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ESR-2302

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DIVISION: 03—CONCRETE
Section: 03151—Concrete Anchoring

REPORT HOLDER:

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EVALUATION SUBJECT:

HILTI KWIK BOLT 3 (KB3) CONCRETE ANCHORS

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)

Property evaluated:

Structural

2.0 USES

The Hilti Kwik Bolt 3 Concrete Anchor (KB3) is used to resist static and wind, tension and shear loads in uncracked normal-weight concrete and uncracked structural sand-lightweight concrete having a specified compressive strength f'_c = 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa), and in uncracked normal-weight or structural sand-lightweight concrete over metal deck having a minimum specified compressive strength f'_c = 3,000 psi (20.7 MPa).

The anchoring system is in compliance with Section 1912 of the 2009 and 2006 IBC and Section 1913 of the 2003 IBC, and is an alternative to cast-in-place anchors described in Section 1911 of the 2009 and 2006 IBC, and Section 1912 of the 2003 IBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the 2006 and 2003 IRC.

3.0 DESCRIPTION

3.1 KB3 Anchors:

The KB3 anchors are torque-controlled, mechanical expansion anchors. KB3 anchors consist of a stud (anchor body), expansion element (wedge), nut, and washer. The stud is manufactured from carbon steel complying with specifications set forth in the approved quality documentation, or AISI Type 304 or 316 stainless steel materials.

The carbon steel version of the anchor is illustrated in Figure 1 of this report. Carbon steel KB3 anchors and components have a minimum 5-micrometer (0.0002 inch) zinc plating. The expansion elements (wedges) for the carbon steel anchors are made from carbon steel, except all $^1/_4$-inch (6.4 mm) anchors and the $^3/_4$-inch-by-12-inch (19.1 mm by 305 mm) anchor have expansion elements made from AISI Type 316 stainless steel.

The $^1/_2$-, $^5/_8$-, and $^3/_4$-inch-diameter (12.7 mm, 15.9 mm, and 19.1 mm) carbon steel KB3 anchors are also available with a hot-dip galvanized coating complying with ASTM A 153, except all $^5/_8$-inch-diameter anchors have a hot-dip galvanized coating. All the hot-dip galvanized anchors use stainless steel expansion elements (wedges). The expansion elements (wedges), nuts and washers of the AISI Types 304 and 316 stainless steel KB3 anchors are made from stainless steel.

The anchor body is comprised of a rod threaded at one end and with 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 engages the wall of the drilled hole. Installation information and dimensions are set forth in Section 4.3 and Table 1 of this report.

3.2 Concrete:

Normal-weight concrete and structural sand-lightweight concrete must comply with Section 1903 of the 2009, 2006 and 2003 IBC.

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Anchor design tension and shear strengths (ΦN_n and ΦV_n) must be determined in accordance with ACI 318-08 (2009 IBC) or ACI 318-05

(2006 IBC) Appendix D using the design parameters as provided in Tables 3, 4 and 5 of this report. Design strengths must be determined in accordance with ACI 318-08 for compliance with (or as an alternative to) the 2003 IBC and Section R301.1 of the IRC. Design parameters are based on the 2009 IBC (ACI 318-08) unless noted otherwise in Sections 4.1.1 through 4.1.11 of this report. Design parameters and nomenclature for the KB3 anchors are provided in Tables 3, 4 and 5. The anchor design must satisfy the requirements in ACI 318 Sections D.4.1.1 and D.4.1.2. Strength reduction factors Φ as given in ACI 318 Section D.4.4 must be used for load combinations calculated in accordance with Section 1605.2.1 of the IBC and Section 9.2 of ACI 318. Strength reduction factors Φ as given in ACI 318 Section D.4.5 must be used for load combinations calculated in accordance with Appendix C of ACI 318. Strength reduction factors Φ corresponding to ductile steel elements are appropriate for stainless steel and carbon steel elements. An example calculation is provided in Figure 5.

4.1.2 Requirements for Static Steel Strength in Tension, N_s: The nominal static steel strength of a single anchor in tension, N_s, must be calculated in accordance with ACI 318 Section D 5.1.2. The resulting values of N_s are described in Tables 3, 4 and 5 of this report.

4.1.3 Requirements for Static Concrete Breakout Strength in Tension, N_{cb} or N_{cbg}: The nominal static concrete breakout strength of a single anchor or group of anchors in tension (N_{cb} and N_{cbg}) must be calculated in accordance with ACI 318 Section D.5.2, with modifications as described in this section. The values of f'_c must be limited to 8,000 psi (55 MPa) in accordance with ACI 318 Section D.3.3. The nominal concrete breakout strength in tension in regions of concrete where analysis indicates no cracking at service loads, must be calculated in accordance with ACI 318 Section D.5.2.6. The basic concrete breakout strength of a single anchor in tension, N_b, must be calculated in accordance with ACI 318 Section D.5.2.2 using the values of h_{ef} and k_{uncr} as given in Tables 3, 4, and 5 in lieu of h_{ef} and k, respectively. For the KB3 installed into the soffit of structural sand-lightweight or normal-weight concrete on metal deck floor and roof assemblies, as shown in Figure 3, calculation of the concrete breakout strength may be omitted.

4.1.4 Requirements for Critical Edge Distance: Values for the critical edge distance c_{ac} for use with ACI 318 Section D.5.2.7 must be taken from Tables 3 through 5 of this report. In applications where c_{a1} is less than c_{ac} and supplemental reinforcement to control splitting of the concrete is not present, the concrete breakout strength in tension for uncracked concrete, calculated in accordance with ACI 318 Section D.5.2, must be further multiplied by the factor $\psi_{cp,N}$ in accordance with ACI 318 Section D.5.2.7. The values of c_{a1} must be taken from Tables 3 through 5 of this report. For all other cases, $\psi_{cp,N} = 1.0$.

