3/4	3 3/4	2,736	3,594	2,997	3,937	3,460	4,546	4,238	5,568
	4 3/4	3,900	3,900	4,272	4,272	4,933	4,933	6,042	6,042

For **SI**: 1 lbf = 4.45 N, 1 psi = 0.00689 MPa For pound-inch units: 1 mm = 0.03937 inches

[1]Values are for single anchors with no edge distance or spacing reduction. For other cases, calculation of R_d as per ACI 318-05 and conversion to ASD in accordance with Section 4.2.1 Eq. (5) is required.

[2]Values are for normal weight concrete. For sand-lightweight concrete, multiply values by 0.60.

[3]Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pullout or pryout strength governs. For cases where the presence of supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 10—KB-TZ CARBON AND STAINLESS STEEL ALLOWABLE SEISMIC SHEAR LOAD (ASD), (pounds)[1]

Nominal Anchor Diameter	Allowable Steel Capacity, Seismic Shear	
	Carbon Steel	Stainless Steel
3/8	999	1,252
1/2	2,839	3,049
5/8	4,678	5,245
3/4	6,313	6,477

For **SI**: 1 lbf = 4.45 N

[1]Values are for single anchors with no edge distance or spacing reduction due to concrete failure.

TABLE 11—KB-TZ CARBON STEEL ALLOWABLE TENSION AND SHEAR LOADS (ASD), INSTALLED INTO THE UNDERSIDE OF A STRUCTURAL SAND LIGHTWEIGHT CONCRETE OVER METAL DECK SLAB (pounds)[1,2,3]

NOMINAL ANCHOR DIAMETER	EMBEDMENT DEPTH, h_{ef} (inches)	TENSION SEISMIC[4]	TENSION NONSEISMIC[5]	SHEAR SEISMIC[4]	SHEAR NONSEISMIC[5]
3/8	2	709	743	944	989
1/2	2	709	743	1,330	1,393
1/2	3-1/4	1,272	1,333	2,192	2,296
5/8	3-1/8	971	1,017	2,039	2,136
5/8	4	2,255	2,362	2,677	2,804

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

[1]Pullout strength values $N_{p,deck}$ are for anchors installed in structural sand lightweight concrete having a minimum 2,500 psi compressive strength at the time of installation. See Table 3. The values listed in Table 11 have been calculated assuming a minimum 3,000 psi concrete compressive strength. The pullout strengths may be adjusted for other lightweight concrete compressive strengths in accordance with Section 4.1.5 using the following reduction equation:

$$N_{p,deck,f'c} = N_{p,deck}\sqrt{\frac{f'_c}{2,500}} \text{ (lb, psi)*}$$

$$N_{p,deck,f'c} = N_{p,deck}\sqrt{\frac{f'_c}{17.2}} \text{ (N, MPa)*}$$

*This equation can be used for structural sand lightweight concrete compressive strengths between 2,500 psi and 4,000 psi (17 MPa and 28 MPa).

[2]Minimum anchor spacing along the flute shall be the greater of $3.0h_{ef}$ or 1.5 times the flute width in accordance with Section 4.1.4.

[3]Anchors in the lower flute may be installed with a maximum 1-inch offset in either direction. See Figure 5.

[4]Allowable seismic tension and shear loads are calculated by multiplying $N_{p,deck}$ and $V_{s,deck}$ by the strength reduction Φ factor of 0.65, the seismic reduction Φ factor of 0.75 according to ACI 318 D3.3.3, and the dividing by an α of 1.1 in accordance with Section 4.2.1.

[5]Allowable nonseismic tension and shear loads are calculated by multiplying $N_{p,deck}$ and $V_{s,deck}$ by the strength reduction Φ factor of 0.65 and dividing by an α of 1.4 in accordance with Section 4.2.1. Allowable nonseismic loads are calculated assuming the lightweight concrete over metal deck is cracked.

