

**Report on Applicability of the
Hilti HSL-3 Heavy Duty Sleeve Anchor
for use in
Components and Structural Supports
in Nuclear Facilities**

A 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

Report WC 11-02

**Prepared for
Hilti, Inc.
Tulsa Oklahoma**

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1. Purpose and Scope

Hilti has developed an expansion anchor known as the HSL-3 Heavy Duty Sleeve Anchor System. The purpose of this document is to evaluate the qualification testing performed on the Hilti HSL-3 Heavy Duty Sleeve 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 HSL-3 anchor system under ACI 349-01 and USNRC Directive 1.199 is given in **Appendix A** (supplied by Hilti, Inc.). All data in **Appendix A** meets the requirements of these two documents.

2. Qualification Testing Program

2.1 Testing was ordered by Hilti in 2003 and conducted under the guidance of Prof. Dr.-ing Rolf Eligehausen of the University of Stuttgart, Germany in 2003 at the Institut Für Werkstoffe Im Bauwesen and other testing laboratories. Testing was performed according to AC193.

2.2 AC193 issued by the ICC Evaluation Service 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 HSL-3 design data will be the focus of this document.

2.3 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.

2.4 All submitted testing of the HSL-3 Heavy Duty Sleeve Anchor System was performed in a satisfactory manner and submitted to ICC-ES for their review. After considerable review, an evaluation service report (ESR) was issued, ESR 1545, which recognized compliance with AC193. The ESR specified the appropriate design data and parameters for use with ACI 318-02, Appendix D.

2.5 Because of differences in evaluation requirements between ACI 355.2-01 and actual testing performed under AC193, this report has been prepared to explain and comment on those differences.

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

3.1 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 355.2-01 shall be performed or witnessed by an independent testing and evaluation agency listed by a recognized accreditation service conforming to the requirements of ISO Guides 25 and 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 355.2-01.”

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 HSL-3 evaluation according to Annex 1, Section 5.3, of AC193, 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 primarily by the Institut Für Werkstoffe Im Bauwesen. Other laboratories were also used as given in the following list, taken from the evaluation report prepared by Prof. Eligehausen. All of the listed laboratories were accredited by the International Laboratory Accreditation Cooperation (ILAC) under ISO/IEC 17025. IAS, the laboratory and testing accrediting body of the ICC, is also a member of ILAC. The European accreditation of these testing laboratories was accepted as being competent in the testing of anchor systems. CSTB was accredited in direct audits by IAS.

Table 1—Testing laboratories used for HSL-3 testing

1. CSTB: Centre Scientific et Technique du Batiment, Marne-la-Vallee, France (accredited by COFRAC (full ILAC-member))
 2. IWB: Institut für Werkstoffe im Bauwesen der Universität Stuttgart, Germany (accredited by ICC ES, IAS, and DAR (full ILAC-member))
 3. Bautest: Gesellschaft für Forschung und Materialprüfung im Bauwesen GmbH, Augsburg (accredited by DAP (full ILAC-member))
 4. IFBT: Institut für Fassaden- und Befestigungstechnik GmbH Liepzig, Germany (DIBt-accredited)
- Limited testing was performed by the manufacturer
5. H: Hilti Entwicklung Befestigungstechnik, Kaufering, Germany or Hilti Konzern-Forschung

3.2 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 was overseen by and the Evaluation report submittal prepared by Prof. Dr.-Ing. Rolf Eligehausen of the University of Stuttgart Institute for Building Materials. (He is now retired.) Prof. Eligehausen is not a registered engineer because there is no formal engineering registration system in Europe. Note that in Europe, licensing of structural engineers is accomplished through accredited educational institutions. Prof. Eligehausen is accredited for performing structural engineering. His experience in the technology of fastening to concrete is significant.

Prof. Eligehausen has been conducting evaluation and approval of anchors in Europe for more than 25 years, initially under DIBt (German) rules, and later under the EOTA (European Organisation for Technical Approvals (<http://www.eota.be>) guidelines. He participated in the development of the criteria for qualification of anchor systems both in Europe and the United States. As the author or co-author of over 230 papers and publications in Europe and the U.S. on the subject of bond and anchorage and as a Fellow of the American Concrete Institute, Prof. Eligehausen has established a reputation on both sides of the Atlantic as the pre-eminent expert in the world

on anchorage to concrete. In addition, Prof. Eligehausen conducts his own structural engineering practice as founder and principal of IEA (Ingenieurbüro Eligehausen und Asmus <http://www.i-ea.de>).

