APPLICABILITY OF THE KB-TZ2 ANCHOR

Usage in components and structural supports in nuclear facilities

Review and recommendation concerning testing compliance with USNRC General Design Criterion (GDC) 1, “Quality Standards and Records,” of Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, and Appendix B of ACI 349-01

August 2021

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Purpose and Scope

Hilti has developed a torque-controlled expansion anchor known as the Hilti Kwik Bolt TZ2 (KB-TZ2) for use in concrete and under static and seismic loadings. The purpose of this document is to evaluate the qualification testing performed on the KB-TZ2 Anchor System and determine whether it is in compliance with the requirements of ACI 355.2-01 and ACI 349-01 as recognized by the United States Nuclear Regulatory Commission in USNRC Regulatory Guide 1.199.

A design guide for use of the KB-TZ2 anchor system under ACI 349-01 and USNRC Directive 1.199 is given in Appendix A. All data in Appendix A meets the requirements of these two documents.

Qualification Testing Program

Testing was ordered by Hilti in 2018 and conducted under the guidance of Luke Tavernit at Element Materials Technology in Saint Paul, Minnesota. Additional testing was performed at Specialized Testing in Santa Fe Springs, California under the supervision of Thomas Kolden. All testing was performed according to ICC Evaluation Services Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC 193), dated October 2017 and editorially revised April 2018.

AC 193 references ACI 355.2 as the base document for the testing and evaluation protocol, adding additional ICC-ES specific requirements as well as modifications to specific testing and evaluation requirements. Those differences and the resulting anchor qualification and KB-TZ2 design data will be the focus of this document.

For anchors to be used in facilities under the purview of the USNRC, USNRC requirements must be met. Those requirements are summarized in Regulatory Guide 1.199. In that guide, ACI 349-01 Appendix B Anchoring to Concrete contains the basic design requirements for anchoring, and ACI 355.2 is an acceptable testing guide for mechanical anchors.

All submitted testing of the KB-TZ2 expansion anchor system was performed in a satisfactory manner and submitted to ICC-ES for their review. After review, an evaluation service report (ESR) was issued, ESR-4266, which recognized compliance with AC 193 and ACI 355.2. ESR-4266 specified the appropriate design data and parameters for use with ACI 318-14, Chapter 17.

Because of differences in evaluation requirements between ACI 355.2-01 and actual testing performed under AC 193, this report had been prepared to explain and comment on those differences.

Testing Differences among ICC-ES AC193, ACI 355.2-01, and ACI 349-01 Requirements and Resolution of those Differences

Testing to be performed or witnessed by an accredited laboratory

ACI 355.2-01 in Section 12.1 states that,

> "The testing and evaluation of anchors under ACI 355.2 shall be performed or witnessed by an independent testing and evaluation agency listed by a recognized accreditation service conforming to the requirements of ISO 17025 and Guide 58. In addition to these standards, listing of the testing and evaluation agency shall be predicated on the documented experience in the testing and evaluation of anchors according to ASTM E 488, including demonstrated competence to perform the tests described in ACI 355.2."

ACI 349-01 states in Section B3.3 that,

> "Post-installed structural anchors shall be tested before use to verify that they are capable of sustaining their design strength in cracked concrete under seismic loads, These verification tests shall be conducted by an independent testing agency and shall be certified by a professional engineer with full description and details of the testing programs, procedures, results, and conclusions."

Test data obtained for the KB-TZ2 evaluation according to Annex 1, Section 5.3, of AC 193, was required to be performed in a laboratory accredited under the requirements of ISO/IEC 17025. Further, a listing, by an accredited listing agency, of the testing and evaluation laboratory was required to be based on the documented experience in the testing and evaluation of anchors according to ASTM E 488.

Resolution: Testing was performed by all laboratories listed in Table 1. Specialized Testing is accredited under ISO 17025 by the International Accreditation Service (IAS) as listed on IAS TL-228. Element Material Technology is accredited under ISO 17025 by American Association for Laboratory Accreditation (A2LA) as listed in their Scope of Accreditation Certificate Number 1479.01.

Table 1 – Testing laboratories used for KB-TZ2 testing

Laboratory Name	Location	Accreditation Agency	Accreditation Number
Element Materials Technology	Saint Paul, Minnesota	American Association for Laboratory Accreditation (A2LA)	1479.01
Specialized Testing	Santa Fe Springs, California	International Accreditation Service (IAS)	IAS TL-228

Testing under the direction of a licensed professional engineer

ACI 355.2-01 states in Section 12.2 that,

> "The testing shall be witnessed and evaluated by a registered engineer employed or retained by the independent testing and evaluation agency."

Resolution: Testing performed at Element Materials Technology was overseen, test reports and the Evaluation report submittal prepared by Luke Tavernit of Element Materials Technology. Luke Tavernit is a registered professional engineer of Minnesota where testing occurred. Testing performed at Specialized Testing was overseen and the test reports prepared by Thomas Kolden of Specialized Testing. Thomas Kolden is a registered professional engineer of California where testing occurred.