4.1.5 Requirements for Static Pullout Strength in Tension: The nominal static pullout strength ($N_{p,uncr}$) of a single anchor installed in uncracked concrete (regions where analysis indicates no cracking in accordance with ACI 318 Section D.5.3.6), where applicable, is given in Tables 3 through 5 of this report. The nominal pullout strength in tension may be adjusted for concrete compressive strengths other than 2,500 psi according to the following equation:

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

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

Where values for $N_{p,uncr}$ are not provided in Table 3, 4, or 5 of this report, the pullout strength in tension need not be evaluated. The pullout strength, in uncracked concrete, of the anchor installed into a soffit of sand-lightweight or normal-weight concrete on metal deck floor and roof assemblies, as shown in Figure 4, is given in Tables 3 and 4. The nominal pullout strength in uncracked concrete must be calculated in accordance with the equation in this section; if the value of $N_{p,deck,uncr}$ is used, it must be substituted for $N_{p,uncr}$ in accordance with ACI 318 Section D.5.3.2. Minimum anchor spacing along the flute for this condition must be the larger of 3.0 h_{ef} or $1^1/_2$ times the flute width.

4.1.6 Requirements for Static Steel Strength of Anchor in Shear, V_s: In lieu of the value of V_s as given in ACI 318 Section D.6.1.2(c), the nominal static steel strength in shear of a single anchor given in Tables 3, 4 and 5 of this report must be used. The shear strength $V_{s,deck}$, as governed by steel failure of the KB3 anchor installed into the soffit of structural sand-lightweight or normal-weight concrete on metal deck floor and roof assemblies, as shown in Figure 4, are given in Tables 3 and 4.

4.1.7 Requirements for Static Concrete Breakout Strength of Anchor in Shear, V_{cb} or V_{cbg}: The nominal static concrete breakout strength of a single anchor or group of anchors, V_{cb} or V_{cbg}, must be calculated in accordance with ACI 318 Section D.6.2, based on the values provided in Tables 3 through 5 of this report. The basic concrete breakout strength of a single anchor in cracked concrete, V_b, must be calculated in accordance with ACI 318 Section D.6.2.2 using the values given in Tables 3, 4 and 5. The value of l_e used in ACI 318 Section D, Eq. (D-24), must be no greater than h_{ef}.

4.1.8 Requirements for Static Concrete Pryout Strength of Anchor in Shear, V_{cp} or V_{cpg}: The nominal static concrete pryout strength of a single anchor or group of anchors (V_{cp} or V_{cpg}) must be calculated in accordance with ACI 318 D.6.3 based on the values given in Tables 3 through 5 of this report; the value of N_{cb} or N_{cbg} is as calculated in Section 4.1.3 of this report.

4.1.9 Requirements for Minimum Member Thickness and 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 3 through 5 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 through 5 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 3.)

4.1.10 Requirements for Interaction of Tensile and Shear Forces: The effects of combined tensile and shear forces must be determined in accordance with ACI 318 Section D.7.

4.1.11 Structural Sand-lightweight Concrete: For ACI 318-05, when anchors are used in structural sand-lightweight concrete, N_b, N_{pn}, V_b *and* V_{cp} must be multiplied by 0.60, in lieu of ACI 318 Section D.3.4.

For ACI 318-08, when anchors are used in structural sand-lightweight concrete, the modification factor λ must be taken as 0.6. In addition, the pullout strength $N_{p,uncr}$ must be multiplied by 0.6, as applicable.

4.2 Allowable Stress Design:

4.2.1 Design values for use with allowable stress design load combinations calculated in accordance with Section 1605.3 of the IBC, must be established using the equations below:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha}$$

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha}$$

where:

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

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

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

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

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

The requirements for member thickness, edge distance and spacing, described in this report, must apply. An example of allowable stress design values for illustrative purposes is shown in Table 6.

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

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

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

For all other cases:

$$\frac{T}{T_{allow,\ ASD}} + \frac{V}{V_{allow,\ ASD}} \leq 1.2$$

4.3 Installation:

Installation parameters are provided in Table 1 and Figure 2. Anchor locations must comply with this report and the plans and specifications approved by the code official. Anchors must be installed in accordance with the manufacturer's installation instructions and this report. Embedment, spacing, edge distance, and concrete thickness are provided in Tables 3 through 5 of this report. Holes must be drilled 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 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 value, T_{inst}, specified in Table 1 is achieved. For installation in the soffit of concrete on metal deck assemblies, the hole diameter in the deck must not exceed the diameter of the hole in the concrete by more than $^1/_8$ inch (3.2 mm).

4.4 Special Inspection:

Special inspection is required in accordance with Section 1704.13 of the 2006 or 2003 IBC, or Section 1704.15 of the 2009 IBC. The special inspector must make periodic inspections during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, drill bit type, hole dimensions, hole cleaning procedure, concrete member thickness, anchor embedment, anchor spacing, edge distances, anchor embedment, tightening torque and adherence to the manufacturer’s printed installation instructions. The special inspector must be present as often as required in accordance with the “statement of special inspection.” Under the IBC, additional requirements as set forth in Sections 1705 and 1706 must be observed, where applicable.

5.0 CONDITIONS OF USE

The Hilti Kwik Bolt 3 (KB3) 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 KB3 anchor sizes, dimensions and installation are as set forth in this report.

5.2 The KB3 anchors must be installed in accordance with the manufacturer’s (Hilti) published instructions and this report in uncracked normal-weight concrete and uncracked structural sand-lightweight concrete having a specified compressive strength f'_c = 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa), and uncracked normal-weight or uncracked structural sand-lightweight concrete over metal deck having a minimum specified compressive strength f'_c = 3,000 psi (20.7 MPa). In case of conflict between the manufacturer’s instructions and this report, this report governs.