3.3 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 AC193 allows the mean values to be used as an alternative to the 5% fractile, and ICC-ES ESR 1545 reports the k -factor calculated from the mean test data.

Resolution: The original test data used in developing ESR 1545 was evaluated using both the 5% fractile and mean values. There is no difference between the k -factors using the 5% fractile of the test data and the mean test data. The published values in ESR 1545 were based on the mean values. The values used in **Appendix A—Design information for the Hilti Heavy Duty Sleeve Anchor HSL-3 in Accordance with ACI 349-01 Appendix B** were based on 5% fractile calculations. They are the same.

Table 2—Comparison of effectiveness factors, k (in.-lb units)		
	Uncracked concrete	Cracked concrete
Based on both mean and 5% fractile calculation		
M8	24	17
M10	24	21
M12	24	21
M16	24	21
M20	24	21
M24	24	21

3.4 Calculation of concrete compressive strengths.

Since the testing was performed in a German test laboratory, the concrete compressive strengths were determined according to European standards using the 150 mm cube strength rather than the 150 mm x 300 mm cylinder strengths used typically in the United States.

Resolution: In the evaluation performed for ESR 1545, these cube strengths were converted from SI units to in.-lb units using standard conversion equations that have been universally accepted in both the European and United States concrete industry. They are as follows.

$$f_{c,cyl} = f_{c,cube\ 150} / 1.25 \quad \text{for low strength concrete } f_{c,cyl} < 50 \text{ N/mm}^2$$

$$f_{c,cyl} = f_{c,cube\ 150} / 1.05 \quad \text{for high strength concrete } f_{c,cyl} \geq 50 \text{ N/mm}^2$$

3.5 Question on measurement of ductility of the HSL-3 anchor steel.

ACI 355.2-01 does not contain criteria for establishing the ductility of mechanical anchor steel. ACI 318-02 (Section D.1 Definitions) define it as, “**ductile steel element**—An element with a tensile test elongation of at least 14 percent and reduction in area of at least 30 percent. A steel element meeting the requirements of ASTM A 307 shall be considered ductile.”

Resolution: AC193 has incorporated a method for determination of anchor steel element ductility.

4.3.9 Classification of Anchor Steel as Ductile or Brittle—Elongation and reduction of area shall be determined according to a recognized standard and reported on the data sheet (Chapter 11). If the elongation is at least 14 percent and the reduction of area is at least 30 percent, the anchor shall be considered to meet the ductile steel requirements. If the ductility and reduction of area cannot be determined, the anchor shall be reported as brittle in the report.

While ACI 355.2-01 does not specify how ductility shall be determined or performed, testing of steel elements in the USA typically uses ASTM F 606. As explained by Eligehausen and Asmus in the submittal to ICC-ES, the elongation is measured over a gage length of $4d$. In Europe, where the ductility testing was performed on the HSL-3 anchor, the elongation is measured according to EN 10002 and ISO 898, using a gage length of $5d$. The elongation is measured after rupture of the steel, and is referred to as rupture elongation. Since the measured elongation contains a small plastic deformation due to contraction of the steel after passing the peak load, the contraction is limited to a small length. Under ISO 898, a minimum 12% elongation is required with a gage length of $5d$, which related to a 14% elongation under ASTM F 606.

Elongation testing performed in accordance with EN 10002 and ISO 898 was submitted, reviewed, and accepted by ICC-ES. The data demonstrated the actual rupture elongation was even greater than required as a ductile steel element.

Therefore the elongation requirement is met. Similarly, the measured reduction of area was greater than 30%. In conclusion, the HSL-3 anchor steel meets the AC193 requirement of “ductility”.