Method used to calculate the effectiveness factor, k

Both ACI 355.2-01 and ACI 349-01 require that the k-factor (effectiveness factor, whose value depends on the type of anchor) reported for the anchors be calculated from the 5% fractile of the test data. ICC-ES AC 193 allows the mean values to be used as an alternative to the 5% fractile, albeit the required calculated k factor is much higher than what is published (for example: to have a calculated k of 17 for cracked concrete, the calculated k of the mean values must be at least 22). When mean values are too low to establish the k value, 5% fractile values are calculated to checked against the published value to determine if a k value can be established via 5% fractile values or if a pullout load must be published (this is only possible because the calculated k values required via mean method are higher than the published values).

Resolution: The published data is based on the AC 193 criteria which utilizes both the mean and 5% fractile methods instead of just the 5% fractile method. In general, the results should be about the same, with a few notable exceptions. It is possible for the 5% fractile method to be less conservative when the COV is small, resulting in a higher 5% fractile value that may obtain a higher k factor than what would have been calculated for the mean method. Similarly, it is possible for the mean method results to be less conservative for test series that have a high average, but also a high COV resulting in a lower 5% fractile value that would have lead to a lower calculated k factor. In regard to the KB-TZ2 evaluation, there are examples of both of these instances occurring. While there are instances of the mean method resulting in higher k factors compared to the 5% fractile method, it should be noted that the mean method results are significantly more stagnant once established, whereas 5% fractile values, and thus k factor derived from them, can be easily influenced and possibly improved by increasing the number of tests performed. While there are subtle differences between these two methods, in general, the mean method of AC 193 typically results in the more conservative value. The intent of the ACI codes is to provide a k factor that will result in an anchor design load that will be met or exceeded by 95% of all anchors with a 90% assurance. It is our belief that the k factors published meet the intent of the code.

Question on measurement of ductility of the KB-TZ2 anchor steel

ACI 355.2-01 does not contain criteria for establishing the ductility of mechanical anchor steel. ACI 318-14 (Chapter 2 – Notation and Terminology) define it as, “steel element, ductile – element with a tensile test elongation of at least 14 percent and reduction in area of at least 30 percent...”

Similarly, ACI 349-01 (Appendix B – Anchoring to Concrete) defines it as, “Ductile steel element – An element with a tensile test elongation of at least 14% and reduction in area of at least 30%...”

Resolution: AC 193 has incorporated a method for determination of anchor steel element ductility. Chapter 6 of AC 193 defines the tests required for steel classification. Table 6.3 of AC 193 similarly requires steel testing to result in elongation of at least 14% and the reduction in area of at least 30% to be considered ductile.

Steel testing was performed at Element Material Technology in conformance with AC 193. Both carbon and stainless steel anchors of every diameter were tested and all were classified as ductile.

Conclusions and Recommendations

The areas where ACI 355.2-01 and ACI 349-01 differ from AC 193 are discussed above. Evidence is provided demonstrating that, while the language of the standards varies, the actual testing and evaluation met their intent and requirements. The remainder of ACI 355.2-01 and ACI 349-01 does not contain any other requirements that are functionally different from AC 193. Therefore, based on all of the pertinent data and evaluations, the testing performed on the Hilti KB-TZ2 meets the intent and requirements of both ACI 355.2-01 and ACI 349-01.

The evaluations performed and the data as presented in **Design information for the Hilti Kwik Bolt TZ2 Expansion Anchor in Accordance with ACI 349-01 Appendix B** attached as Appendix A to this report are accurate and comply with the intent and requirements of ACI 355.2-01, ACI 349-01, and USNRC Regulatory Guide 1.199.

References

ACI 349-01 Code Requirements for Nuclear Safety Related Concrete Structures; Appendix B, Anchoring to Concrete; American Concrete Institute, Farmington Hills, MI.

ACI 355.2-01 Evaluating the Performance of Post-Installed Mechanical Anchors in Concrete; American Concrete Institute; Farmington Hills, MI.

ASTM E 488-15, Standard Test Methods for Anchors in Concrete and Masonry Elements; American Society for Testing and Materials; West Conshohocken, PA.

ICC-Evaluation Service Inc., Whittier, CA; Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC 193); October, 2017 (Corrected April, 2018).

ISO / IEC 17025; General Requirements for the Competence of Testing and Calibration Laboratories; International Standards Organization; November, 2017 (Corrected March, 2018).

ICC-ES Evaluation Service Report ESR 4266, Hilti Kwik Bolt TZ2 Carbon and Stainless Steel Expansion Anchors in Cracked and Uncracked Concrete, issued December 2020 Revised July 2021.