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

5.4 Strength design values are established in accordance with Section 4.1 of this report.

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

5.6 Anchor spacing, edge distance and minimum member thickness must comply with Tables 3 through 5 of this report.

5.7 Prior to installation, calculations and details demonstrating compliance 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.

5.8 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.

5.9 Use of carbon steel anchors and hot-dipped $^{5}/_{8}$-inch (15.9 mm) galvanized KB3 anchors is limited to dry, interior locations.

5.10 Use of KB3 anchors in structures assigned to Seismic Design Category C, D, E or F (IBC) is beyond the scope of this report. Anchors may be used to resist short-term loading due to wind forces, subject to the conditions of this report.

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

5.12 Where not otherwise prohibited in the code, KB3 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 forces only.
- Anchors that support fire-resistance-rated construction or gravity load bearing structural elements are within 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 The anchors are manufactured by Hilti AG, Schaan, Liechtenstein; Hilti Operaciones de Mexico S.A., Matamoros, Tamaulipas, Mexico or AMS Tulsa, Oklahoma, with quality control 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 October 2009.

7.0 IDENTIFICATION

The concrete anchors are identified by their dimensional characteristics, size, and the length code stamped on the anchor, as indicated in Table 2. Packages are identified with the manufacturer's name (Hilti, Inc.) and address, anchor name, anchor size, evaluation report number (ESR-2302), and the name of the inspection agency (Underwriters Laboratories Inc.).

TABLE 1—INSTALLATION INFORMATION

Setting Information	Symbol		Nominal anchor diameter									
			$^{1}/_{4}$	**$^{3}/_{8}$**	**$^{1}/_{2}$**		**$^{5}/_{8}$**		**$^{3}/_{4}$**		**1**	
Anchor O.D.	d_o	in.	0.25	0.375	0.5		0.625		0.75		1	
		(mm)	(6.4)	(9.5)	(12.7)		(15.9)		(19.1)		(25.4)	
ANSI drill bit dia	d_{bit}	in.	$^{1}/_{4}$	$^{3}/_{8}$	$^{1}/_{2}$		$^{5}/_{8}$		$^{3}/_{4}$		1	
		(mm)	(6.4)	(9.5)	(12.7)		(15.9)		(19.1)		(25.4)	
Effective min. embedment	h_{ef}	in.	$1^{1}/_{2}$	2	2	$3^{1}/_{4}$	$3^{1}/_{8}$	4	$3^{3}/_{4}$	5	4	$5^{3}/_{4}$
		(mm)	(38)	(51)	(51)	(83)	(79)	(102)	(95)	(127)	(102)	(146)
Min. hole depth	h_o	in.	2	$2^{5}/_{8}$	$2^{5}/_{8}$	4	$3^{7}/_{8}$	$4^{3}/_{4}$	$4^{1}/_{2}$	$5^{3}/_{4}$	5	$6^{3}/_{4}$
		(mm)	(51)	(67)	(67)	(102)	(98)	(121)	(114)	(146)	(127)	(171)
Installation torque	T_{inst}	ft-lb	4	20	40		60		110		150	
		(Nm)	(5)	(27)	(54)		(81)		(149)		(203)	
Expansion element clearance hole	d_h	in.	$^{5}/_{16}$	$^{7}/_{16}$	$^{9}/_{16}$		$^{11}/_{16}$		$^{13}/_{16}$		$1^{1}/_{8}$	
		(mm)	(7.9)	(11.1)	(14.3)		(17.5)		(20.6)		(28.6)	

TABLE 2—LENGTH IDENTIFICATION SYSTEM

Length marking on the bolt head		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Length of anchor (in.)	From	$1^{1}/_{2}$	2	$2^{1}/_{2}$	3	$3^{1}/_{2}$	4	$4^{1}/_{2}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7	$7^{1}/_{2}$	8	$8^{1}/_{2}$	9	$9^{1}/_{2}$	10	11
	Up to but not including	2	$2^{1}/_{2}$	3	$3^{1}/_{2}$	4	$4^{1}/_{2}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7	$7^{1}/_{2}$	8	$8^{1}/_{2}$	9	$9^{1}/_{2}$	10	11	12