4. Conclusions and Recommendations

4.1 The areas where ACI 355.2-01 and ACI 349-01 differ from AC193 are discussed above. Evidence is provided demonstrating that, while the language of the standards varies, the actual testing and evaluation nevertheless 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 AC193. Therefore after review of all pertinent data and evaluations, it is my opinion that the testing performed on the Hilti HSL-3 ANCHOR system meets the intent and requirements of ACI 355.2-01 and ACI 349-01.

The evaluations performed and the data as presented in the **Design information for the Hilti Heavy Duty Sleeve Anchor HSL-3 in Accordance with ACI 349-01 Appendix B** as attached in Appendix A are accurate and comply with the intent and requirements of ACI 355.2-01, ACI 349-01, and USNRC Regulatory Guide 1.199.



Richard E. Wollmershauser, P.E., FACI
September 30, 2011
Tulsa, Oklahoma

5. References

1. ACI 349-01 *Code Requirements for Nuclear Safety Related Concrete Structures*; Appendix B, Anchoring to Concrete; American Concrete Institute, Farmington Hills, MI.
2. ACI 355.2-01 *Evaluating the Performance of Post-Installed Mechanical Anchors in Concrete*; American Concrete Institute; Farmington Hills, MI.
3. ASTM E 488-96 (Reapproved 2003), *Standard Test Methods for Anchors in Concrete and Masonry Elements*; American Society for Testing and Materials; West Conshohocken, PA
4. ASTM F 606-02, *Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets*; American Society for Testing and Materials; West Conshohocken, PA.
5. ICC-Evaluation Service Inc., Whittier, CA; *Acceptance Criteria for Mechanical Anchors in Concrete Elements (AC193)*; January, 2003.
6. EN 10002-01:2001; *Tensile testing of metallic materials*; International Standards Organization; September 2001.
7. ISO/IEC 17025; *General Requirements for the Competence of Testing and Calibration Laboratories*; International Standards Organization; December 1999.
8. ISO 898, *Mechanical Properties of Fasteners made of Carbon Steel and Alloy Steel – Part 1: Bolts, Screws and Studs with Specified Property Classes – Coarse Thread and Fine Pitch Thread*; International Standards Organization; August 1999;
9. ICC-ES Evaluation Service Report ESR 1545, *Hilti HSL-3 Carbon Steel Heavy Duty Expansion Anchors for Cracked and Uncracked Concrete*, issued August 2004.
10. U.S. Nuclear Regulatory Commission, Washington, DC: *Regulatory Guide 1.199, Anchoring Components and Structural Supports in Concrete*; November 2003.
11. Hilti, Inc., Tulsa, OK: *Design Information for the Hilti Heavy Duty Sleeve Anchor HSL-3 in Accordance with ACI 349-01 Appendix B*, June 2011.

Appendix A

(Supplied by Hilti, Inc, Tulsa, Oklahoma)

Design information for the Hilti Heavy Duty Sleeve Anchor HSL-3 in Accordance with ACI 349-01 Appendix B.

1.0 SCOPE

This guide is intended to provide guidance on the design of anchorages with Hilti Sleeve Anchors HSL-3 in accordance with ACI 349-01 Appendix B. Note this design varies from current general industry practice following ACI 318 Appendix D. 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 30, 2010, and subject to change. Updates and changes may be made based on later 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 HSL-3 Sleeve 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 $2,500 \text{ psi} \leq f'_c \leq 8,500 \text{ psi}$ ($17.2 \text{ MPa} \leq f'_c \leq 58.6 \text{ MPa}$). 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. See Figure 4 for a worked example for static tension loading.