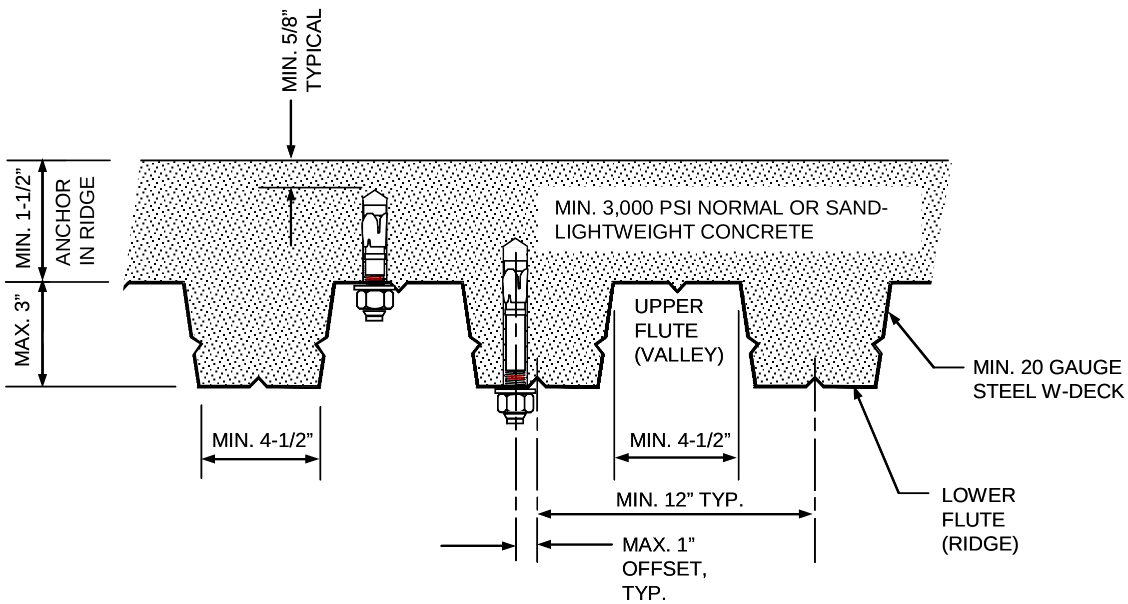


FIGURE 5—INSTALLATION IN THE SOFFIT OF CONCRETE OVER METAL DECK FLOOR AND ROOF ASSEMBLIES

Given:

Two 1/2-inch KB-TZ anchors under static tension load as shown.

h_{ef} = 3.25 in.

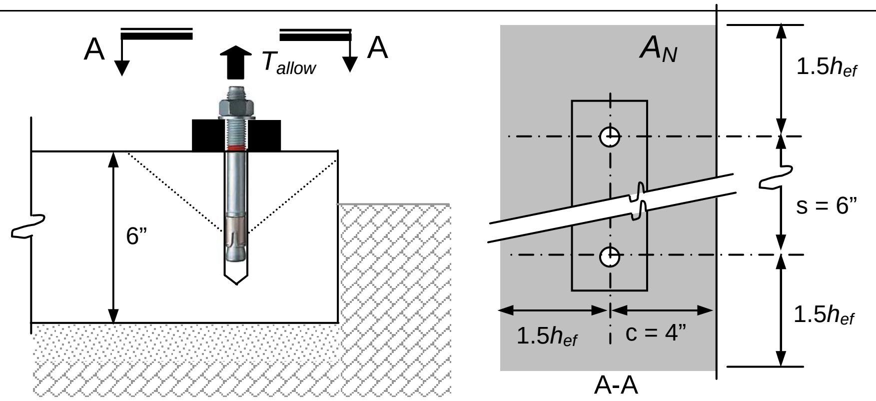
Normal wt. concrete, f'_c = 3,000 psi

No supplementary reinforcing.

Assume uncracked concrete.

Condition B per ACI 318 D.4.4 c)

Calculate the allowable tension load for this configuration.