U.S. Nuclear Regulatory Commission, Washington, DC: Regulatory Guide 1.199, Anchoring Components and Structural Supports in Concrete; November, 2003.

Appendix A

Design information for the Hilti Kwik Bolt TZ2 Expansion Anchor in Accordance with ACI 349-01 Appendix B.

1.0 – SCOPE

This guide is intended to provide guidance on the design of anchorages using the Hilti Kwik Bolt TZ2 (KB-TZ2) in accordance with ACI 349-01 Appendix B. Note this design varies from current general industry practice following ACI 318 Chapter 17. It is the responsibility of the engineer of record to verify the accuracy and suitability of all design calculations, methodologies, capacities and code compliance. Information contained in this document was current as of August 1, 2021, and subject to change. Updates and changes may be made based on future testing. If verification is needed that the data is still current, please contact Hilti Technical Services at 1-877-749-6337.

2.0 – USES

The Hilti Kwik Bolt TZ2 expansion anchor is used to resist static, wind, and seismic tension and shear loads in cracked and uncracked normal-weight concrete having a specified compressive strength 2,500 psi ≤ f ′c ≤ 8,500 psi (17.2 MPa ≤ f ′c ≤ 58.6 MPa). The values of f ′c used for calculations in this guide shall not exceed 8000 psi (55.2 MPa).

3.0 – INSTALLATION

Installation shall be in accordance with Hilti's printed installation instructions as included in the anchor packaging.

4.0 – DESIGN

The design shall be in accordance with this document and ACI 349-01 Appendix B.

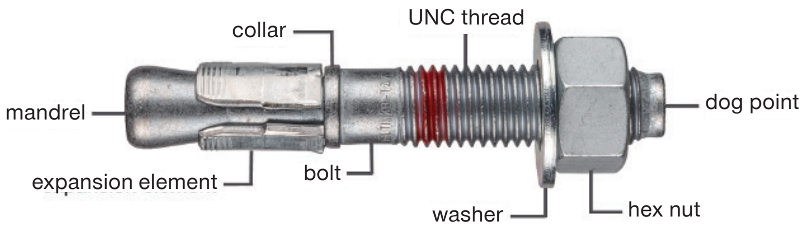


Figure 1 — Hilti carbon steel KWIK BOLT TZ (KB-TZ2)

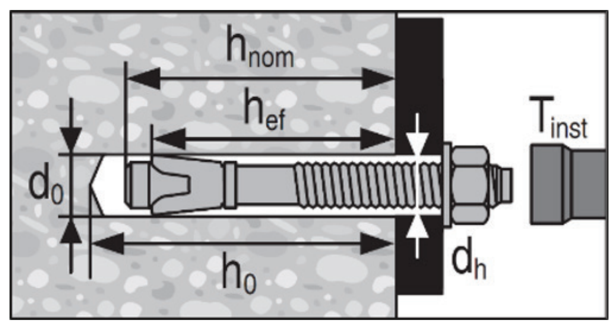


Figure 2 — Hilti KB-TZ2 installed

Table 2 - Hilti carbon steel KB-TZ2 design information for hammer and core drilled installations, tension[6]

Design parameter	Symbol	Units	Nominal anchor diameter (in)																
			1/4	3/8			1/2				5/8			3/4			1	
Effective min. embedment[1]	h_{ef}	in. (mm)	1-1/2 (38)	1-1/2 (38)	2 (51)	2-1/2 (64)	1-1/2 (38)	2 (51)	2-1/2 (64)	3-1/4 (83)	2-3/4 (70)	3-1/4 (83)	4 (102)	3-1/4 (83)	3-3/4 (95)	4-3/4 (121)	4 (102)	5-3/4 (146)
Tension, steel failure modes																			
Strength reduction factor for steel in tension[2]	$\Phi_{sa,N}$	-	0.80	0.80			0.80				0.80			0.80			0.80	
Min. specified yield strength	f_y	lb/in² (N/mm²)	100,900 (696)	100,900 (696)			96,300 (664)				87,000 (600)			84,700 (584)			75,000 (517)	
Min. specified ult. strength	f_{uta}	lb/in² (N/mm²)	122,400 (844)	126,200 (870)			114,000 (786)				106,700 (736)			105,900 (730)			88,000 (607)	
Effective tensile stress area	$A_{se,N}$	In² (mm²)	0.024 (15.4)	0.051 (33.2)			0.099 (63.6)				0.164 (106.0)			0.239 (154.4)			0.47 (303.2)	
Steel strength in tension	N_{sa}	lb (kN)	2,920 (13.0)	6,490 (28.9)			11,240 (50.0)				17,535 (78.0)			25,335 (112.7)			41,365 (184.1)	
Tension, concrete failure modes																			
Strength reduction factor for concrete and pullout failure in tension	$\Phi_{c,N}$, $\Phi_{p,N}$	-	0.75	0.75			0.75				0.75			0.75			0.75	
Effectiveness factor for uncracked concrete	k_{uncr}	-	24	24			27		24		24			27	27[5]	24	27	24
Effectiveness factor for cracked concrete[6]	k_{cr}	-	17	21		17	24	21		17	21		17	21			21	
Modification factor for anchor resistance, tension[3]	Ψ_3	-	1.0	1.0			1.0				1.0			1.0			1.0	
Pullout strength uncracked concrete[4]	$N_{p,uncr}$	lb (kN)	2,100 (9.3)	N/A	N/A	4,180 (18.6)	N/A	N/A	N/A	N/A	5,380 (23.9)	N/A	8,995 (40.0)	N/A	N/A	N/A	N/A	N/A
Pullout strength cracked concrete[4]	$N_{p,cr}$	lb (kN)	625 (2.8)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8,835 (39.3)	N/A	11,810 (52.6)
Pullout strength seismic[4]	$N_{p,eq}$	lb (kN)	625 (2.8)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8,700 (38.7)	N/A	11,810 (52.6)
Normalization factor, uncracked concrete	n_{uncr}	-	0.20	N/A	N/A	0.35	N/A	N/A	N/A	N/A	0.50	N/A	0.50	N/A	N/A	0.39	N/A	N/A
Normalization factor, cracked concrete, seismic	n_{cr}	-	0.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.29	N/A	0.50
Tension, axial stiffness																			
Axial stiffness in service load range	β_{uncr}	lb/in.	322,360	131,572			158,583				290,360			412,333			199,845	
	β_{cr}	lb/in.	31,033	91,336			113,514				167,367			62,179			122,400	