TABLE 3—DESIGN INFORMATION CARBON STEEL KB3

DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter												
			1/4	3/8		1/2				5/8 (M16)			3/4 (M20)		
Anchor O.D.	d_0	in. (mm)	0.25 (6.4)	0.375 (9.5)		0.5 (12.7)				0.625 (15.9)			0.75 (19.1)		
Effective min. embedment[2]	h_{ef}	in. (mm)	1 1/2 (38)	2 (51)		2 (51)		3 1/4 (83)		3 1/8 (79)	4 (102)		3 3/4 (95)		5 (127)
Min. member thickness	h_{min}	in. (mm)	4 (102)	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_{cr}	in. (mm)	2 3/4 (70)	4 1/2 (114)	3 7/8 (98)	4 7/8 (124)	3 5/8 (92)	6 3/4 (171)	5 5/8 (143)	7 1/2 (191)	9 1/2 (241)	7 1/2 (191)	9 3/4 (248)	7 1/2 (191)	9 1/2 (241)
Min. edge distance	c_{min}	in. (mm)	1 3/8 (35)	2 (51)	1 1/2 (38)	2 1/8 (54)	2 (51)	1 5/8 (41)	1 5/8 (41)	2 1/4 (57)	1 3/4 (44)	1 3/4 (44)	2 3/4 (70)	2 5/8 (67)	2 1/2 (64)
	for s ≥	in. (mm)	1 3/4 (44)	2 7/8 (73)	3 1/2 (89)	4 7/8 (124)	4 3/4 (121)	4 1/4 (108)	4 (102)	5 1/4 (133)	4 3/4 (121)	4 (102)	6 7/8 (175)	6 1/2 (165)	6 3/8 (162)
Min. anchor spacing	s_{min}	in. (mm)	1 1/4 (32)	1 3/4 (44)	1 3/4 (44)	2 1/2 (64)	2 1/4 (57)	2 (51)	1 7/8 (48)	2 3/8 (60)	2 1/8 (54)	2 1/8 (54)	3 3/4 (95)	3 3/8 (86)	3 1/4 (83)
	for c ≥	in. (mm)	1 5/8 (41)	2 3/8 (60)	2 3/8 (60)	2 5/8 (67)	2 3/8 (60)	2 1/4 (57)	2 (51)	3 1/8 (79)	2 3/8 (60)	2 1/4 (57)	3 3/4 (95)	3 3/8 (86)	3 3/8 (86)
Min. hole depth in concrete	h_0	in. (mm)	2 (51)	2 5/8 (67)		2 5/8 (67)		4 (102)		3 7/8 (98)	4 3/4 (121)		4 1/2 (114)		5 3/4 (146)
Min. specified yield strength	f_y	psi (N/mm^2)	84,800 (585)	84,800 (585)		84,800 (585)				84,800 (585)			84,800 (585)		
Min. specified ult. strength	f_{ut}	psi (N/mm^2)	106,000 (731)	106,000 (731)		106,000 (731)				106,000 (731)			106,000 (731)		
Effective tensile stress area	A_{se}	in^2 (mm^2)	0.02 (12.9)	0.06 (38.7)		0.11 (71.0)				0.17 (109.7)			0.24 (154.8)		
Steel strength in tension	N_s	lb (kN)	2,120 (9.4)	6,360 (28.3)		11,660 (51.9)				18,020 (80.2)			25,440 (113.2)		
Steel strength in shear	V_s	lb (kN)	1,640 (7.3)	4,470 (19.9)		6,635 (29.5)		6,750 (30.0)		12,230 (54.4)			15,660 (69.7)		16,594 (73.8)
Steel strength in shear, concrete on metal deck[3]	$V_{s,deck}$	lb (kN)	1,930 (8.6)	2,840 (12.6)		3,155 (14.0)				6,585 (29.3)			NP		
Pullout strength uncracked concrete[4]	$N_{p,uncr}$	lb (kN)	1,575 (7.0)	NA		NA		6,800 (30.2)		NA			NA		10,585 (47.1)
Pullout strength concrete on metal deck[5]	$N_{p,deck,\ uncr}$	lb (kN)	1,750 (7.8)	2,245 (10.0)		2,730 (12.1)				4,765 (21.2)			NP		
Anchor category[6]	1,2 or 3	-	1												
Effectiveness factor k_{uncr} uncracked concrete[7]	k_{uncr}	-	24												
Installation torque	T_{inst}	ft*lb (Nm)	4 (5)	20 (27)		40 (54)				60 (81)			110 (149)		
Axial stiffness in service load range	β_{uncr}	(lb/in)	116,150	162,850		203,500		191,100		222,150	170,700		207,400		164,000
COV β_{uncr}		%	60	42		29		29		25	21		19		24
Strength reduction factor Φ for tension, steel failure modes[8]			0.75												
Strength reduction factor Φ for shear, steel failure modes[8]			0.65												
Strength reduction factor Φ for tension , concrete failure modes, Condition B[9]			0.65												
Strength reduction factor Φ for shear , concrete failure modes, Condition B[9]			0.70												

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

[1]For KB3 into the soffit of sand lightweight or normal-weight concrete on metal deck floor and roof assemblies, see Fig. 5.

[2] See Fig. 2

[3] See Section 4.1.4 of this report, NP (not permitted) denotes that the condition is not supported by this report.

[4] See Section 4.1.3 of this report, NA (not applicable) denotes that this value does not govern for design.

[5] See Section 4.1.3 of this report, NP (not permitted) denotes that the condition is not supported by this report.

[6] See ACI 318-05 Section D.4.4.

[7] See ACI 318-05 Section D.5.2.2.

[8] The carbon Steel KB3 is a ductile steel element as defined by ACI 318 Section D.1.

[9] For use with the load combinations of ACI 318 Section 9.2 or IBC Section 1605.2.1. Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pull-out or pry out strength governs. For cases where the prescence of supplimentray reinfircement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 4—DESIGN INFORMATION, STAINLESS STEEL KB3

DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter														
			1/4	3/8		1/2				5/8 (M16)			3/4 (M20)			1	
Anchor O.D.	d_0	in. (mm)	0.25 (6.4)	0.375 (9.5)		0.5 (12.7)				0.625 (15.9)			0.75 (19.1)			1 (25.4)	
Effective min. embedment[2]	h_{ef}	in. (mm)	1 1/2 (38)	2 (51)		2 (51)		3 1/4 (83)		3 1/8 (79)	4 (102)		3 3/4 (95)		5 (127)	4 (102)	5 3/4 (146)
Min. member thickness	h_{min}	in. (mm)	4 (102)	4 (102)	5 (127)	4 (102)	6 (152)	6 (152)	8 (203)	5 (127)	6 (152)	8 (203)	6 (152)	8 (203)	8 (203)	8 (203)	10 (254)
Critical edge distance	c_{cr}	in. (mm)	3 (76)	4 3/8 (111)	3 7/8 (98)	4 7/8 (124)	4 (102)	6 3/4 (171)	5 3/4 (146)	7 3/8 (187)	9 1/2 (241)	7 1/2 (191)	10 1/2 (267)	9 1/4 (235)	9 3/4 (248)	10 (254)	11 (279)
Min. edge distance	c_{min}	in. (mm)	1 3/8 (35)	2 (51)	1 5/8 (41)	2 1/2 (64)	1 7/8 (48)	1 5/8 (41)	1 5/8 (41)	3 1/4 (83)	2 1/2 (64)	2 1/2 (64)	3 1/4 (83)	3 (76)	2 7/8 (73)	3 1/2 (89)	3 (76)
	for s ≥	in. (mm)	1 3/4 (44)	4 (102)	3 5/8 (92)	5 (127)	4 5/8 (117)	4 1/2 (114)	4 1/4 (108)	5 5/8 (143)	5 1/4 (133)	5 (127)	7 (178)	6 7/8 (175)	6 5/8 (168)	6 3/4 (172)	6 3/4 (172)
Min. anchor spacing	s_{min}	in. (mm)	1 1/4 (32)	2 (51)	1 3/4 (44)	2 1/2 (64)	2 1/4 (57)	2 1/8 (54)	1 7/8 (48)	3 1/8 (79)	2 1/8 (54)	2 1/8 (54)	4 (102)	3 1/2 (89)	3 1/2 (89)	5 (127)	4 3/4 (121)
	for c ≥	in. (mm)	1 5/8 (41)	3 1/4 (83)	2 1/2 (64)	2 7/8 (73)	2 3/8 (60)	2 3/8 (60)	2 1/8 (54)	3 7/8 (98)	3 (76)	2 3/4 (70)	4 1/8 (105)	3 3/4 (95)	3 3/4 (95)	4 1/4 (108)	3 3/4 (95)
Min. hole depth in concrete	h_0	in. (mm)	2 (51)	2 5/8 (67)		2 5/8 (67)		4 (102)		3 7/8 (98)	4 3/4 (121)		4 1/2 (114)		5 3/4 (146)	5 (127)	6 3/4 (171)
Min. specified yield strength	f_y	psi (N/mm²)	92000 (634)	92,000 (634)		92,000 (634)				92,000 (634)			76,000 (524)			76,000 (524)	
Min. specified ult. strength	f_{ut}	psi (N/mm²)	115000 (793)	115,000 (793)		115,000 (793)				115,000 (793)			90,000 (621)			90,000 (621)	
Effective tensile stress area	A_{se}	in² (mm²)	0.02 (12.9)	0.06 (38.7)		0.11 (71.0)				0.17 (109.7)			0.24 (154.8)			0.47 (303.2)	
Steel strength in tension	N_s	lb (kN)	2300 (10.2)	6,900 (30.7)		12,650 (56.3)				19,550 (87.0)			21,600 (96.1)			42,311 (188.2)	
Steel strength in shear	V_s	lb (kN)	1680 (7.5)	4,980 (22.2)		4,195 (18.7)		6,940 (30.9)		8,955 (39.8)	14,300 (63.6)		11,900 (52.9)		23,545 (104.7)	12,510 (55.6)	27,345 (121.6)
Steel strength in shear, concrete on metal deck[3]	$V_{s,deck}$	lb (kN)	2020 (9.0)	2,580 (11.5)		1,745 (7.8)				5,690 (25.3)			NP			NP	
Pullout strength uncracked concrete[4]	$N_{p,uncr}$	lb (kN)	1325 (5.9)	2,965 (13.2)		3,310 (14.7)		6,030 (26.8)		6,230 (27.7)	7,830 (34.8)		8,555 (38.1)		10,830 (48.2)	NA	15,550 (69.2)
Pullout strength concrete on metal deck[5]	$N_{p,deck,\ uncr}$	lb (kN)	1805 (8.0)	2,580 (11.5)		1,945 (8.7)				4,430 (19.7)			NP			NP	
Anchor category[6]	1,2 or 3	-	2	1													
Effectiveness factor k_{uncr} uncracked concrete[7]	k_{uncr}	-	24														
Installation torque	T_{inst}	ft*lb (Nm)	4 (5)	20 (27)		40 (54)				60 (81)			110 (149)			150 (203)	
Axial stiffness in service load range	β_{uncr}	(lb/in)	57,400	158,300		154,150		77,625		227,600	189,200		275,600		187,000	126,400	174,800
COV β_{uncr}		%	40	34		36		17		31	22		35		21	38	22
Strength reduction factor Φ for tension, steel failure modes[8]			0.75														
Strength reduction factor Φ for shear, steel failure modes[8]			0.65														
Strength reduction factor Φ for tension , concrete failure modes, Condition B[9]			0.65														
Strength reduction factor Φ for shear , concrete failure modes, Condition B[9]			0.70														

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

[1]For KB3 into the soffit of sand lightweight or normal-weight concrete on metal deck floor and roof assemblies, see Fig. 5.

[2] See Fig. 2

[3] See Section 4.1.4 of this report, NP (not permitted) denotes that the condition is not supported by this report.

[4] See Section 4.1.3 of this report, NA (not applicable) denotes that this value does not govern for design.

[5] See Section 4.1.3 of this report, NP (not permitted) denotes that the condition is not supported by this report.

[6] See ACI 318-05 Section D.4.4.

[7] See ACI 318-05 Section D.5.2.2.

[8] The Stainless Steel KB3 is a ductile steel element as defined by ACI 318 Section D.1.