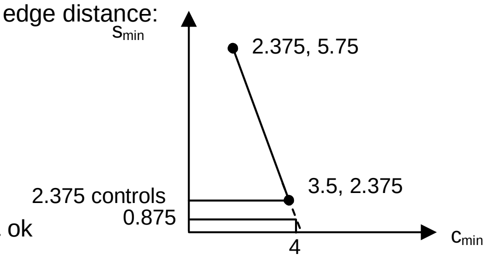
Calculation per ACI 318-02 Appendix D and this report.	Code Ref.	Report Ref.
Step 1. Calculate steel capacity: $\phi N_s = \phi n A_{se} f_{ut} = 0.75 \times 2 \times 0.101 \times 106{,}000 = 16{,}059$ lb Check whether f_{ut} is not greater than $1.9f_{ya}$ and 125,000 psi.	D.5.1.2 D.4.4 a)	Table 3
Step 3. Calculate concrete breakout strength of anchor in tension: $N_{cbg} = \frac{A_{NC}}{A_{NCO}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$	D.5.2.1	§ 4.1.2 § 4.1.3
Step 3a. Verify minimum member thickness, spacing and edge distance: h_{min} = 6 in. ≤ 6 in. ∴ ok slope = $\frac{2.375 - 5.75}{3.5 - 2.375} = -3.0$ For $c_{min} = 4\text{in} \Rightarrow$ $s_{min} = 5.75 - \left[(2.375 - 4.0)(-3.0)\right] = 0.875 < 2.375\text{in} < 6\text{in}$ ∴ ok  	D.8	Table 3 Fig. 4
Step 3b. For A_N check $1.5h_{ef} = 1.5(3.25) = 4.88$ in > c $3.0h_{ef} = 3(3.25) = 9.75$ in > s	D.5.2.1	Table 3
Step 3c. Calculate A_{No} and A_N for the anchorage: $A_{No} = 9h_{ef}^2 = 9 \times (3.25)^2 = 95.1\text{in}^2$ $A_N = (1.5h_{ef} + c)(3h_{ef} + s) = \left[1.5 \times (3.25) + 4\right]\left[3 \times (3.25) + 6\right] = 139.8\text{in}^2 < 2 \cdot A_{No}$ ∴ ok	D.5.2.1	Table 3
Step 3d. Determine $\psi_{ec,N}$: $e'_N = 0 \therefore \psi_{ec,N} = 1.0$	D.5.2.4	-
Step 3e. Calculate N_b: $N_b = k_{uncr} \sqrt{f'_c}\, h_{ef}^{1.5} = 17 \times \sqrt{3{,}000} \times 3.25^{1.5} = 5{,}456$ lb	D.5.2.2	Table 3
Step 3f. Calculate modification factor for edge distance: $\psi_{ed,N} = 0.7 + 0.3\frac{4}{1.5(3.25)} = 0.95$	D.5.2.5	Table 3
Step 3g. $\psi_{c,N}$ =1.41 (uncracked concrete)	D.5.2.6	Table 3
Step 3h. Calculate modification factor for splitting: $\psi_{cp,N} = \max\left\lvert \frac{c;1.5h_{ef}}{c_{ac}} \right\rvert$ $check: \frac{4}{7.5} = 0.53; \frac{1.5(3.25)}{7.5} = 0.65$ $0.65 > 0.53 \therefore \frac{1.5h_{ef}}{c_{ac}}$ controls	-	§ 4.1.3 Table 3
Step 3i. Calculate ΦN_{cbg} : ΦN_{cbg} $0.65 \times \frac{139.8}{95.1} \times 1.00 \times 0.95 \times 1.41 \times 5{,}456 \times 0.65 = 4{,}539$ lb	D.5.2.1 D.4.4 c)	§ 4.1.2 Table 3
Step 4. Check pullout strength: Per Table 3, $\Phi n N_{pn,f'c} = 0.65 \times 2 \times 5{,}515$ lb $\sqrt{\frac{3{,}000}{2{,}500}}$ = 7,852 lb >4539 ∴ OK	D.5.3.2 D.4.4 c)	§ 4.1.5 Table 3
Step 5. Controlling strength: ΦN_{cbg} = 4,539 lb < $\Phi n N_{pn}$ < ΦN_s ∴ ΦN_{cbg} controls	D.4.1.2	Table 3
Step 6. Convert value to ASD: $T_{allow} = \frac{4{,}539}{1.4}$ = 3,242 lb.	-	§ 4.2

FIGURE 6—EXAMPLE CALCULATION