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] Figure 2 of this report illustrates the installation parameters.

[2] The KB-TZ2 is considered a ductile steel element in accordance with ACI 349-01 Appendix B

[3] For all design cases, Ψ_3 = 1.0. The appropriate effectiveness factor for cracked concrete (k_{cr}) or uncracked concrete (k_{uncr}) shall be used.

[4] For all design cases, Ψ_4 = 1.0. Tabular value for pullout strength is for a concrete compressive strength of 2,500 psi (17.2 MPa). Pullout strength for concrete compressive strength greater than 2,500 psi (17.2 MPa) may be increased by multiplying the tabular pullout strength by $(f'c / 2,500)^n$ for psi, or $(f'c / 17.2)^n$ for MPa, where n is given as n_{uncr} for uncracked concrete and n_{cr} for cracked concrete and seismic. NA (not applicable) denotes that pullout strength does not need to be considered for design.

[5] For core drill installations, k_{uncr} = 24 for 3/4-inch diameter anchors installed at 3-3/4 inches (95 mm) effective embedment.

[6] 1/4-inch and 1-inch diameter anchors are not permitted for core drilling installations.

Table 3 - Hilti stainless steel KB-TZ2 design information for hammer and core drilled installations, tension[7]

Design parameter	Symbol	Units	Nominal anchor diameter (in)														
			1/4	3/8			1/2			5/8			3/4			1	
Effective min. embedment[1]	h_{ef}	in. (mm)	1-1/2 (38)	1-1/2 (38)	2 (51)	2-1/2 (64)	2 (51)	2-1/2 (64)	3-1/4 (83)	2-3/4 (70)	3-1/4 (83)	4 (102)	3-1/4 (83)	3-3/4 (95)	4-3/4 (121)	4 (102)	5-3/4 (146)
Tension, steel failure modes																	
Strength reduction factor for steel in tension[2]	$\Phi_{sa,N}$	-	0.80	0.80			0.80			0.80			0.80			0.80	
Min. specified yield strength	f_y	lb/in^2 (N/mm^2)	100,900 (696)	96,300 (664)			96,300 (664)			91,600 (632)			84,100 (580)			65,000 (448)	
Min. specified ult. strength	f_{uta}	lb/in^2 (N/mm^2)	122,400 (844)	120,100 (828)			120,400 (830)			114,600 (790)			100,500 (693)			99,900 (689)	
Effective tensile stress area	$A_{se,N}$	In^2 (mm^2)	0.024 (15.4)	0.051 (33.2)			0.099 (63.6)			0.164 (106.0)			0.239 (154.4)			0.47 (303.2)	
Steel strength in tension	N_{sa}	lb (kN)	2,920 (13.0)	6,180 (27.5)			11,870 (52.8)			18,835 (83.8)			24,045 (107.0)			46,955 (208.9)	
Tension, concrete failure modes																	
Strength reduction factor for concrete and pullout failure in tension	$\Phi_{c,N}$, $\Phi_{p,N}$	-	0.75	0.75			0.75			0.75			0.75			0.75	
Effectiveness factor for uncracked concrete	k_{uncr}	-	24	24			24			24			24	27[5]	24	27	
Effectiveness factor for cracked concrete[6]	k_{cr}	-	17	21		17	17	21	17	21		17	21			24	21
Modification factor for anchor resistance, tension, uncracked concrete[3]	Ψ_3	-	1.0	1.0			1.0			1.0			1.0			1.0	
Pullout strength uncracked concrete[4]	$N_{p,uncr}$	lb (kN)	1,570 (7.0)	N/A	N/A	4,185 (18.6)	3,380 (15.0)	4,010 (17.8)	5,500 (24.5)	4,085 (18.2)	6,015 (26.8)	8,050 (35.8)	N/A	N/A	N/A	N/A	N/A
Pullout strength cracked concrete[4]	$N_{p,cr}$	lb (kN)	670 (3.0)	N/A	N/A	N/A	N/A	N/A	N/A[6]	N/A	N/A	N/A	N/A	N/A	8,795 (39.1)	N/A	N/A
Pullout strength seismic[4]	$N_{p,eq}$	lb (kN)	670 (3.0)	N/A	N/A	N/A	N/A	N/A	N/A[6]	N/A	N/A	N/A	N/A	N/A	8,795 (39.1)	N/A	N/A
Normalization factor, uncracked concrete	n_{uncr}	-	0.39	N/A	N/A	0.37	0.46	0.50	0.50	0.50	0.42	0.47	N/A	N/A	0.30	N/A	N/A
Normalization factor, cracked concrete, seismic	n_{cr}	-	0.50	N/A	N/A	N/A	N/A	N/A	0.50	N/A	N/A	N/A	N/A	N/A	0.50	N/A	N/A
Tension, axial stiffness																	
Axial stiffness in service load range	β_{uncr}	lb/in.	166,491	175,802			137,147			153,923			342,679			105,970	
	β_{cr}	lb/in.	33,806	79,861			97,983			69,627			75,715			117,630	