[9] For use with the load combinations of ACI 318 Section 9.2 or IBC Section 1605.2.1. Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pull-out or pry out strength governs. For cases where the prescence of supplimentray reinfircement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 5—DESIGN INFORMATION, HOT-DIP GALVANIZED KB3

DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter									
			1/2				5/8			3/4		
Anchor O.D.	d_0	in. (mm)	0.5 (12.7)				0.625 (15.9)			0.75 (19.1)		
Effective min. embedment[1]	h_{ef}	in. (mm)	2 (51)		3 1/4 (83)		3 1/8 (79)	4 (102)		3 3/4 (95)		5 (127)
Min. member thickness	h_{min}	in. (mm)	4 (102)	6 (152)	6 (152)	8 (203)	5 (127)	6 (152)	8 (203)	6 (152)	8 (203)	8 (203)
Critical edge distance	c_{cr}	in. (mm)	4 7/8 (124)	3 5/8 (92)	7 1/2 (191)	5 3/4 (146)	7 5/8 (194)	9 1/2 (241)	7 3/4 (197)	9 3/4 (248)	7 1/2 (191)	9 1/2 (241)
Min. edge distance	c_{min}	in. (mm)	3 1/4 (83)	2 5/8 (67)	2 (51)		2 1/4 (57)	2 (51)	1 7/8 (48)	3 1/2 (89)		3 5/8 (92)
	for s ≥	in. (mm)	6 1/4 (159)	5 1/2 (140)	4 7/8 (124)		5 1/4 (133)	5 (127)	4 3/4 (121)	7 1/2 (191)		7 3/8 (187)
Min. anchor spacing	s_{min}	in. (mm)	3 1/8 (79)	2 3/4 (70)	2 3/8 (60)	2 1/8 (54)	2 1/2 (64)	2 1/8 (54)	2 1/8 (54)	4 (102)		3 7/8 (98)
	for c ≥	in. (mm)	3 3/4 (95)	2 3/4 (70)	2 5/8 (67)	2 1/4 (57)	3 1/2 (89)	2 1/2 (64)	2 1/4 (57)	6 1/2 (165)		4 3/4 (121)
Min. hole depth in concrete	h_0	in. (mm)	2 5/8 (67)		4 (102)		3 7/8 (98)	4 3/4 (121)		4 1/2 (114)		5 3/4 (146)
Min. specified yield strength	f_y	psi (N/mm^2)	84,800 (585)				84,800 (585)			84,800 (585)		
Min. specified ult. strength	f_{ut}	psi (N/mm^2)	106,000 (731)				106,000 (731)			106,000 (731)		
Effective tensile stress area	A_{se}	in^2 (mm^2)	0.11 (71.0)				0.17 (109.7)			0.24 (154.8)		
Steel strength in tension	N_s	lb (kN)	11,660 (51.9)				18,020 (80.2)			25,440 (113.2)		
Steel strength in shear	V_s	lb (kN)	4,500 (20.0)		5,870 (26.1)		11,635 (51.8)			17,000 (75.6)		
Pullout strength uncracked concrete[2]	$N_{p,uncr}$	lb (kN)	NA		6,540 (29.1)		6,465 (28.8)	9,017 (40.1)		NA		10,175 (45.3)
Anchor category[3]	1,2 or 3	-	1									
Effectiveness factor k_{uncr} uncracked concrete[4]	k_{uncr}	-	24									
Installation torque	T_{inst}	ft*lb (Nm)	40 (54)				60 (81)			110 (149)		
Axial stiffness in service load range	β_{uncr}	(lb/in)	177,000		332,850		347,750	190,130		364,725		314,650
COV β_{uncr}		%	42		18		37	36		27		21
Strength reduction factor Φ for tension, steel failure modes[5]			0.75									
Strength reduction factor Φ for shear, steel failure modes[5]			0.65									
Strength reduction factor Φ for tension , concrete failure modes, Condition B[6]			0.65									
Strength reduction factor Φ for shear , concrete failure modes, Condition B[6]			0.70									

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

[1] See Fig. 2

[2] See Section 4.1.3 of this report, NA (not applicable) denotes that this value does not govern for design.

[3] See ACI 318-05 Section D.4.4.

[4] See ACI 318-05 Section D.5.2.2.

[5] The carbon Steel KB3 is a ductile steel element as defined by ACI 318 Section D.1.

[6] For use with the load combinations of ACI 318 Section 9.2 or IBC Section 1605.2.1. Condition B applies where supplementary reinforcement in conformance with ACI 318-05 Section D.4.4 is not provided, or where pull-out or pry out strength governs. For cases where the prescence of supplimentray reinfircement can be verified, the strength reduction factors associated with Condition A may be used.

TABLE 6—EXAMPLE ALLOWABLE STRESS DESIGN VALUES FOR ILLUSTRATIVE PURPOSES

Nominal Anchor diameter (in.)	Embedment depth (in.)	Allowable tension (lbf) f'_c=2500 psi		
		Carbon Steel	Stainless Steel	HDG
$^1/_4$	$1^1/_2$	692	492	
$^3/_8$	2	1491	1370	
$^1/_2$	2	1491	1537	1490
	$3^1/_4$	3026	2784	2870
$^5/_8$	$3^1/_8$	2911	2893	2840
	4	4216	3439	4120
$^3/_4$	$3^3/_4$	3827	3757	3830
	5	5892	4756	4470
1	4		4216	
	$5^3/_4$		6829	

For **SI:** 1 lbf = 4.45 N, 1 psi = 0.00689 MPa 1 psi = 0.00689 MPa. 1 inch = 25.4 mm.

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

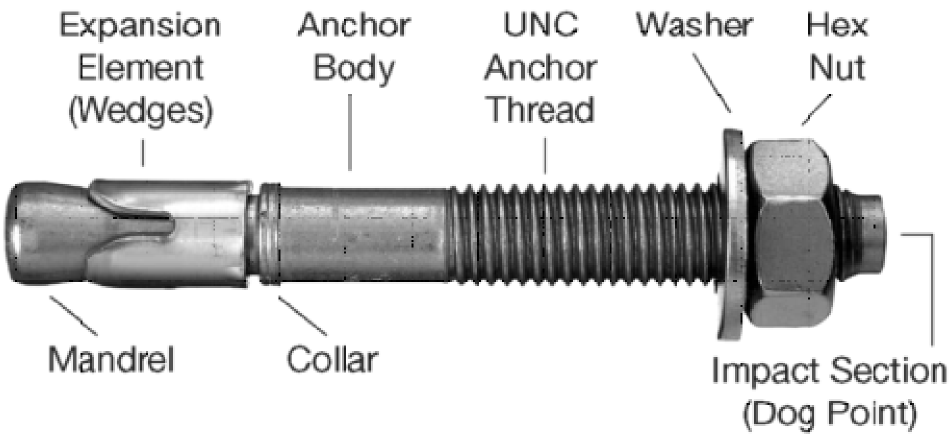


FIGURE 1—HILTI CARBON STEEL KWIK BOLT 3 (KB3)