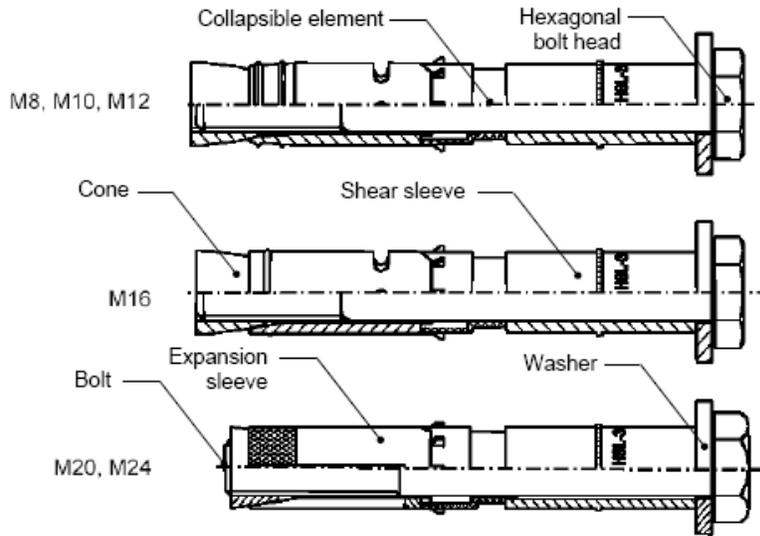


FIGURE 1—HSL-3 (BOLT VERSION SHOWN)

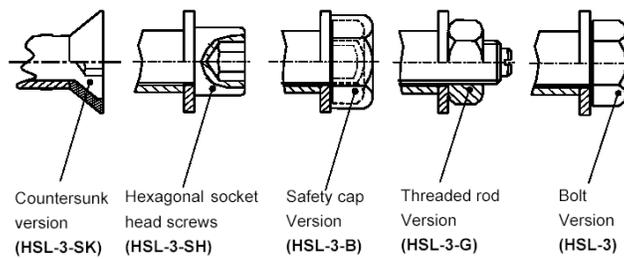


FIGURE 2—HSL-3 HEAD CONFIGURATIONS

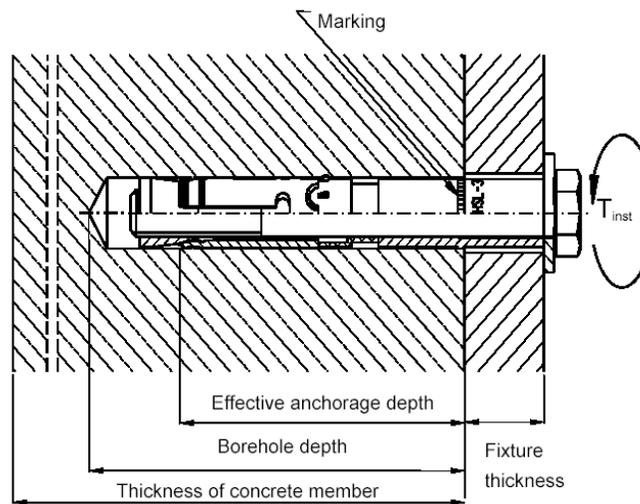


FIGURE 3—CORRECT INSTALLATION OF HSL-3 (BOLT VERSION SHOWN)

TABLE 1—HSL-3 DESIGN INFORMATION

Design parameter	Symbol	Units	Nominal anchor diameter					
			M8	M10	M12	M16	M20	M24
Anchor O.D.	d_o	mm	12	15	18	24	28	32
		in.	0.47	0.59	0.71	0.94	1.10	1.26
Effective min. embedment depth	$h_{ef,min}$	mm	60	70	80	100	125	150
		in.	2.36	2.76	3.15	3.94	4.92	5.91
Strength reduction factor for tension, steel failure modes ¹	ϕ	-	0.80					
Strength reduction factor for shear, steel failure modes ¹	ϕ	-	0.75					
Strength reduction factor for concrete breakout, side-face blowout, pullout or pryout strength ¹	ϕ	-	0.75					
Yield strength of anchor steel	f_{ya}	lb/in ²	92,800					
Ultimate strength of anchor steel	f_{uta}	lb/in ²	116,000					
Tensile stress area	A_{se}	in ²	0.057	0.090	0.131	0.243	0.380	0.547
Steel strength in tension	N_s	lb	6,612	10,440	15,196	28,188	44,080	63,452
Effectiveness factor uncracked concrete	k_{uncr}	-	24	24	24	24	24	24
Effectiveness factor cracked concrete ²	k_{cr}	-	17	21	21	21	21	21
Modification factor for cracked and uncracked concrete – concrete failure ³	ψ_3	-	1.4	1.1	1.1	1.1	1.1	1.1
Pullout strength uncracked concrete ⁴	$N_{p,uncr}$	lb	4,204	-	-	-	-	-
Pullout strength cracked concrete ⁴	$N_{p,cr}$	lb	2,810	4,496	-	-	-	-
Modification factor for cracked and uncracked concrete – pull out failure ⁴	ψ_4	-	1.0	1.0	-	-	-	-
Steel strength in shear HSL-3,-B,-SH,-SK	V_s	lb	7,239	10,229	14,725	26,707	39,521	45,951
Steel strength in shear HSL-3-G	V_s	lb	6,070	8,385	12,162	22,683	33,159	
Coefficient for pryout strength	k_{cp}	-	1.0	2.0				
Load bearing length of anchor in shear	ℓ	mm	24	30	36	48	56	64
		in.	0.94	1.18	1.42	1.89	2.20	2.52
Tension pullout strength seismic ⁵	$N_{seismic}$	lb	-	-	-	-	-	14,320
Steel strength in shear, seismic ⁶ HSL-3,-B,-SH,-SK	$V_{seismic}$	lb	4,609	8,453	11,892	24,796	29,135	38,173
Steel strength in shear, seismic ⁶ HSL-3-G		lb	3,777	6,924	9,824	21,065	24,459	
Axial stiffness in service load range ⁷	uncracked concrete	β_{uncr}	10 ³ lb/in.	300				
	cracked concrete	β_{cr}		30	70	130	130	130