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] Figure 2 of this report illustrates the installation parameters.

[2] The KB-TZ2 is considered a ductile steel element in accordance with ACI 349-01 Appendix B

[3] For all design cases, Ψ_3 = 1.0. The appropriate effectiveness factor for cracked concrete (k_{cr}) or uncracked concrete (k_{uncr}) shall be used.

[4] For all design cases, Ψ_4 = 1.0. Tabular value for pullout strength is for a concrete compressive strength of 2,500 psi (17.2 MPa). Pullout strength for concrete compressive strength greater than 2,500 psi (17.2 MPa) may be increased by multiplying the tabular pullout strength by $(f'c / 2{,}500)^n$ for psi, or $(f'c / 17.2)^n$ for MPa, where n is given as n_{uncr} for uncracked concrete and n_{cr} for cracked concrete and seismic. NA (not applicable) denotes that pullout strength does not need to be considered for design.

[5] For core drill installations, k_{uncr} and k_{cr} = 17 for 3/4-inch diameter anchors installed at 3-3/4 inches (95 mm) effective embedment.

[6] For core drill installations, $N_{p,cr}$ = 4245 lb (18.9 kN) and $N_{p,eq}$ = 4245 lb (18.9 kN) for 1/2-inch diameter anchors installed at 3-1/4 inches (83 mm) effective embedment.

[7] 1/4-inch and 1-inch diameter anchors are not permitted for core drilling installations.

Table 4 - Hilti carbon steel KB-TZ2 design information for hammer and core drilled installations, shear[3]

Design parameter	Symbol	Units	Nominal anchor diameter (in)															
			1/4	3/8			1/2				5/8			3/4			1	
Anchor O.D.	d_a	in.	0.250	0.375			0.500				0.625			0.750			1.00	
		(mm)	(6.4)	(9.5)			(12.7)				(15.9)			(19.1)			(25.4)	
Effective min. embedment[1]	h_{ef}	in.	1-1/2	1-1/2	2	2-1/2	1-1/2	2	2-1/2	3-1/4	2-3/4	3-1/4	4	3-1/4	3-3/4	4-3/4	4	5-3/4
		(mm)	(38)	(38)	(51)	(64)	(38)	(51)	(64)	(83)	(70)	(83)	(102)	(83)	(95)	(121)	(102)	(146)
Shear, steel failure modes																		
Strength reduction factor for steel in shear[2]	$\Phi_{sa,V}$	-	0.75	0.75			0.75				0.75			0.75			0.75	
Steel strength in shear	V_{sa}	lb	1,345	3,225	3,385		5,535		6,875		10,255			13,805			18,795	22,825
		(kN)	(6.0)	(14.4)	(15.1)		(24.6)		(30.6)		(45.6)			(61.4)			(83.6)	(101.6)
Steel strength in shear, seismic	$V_{sa,eq}$	lb	1,345	3,225	3,385		5,535		6,875		10,255			13,805			13,805	
		(kN)	(6.0)	(14.4)	(15.1)		(24.6)		(30.6)		(45.6)			(61.4)			(61.4)	
Shear, concrete failure modes																		
Strength reduction factor for concrete breakout and pryout failure in shear	$\Phi_{c,V}$, $\Phi_{p,V}$	-	0.75	0.75			0.75				0.75			0.75			0.75	
Load bearing length of anchor in shear	N	in.	1-1/2	1-1/2	2	2-1/2	1-1/2	2	2-1/2	3-1/4	2-3/4	3-1/4	4	3-1/4	3-3/4	4-3/4	4	5-3/4
		(mm)	(38)	(38)	(51)	(64)	(38)	(51)	(64)	(83)	(70)	(83)	(102)	(83)	(95)	(121)	(102)	(146)
Coefficient for pryout strength	k_{cp}	-	1	1	1	2	1	1	2	2	2	2	2	2	2	2	2	2