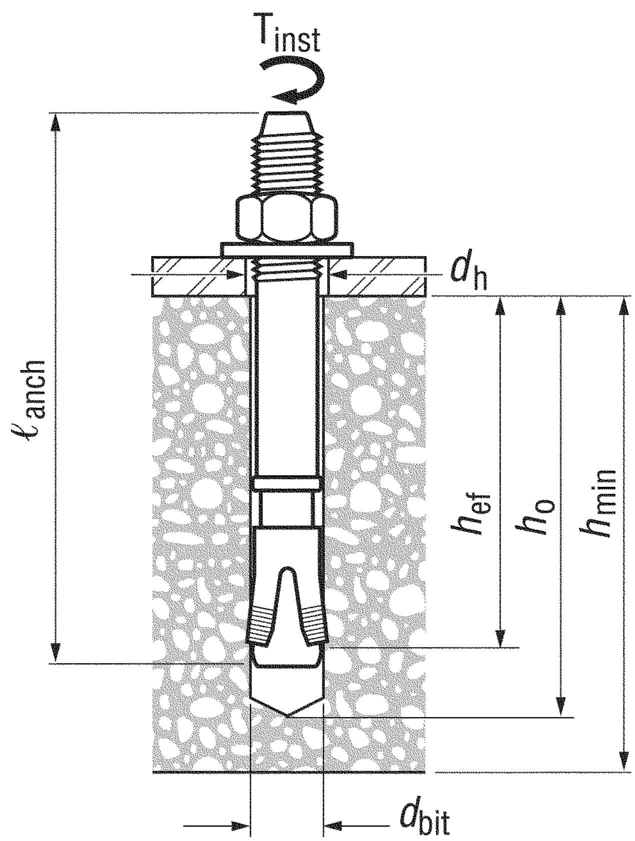


FIGURE 2—KB3 INSTALLED

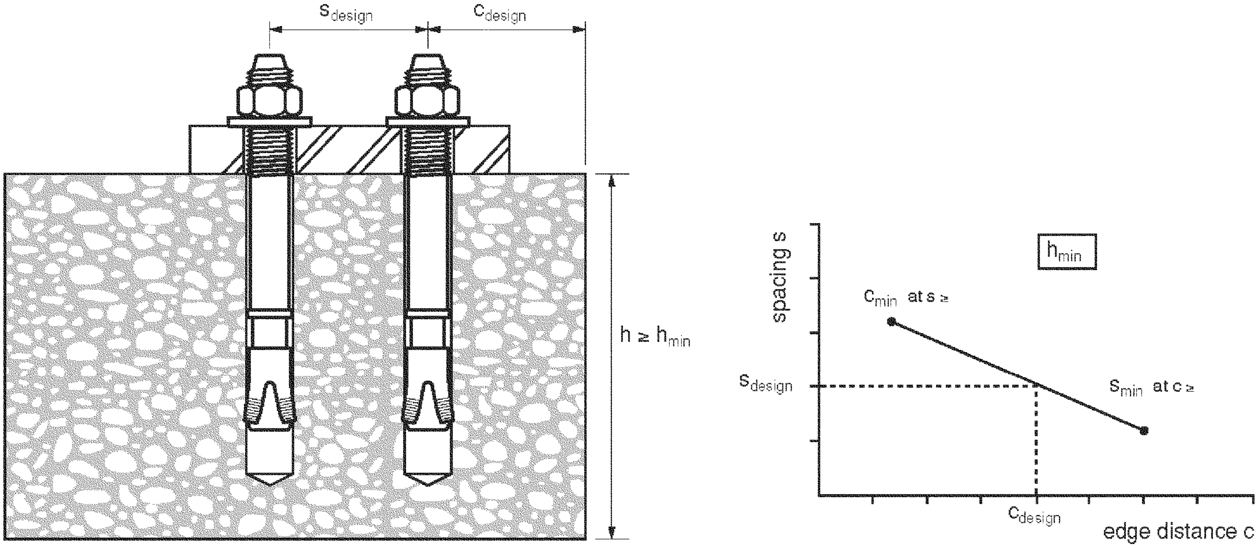


FIGURE 3—INTERPOLATION OF MINIMUM EDGE DISTANCE AND ANCHOR SPACING (ALSO SEE TABLES 3, 4 AND 5)