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 ACI 349-01, Appendix B, section B.4.4. For use with the load combinations of ACI 349-01, section 9.2.

² See ACI 349-01 Appendix B, section B.5.2.2 and B.5.2.8

³ See ACI 349-01 Appendix B, section B.5.2.6

⁴ In lieu of ACI 349-01 Appendix B, section B.5.3.1 for pull out failure, $N_{p,cr}$ shall be used to calculate the pull out strength for cracked concrete and $N_{p,uncr}$ shall be used to calculate the pull out strength for uncracked concrete. The modification factor ψ_4 shall then be taken as 1.0.

⁵ $N_{seismic}$ shall be used in lieu of $N_{p,cr}$ for load combinations that include earthquake loads.

⁶ $V_{seismic}$ shall be used in lieu of V_s for load combinations that include earthquake loads.

⁷ Minimum axial stiffness values, maximum values may be 3 times larger (e.g., due to high-strength concrete).

TABLE 2—HSL-3 EDGE DISTANCE, SPACING AND MEMBER THICKNESS REQUIREMENTS^{1,2}

Case	Dimensional parameter	Symbol	Units	Nominal anchor diameter					
				M8	M10	M12	M16	M20	M24
A	Minimum concrete thickness	$h_{min,A}$	in. (mm)	4-3/4 (120)	5-1/2 (140)	6-1/4 (160)	7-7/8 (200)	9-7/8 (250)	11-7/8 (300)
A	Critical edge distance ²	$C_{ac,A}$	in. (mm)	4-3/8 (110)	4-3/8 (110)	4-3/4 (120)	5-7/8 (150)	8-7/8 (225)	8-7/8 (225)
A	Minimum edge distance ³	$C_{min,AA}$	in. (mm)	2-3/8 (60)	2-3/4 (70)	3-1/2 (90)	4-3/4 (120)	5 (125)	5-7/8 (150)
A	Minimum anchor spacing ³	$S_{min,AA}$	in. (mm)	5-1/2 (140)	9-1/2 (240)	11 (280)	12-5/8 (320)	13-3/4 (350)	11-7/8 (300)
A	Minimum edge distance ³	$C_{min,AB}$	in. (mm)	3-3/8 (85)	5 (125)	6-1/8 (155)	7-7/8 (200)	8-1/4 (210)	8-1/4 (210)
A	Minimum anchor spacing ³	$S_{min,AB}$	in. (mm)	2-3/8 (60)	2-3/4 (70)	3-1/8 (80)	4 (100)	5 (125)	5-7/8 (150)
B	Minimum concrete thickness	$h_{min,B}$ ⁴	in. (mm)	4-3/8 (110)	4-3/4 (120)	5-3/8 (135)	6-1/4 (160)	7-1/2 (190)	8-7/8 (225)
B	Critical edge distance ²	$C_{ac,B}$	in. (mm)	5-7/8 (150)	6-7/8 (175)	7-7/8 (200)	9-7/8 (250)	12-3/8 (312.5)	14-3/4 (375)
B	Minimum edge distance ³	$C_{min,BA}$	in. (mm)	2-3/8 (60)	3-1/2 (90)	4-3/8 (110)	6-1/4 (160)	7-7/8 (200)	8-7/8 (225)
B	Minimum anchor spacing ³	$S_{min,BA}$	in. (mm)	7 (180)	10-1/4 (260)	12-5/8 (320)	15 (380)	15-3/4 (400)	15 (380)
B	Minimum edge distance ³	$C_{min,BB}$	in. (mm)	4 (100)	6-1/4 (160)	7-7/8 (200)	10-5/8 (270)	11-7/8 (300)	12-5/8 (320)
B	Minimum anchor spacing ³	$S_{min,BB}$	in. (mm)	2-3/8 (60)	2-3/4 (70)	3-1/8 (80)	4 (100)	5 (125)	5-7/8 (150)