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] Figure 2 of this report illustrates the installation parameters.

[2] The KB-TZ2 is considered a ductile steel element in accordance with ACI 349-01 Appendix B

[3] 1/4-inch and 1-inch diameter anchors are not permitted for core drilling installations.

Table 5 - Hilti stainless steel KB-TZ2 design information for hammer and core drilled installations, shear[3]

Design parameter	Symbol	Units	Nominal anchor diameter (in)														
			1/4	3/8			1/2			5/8			3/4			1	
Anchor O.D.	d_a	in.	0.250	0.375			0.500			0.625			0.750			1.00	
		(mm)	(6.4)	(9.5)			(12.7)			(15.9)			(19.1)			(25.4)	
Effective min. embedment[1]	h_{ef}	in.	1-1/2	1-1/2	2	2-1/2	2	2-1/2	3-1/4	2-3/4	3-1/4	4	3-1/4	3-3/4	4-3/4	4	5-3/4
		(mm)	(38)	(38)	(51)	(64)	(51)	(64)	(83)	(70)	(83)	(102)	(83)	(95)	(121)	(102)	(146)
Shear, steel failure modes																	
Strength reduction factor for steel in shear[2]	$\Phi_{sa,V}$	-	0.75	0.75			0.75			0.75			0.75			0.75	
Steel strength in shear	V_{sa}	lb	1,460	4,615	4,885		8,345			12,355			16,560			22,955	34,400
		(kN)	(6.5)	(20.5)	(21.7)		(37.1)			(55.0)			(73.7)			(102.1)	(139.7)
Steel strength in shear, seismic	$V_{sa,eq}$	lb	1,110	4,615	4,885		8,345			12,355			13,470			13,470	
		(kN)	(4.9)	(20.5)	(21.7)		(37.1)			(55.0)			(59.9)			(59.9)	
Shear, concrete failure modes																	
Strength reduction factor for concrete breakout and pryout failure in shear	$\Phi_{c,V}$, $\Phi_{p,V}$	-	0.75	0.75			0.75			0.75			0.75			0.75	
Load bearing length of anchor in shear	N	in.	1-1/2	1-1/2	2	2-1/2	2	2-1/2	3-1/4	2-3/4	3-1/4	4	3-1/4	3-3/4	4-3/4	4	5-3/4
		(mm)	(38)	(38)	(51)	(64)	(51)	(64)	(83)	(70)	(83)	(102)	(83)	(95)	(121)	(102)	(146)
Coefficient for pryout strength	k_{cp}	-	1	1	1	2	1	2	2	2	2	2	2	2	2	2	2

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] Figure 2 of this report illustrates the installation parameters.

[2] The KB-TZ2 is considered a ductile steel element in accordance with ACI 349-01 Appendix B

[3] 1/4-inch and 1-inch diameter anchors are not permitted for core drilling installations.