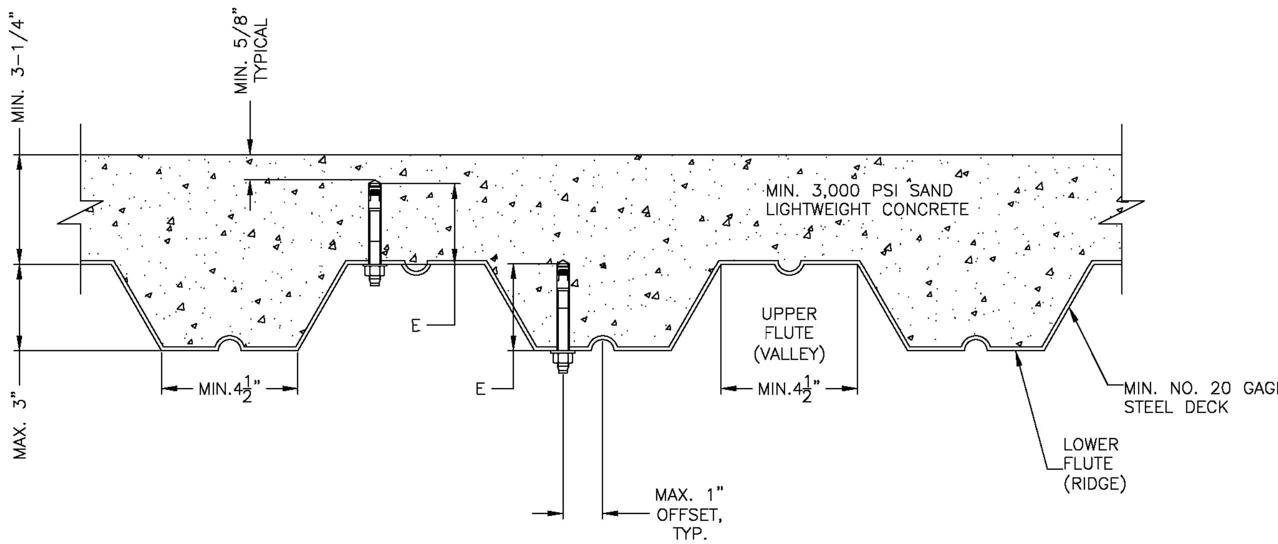


FIGURE 4—PROFILE OF STRUCTURAL LIGHTWEIGHT CONCRETE OVER METAL DECK

Given:

2 – 1/2-in. KB3 anchors under static tension load as shown.

h_{ef} = 3.25 in.

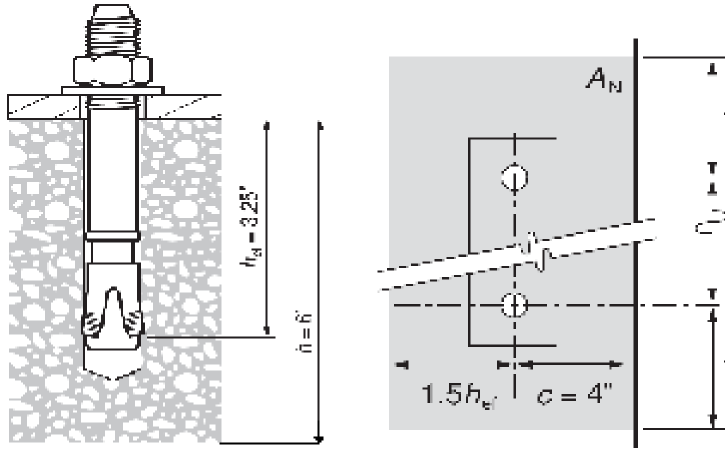
Normal wt. concrete, f'_c = 3,000 psi

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 318-05 Appendix D and this report.	**Code Ref.**	**Report Ref.**
Step 1. Calculate steel strength of anchor in tension $N_{sa} = nA_{se}f_{ut}$ = 2 x 0.11 x 106,000 = 23,320 lb	D.5.1.2	Table 3
Step 2. Calculate steel capacity ΦN_{sa} = 0.75 x 23,320 = 17,490 lb	D.4.4 a)	Table 3
Step 3. Calculate concrete breakout strength of anchor in tension $N_{cbg} = \frac{A_N}{A_{N0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$	D.5.2.1	§ 4.1.1 § 4.1.2
Step 3a. Verify minimum member thickness, spacing and edge distance: h_{min} = 6 in. ≤ 6 in. ∴ OK From Table 3; $c_{a,min}$ = 1.625-in. when s ≥ 4.25-in. ∴ OK	D.8	Table 3
Step 3b. Check 1.5*h_{ef} = 1.5*(3.25) = 4.88 in. > c 3.0*h_{ef} = 3.0*(3.25) = 9.75 in. > s	D.5.2.1	Table 3
Step 3c. Calculate A_{No} and A_N for the anchorage: $A_{No} = 9h_{ef}^2 = 9 \times (3.25)^2 = 95.1 \text{in}^2$ $A_N = (1.5h_{ef} + c)(3h_{ef} + s) = [1.5\text{x}(3.25) + 4] \bullet [3\text{x}(3.25) + 6] = 139.8 \text{ in}^2 < 2\text{x}A_{N0}$ ∴ OK	D.5.2.1	Table 3
Step 3d. Calculate $\Psi_{ec,N}$: $e_{n'}$ = 0: $\Psi_{ec,N}$ = 1.0	D.5.2.4	
Step 3e. Calculate N_b: $N_b = k_{uncr}\sqrt{f'_c}\,h_{ef}^{1.5}$ $N_b = 24\sqrt{3000}\text{x}3.25^{1.5}$ = 7,702 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. Calculate modification factor for splitting: $\psi_{cp,N} = \frac{\max\lvert c_{a,min} : 1.5\text{x}h_{ef}\rvert}{c_{ac}} = \frac{\max\lvert 4 : 1.5\text{x}3.25\rvert}{6.75} = 0.72$	D.5.2.7	§ 4.1.2 Table 3
Step 3h. Calculate N_{cbg}: $N_{cbg} = \frac{139.8}{95.1}\text{x}1.0\text{x}0.95\text{x}1.0\text{x}0.72\text{x}7{,}702 = 7{,}744$ lb	D.5.2.1	§ 4.1.1 Table 3
Step 4. Check pullout strength: Per Table 3, $N_{p,uncr} = 2\text{x}6890\text{x}\sqrt{\frac{3000}{2500}}$ = 15,095 lb does not control	D.5.3.2	§ 4.1.5 Table 3
Step 5. Controlling strength: ΦN_{cbg} = 0.65 x 7,744 lb = 5,034 lb, controls	D.4.4 c)	Table 3
Step 6. Convert value to ASD: $T_{allow} = \frac{5{,}034}{1.48}$ = 3,401 lb	-	§ 4.2

FIGURE 5—DESIGN EXAMPLE