Table 6 - Minimum edge distance, spacing and concrete thickness for KB-TZ2

Setting information	Symbol	Units	Nominal anchor diameter (in)															
			1/4	3/8			1/2				5/8			3/4			1	
Effective min. embedment	h_{ef}	in.	1-1/2	1-1/2	2	2-1/2	1-1/2	2	2-1/2	3-1/4	2-3/4	3-1/4	4	3-1/4	3-3/4	4-3/4	4	5-3/4
		(mm)	(38)	(38)	(51)	(64)	(38)	(51)	(64)	(83)	(70)	(83)	(102)	(83)	(95)	(121)	(102)	(146)
Min. member thickness	h_{min}	in.	3-1/4	3-1/4	4	5	3-1/2	4	5	5-1/2	5	5-1/2	6	5-1/2	6	8	8	10
		(mm)	(83)	(83)	(102)	(127)	(89)	(102)	(127)	(140)	(127)	(140)	(152)	(140)	(152)	(203)	(203)	(254)
Carbon steel																		
Min. edge distance	c_{min}	in.	1-1/2	5	2-1/2	2-1/2	8	2-3/4	2-3/4	2-1/4	4-1/2	3-1/2	2-3/4	5	4	3-1/2	8	3
		(mm)	(38)	(127)	(64)	(64)	(203)	(70)	(70)	(57)	(114)	(89)	(70)	(127)	(102)	(89)	(203)	(76)
	for s ≥	in.	1-1/2	8	6	5	12	5-1/2	9-3/4	5-1/4	6-1/2	5-1/2	7-1/4	10	5-3/4	5-1/2	8	6-3/4
		(mm)	(38)	(203)	(152)	(127)	(305)	(140)	(248)	(133)	(165)	(140)	(184)	(254)	(146)	(140)	(203)	(171)
Min. anchor spacing	s_{min}	in.	1-1/2	5	2-1/4	2	12	3-1/2	3	2	4-1/2	2-3/4	2-1/4	4-1/2	3-3/4	3-3/4	8	4-3/4
		(mm)	(38)	(127)	(57)	(51)	(305)	(89)	(76)	(51)	(114)	(70)	(57)	(114)	(95)	(95)	(203)	(121)
	for c ≥	In.	1-1/2	8	3-1/2	4	8	10	8	4-3/4	5-1/2	7	4-1/4	6	7-1/4	4-3/4	8	3-3/4
		(mm)	(38)	(203)	(89)	(102)	(203)	(254)	(203)	(121)	(140)	(178)	(108)	(152)	(184)	(121)	(203)	(95)
Stainless steel																		
Min. edge distance	c_{min}	in.	1-1/2	5	2-1/2	2-1/2		2-3/4	2-1/2	2-1/4	4	3-1/4	2-1/4	5	4	3-3/4	3-3/4	3
		(mm)	(38)	(127)	(64)	(64)		(70)	(64)	(57)	(102)	(83)	(57)	(127)	(102)	(95)	(95)	(76)
	for s ≥	in.	1-1/2	8	5	5		5-1/2	4-1/2	5-1/4	7	5-1/2	7	11	7-1/2	5-3/4	10	6-3/4
		(mm)	(38)	(203)	(127)	(127)		(140)	(114)	(133)	(178)	(140)	(178)	(279)	(191)	(146)	(254)	(171)
Min. anchor spacing	s_{min}	in.	1-1/2	5	2-1/4	2-1/4		2-3/4	2-1/2	2	5-1/2	2-3/4	3	5	4	4	5	4-3/4
		(mm)	(38)	(127)	(57)	(57)		(70)	(64)	(51)	(140)	(70)	(76)	(127)	(102)	(102)	(127)	(121)
	for c ≥	In.	1-1/2	8	4	3-1/2		4-1/8	4-1/2	4-1/2	5-1/2	4	4-1/4	8	6	5-1/4	4-1/4	3-3/4
		(mm)	(38)	(203)	(102)	(89)		(105)	(114)	(114)	(140)	(102)	(108)	(203)	(152)	(133)	(108)	(95)

For **SI**: 1 inch = 25.4 mm

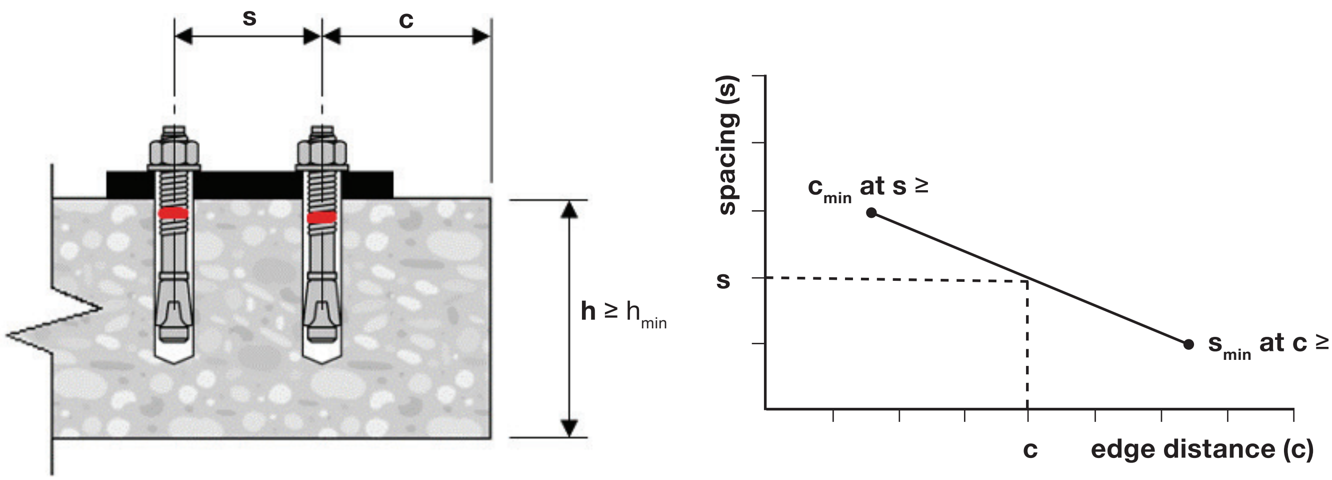
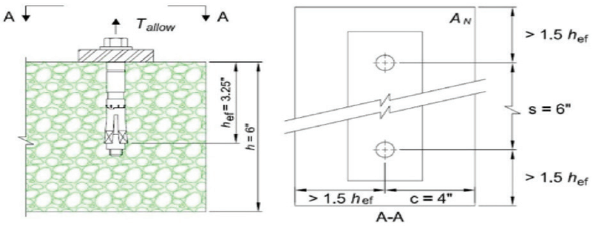


Figure 3 — Interpolation of minimum edge distance and anchor spacing

Figure 4 - Example calculation

Given:
(2) CS 1/2" KB-TZ2 anchors under static tension load as shown.
hef = 3-1/4 in.
Slab on grade with f 'c = 3,000 psi.
No supplementary reinforcing.
Assume cracked normal-weight concrete.
Calculate the design strength in tension for this configuration.



Calculation per ACI 349-01 Appendix B and this document.	ACI 349-01	Guide Ref.
Step 1. Calculate steel strength of anchor in tension $N_{sa} = nA_{sa,N}\ f_{ut} = 2 \times 0.099 \times 114{,}000 = 22{,}572$ lbf	B.5.1.2	Table 2
Step 2. Calculate steel capacity $\Phi N_{sa} = 0.8 \times 22{,}572 = 18{,}058$ lbf	B.4.4 a	Table 2
Step 3. Calculate concrete breakout strength of anchor in tension $N_{cbg} = \frac{A_N}{A_{No}} \Psi_1 \Psi_2 \Psi_3 N_b$	B.5.2.1	
Step 4. Verify minimum spacing and edge distance: h_{min} = 5-1/2 in. < 6 in. okay c_{min} = 2-1/4 in. < 4 in. okay s (@ c_{min}) = 5-1/4 in. < 6 in. okay	B.8	Table 6
Step 5. Calculate ANo and AN for the anchorage: $A_{No} = 9h_{ef}^2 = 9(3.25)^2 = 95.06$ in^2 $A_N = (1.5h_{ef} + c) \times (3h_{ef} + s) = (1.5 \times 3.25 + 4) \times (3 \times 3.25 + 6) = 139.78$ in^2	B.5.2.1	Table 2
Step 6. Calculate $N_b = k_{cr} \sqrt{(f_c')}\ h_{ef}^{1.5} = 17\sqrt{3{,}000}\ (3.25)^{1.5} = 5{,}456$ lbf	B.5.2.2	Table 2
Step 7. Modification factor for eccentricity no eccentricity $\rightarrow \Psi_1 = 1.0$	B.5.2.4	-
Step 8. Modification factor for edge $c_{min} = 4$ in $< 1.5h_{ef} = 1.5 \times 3.25 = 4.875$ in $\rightarrow \Psi_2 = 0.7 + 0.3 \frac{c_{min}}{1.5h_{ef}} = 0.7 + 0.3 \frac{4}{4.875} = 0.95$	B.5.2.5	Table 2
Step 9. Modification factor for cracked concrete $\Psi_3 = 1.0$	B.5.2.2 B.5.2.8	Table 2
Step 10. Calculate $N_{cbg} = \frac{A_N}{A_{No}} \Psi_1 \Psi_2 \Psi_3 N_b = \frac{139.78}{95.06}$ x 1.0 x 0.95 x 1.0 x 5,456 = 7,622 lbf	B.5.2.1	-
Step 11. $\Phi N_{cbg} = 0.75 \times 7{,}622 = 5{,}717$ lbf ← controls	B.4.4.c	Table 2
Step 12. Calculate pullout strength: N/A; pullout does not need to be considered	B.5.3.2	Table 2
Step 13. Ductility check according to B.3.6.1 For tension $\Phi \min[N_{cbg}; N_{p,cr}] \geq A_{se}\ f_{uta}$ where $\Phi = 0.85$ 0.85 (7,619 lb) < 22,572 lb => ductility not met B.3.6.3 requires an additional reduction factor of 0.6 for non-ductile anchors $\Phi N_{cbg} = 0.6 \times 5{,}717 = 3{,}430$ lbf Note: According to B.3.6.2, alternatively the attachment / base plate can be designed to yield at a load level of 75% of the anchor design strength. In this case, the 0.6 factor would not have to be applied.	B.3.6.1 B.3.6.3 B.4.1	Table 2

The data contained herein was current as of the date of publication. Updates and changes may be made based on later testing. If verification is needed that the data is still current, please contact the Hilti Technical Support Specialists at 1-877-749-6337. All published load values herein represent the results of testing by Hilti or test organizations. Because of variations in materials, on-site testing may be necessary to determine performance at any specific site.

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