For pound-inch units: 1 mm = 0.03937 inches.

¹ The minimum edge distance, spacing and member thickness in this table is based on testing. In addition, the requirements of ACI 349-01, section 8 for post-installed expansion anchors shall apply. Additional combinations for minimum edge distance c_{min} and spacing s_{min} may be derived by linear interpolation between the given boundary values.

² See ACI 349-01, B.8 and ACI 355.2-01 9.4.

³ Denotes admissible combinations of h_{min} , C_{cr} , C_{min} and s_{min} . For example, $h_{min,A} + C_{cr,A} + C_{min,AA} + S_{min,AA}$ or $h_{min,A} + C_{cr,A} + C_{min,AB} + S_{min,AB}$ are admissible, but $h_{min,A} + C_{cr,B} + C_{min,AB} + S_{min,BB}$ is not. However, other admissible combinations for minimum edge distance c_{min} and spacing s_{min} for $h_{min,A}$ or $h_{min,B}$ may be derived by linear interpolation between boundary values (see example for $h_{min,A}$ below).

⁴ For the HSL-3-SH M8, M10 and M12 diameters, the minimum slab thickness $h_{min,B}$ must be increased by 5 mm (3/16").

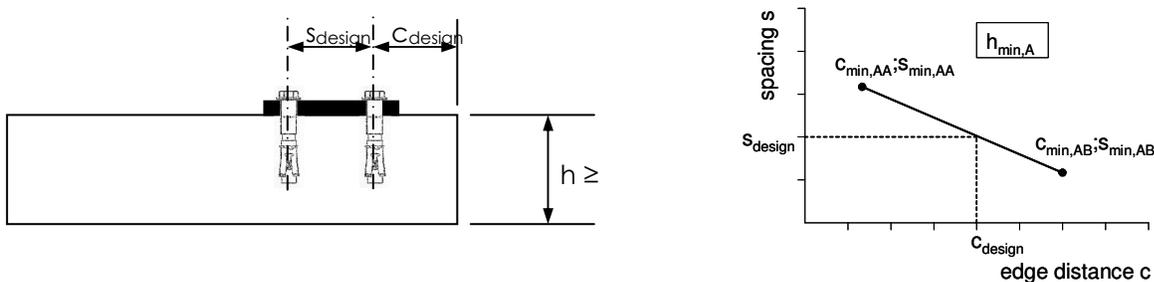


FIGURE 4—Example of allowable interpolation of minimum edge distance and minimum spacing

FIGURE 5—EXAMPLE CALCULATION

<p>Given: (2) HSL-3 M10 anchors under static tension load as shown. $h_{ef} = 2.76$ 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.</p>			
<p>Calculation per ACI 349-01 Appendix B and this document.</p>		<p>ACI 349-01</p>	<p>Guide Ref.</p>
<p>Step 1. Calculate steel strength of anchor in tension $N_s = nA_{se,N}f_{ut} = 2 \times 0.090 \times 116,000 = 20,880$ lb</p>		<p>B.5.1.2</p>	<p>Table 1</p>
<p>Step 2. Calculate steel capacity $\Phi N_s = 0.8 \times 20,880 = 16,704$ lb</p>		<p>B.4.4 a</p>	<p>Table 1</p>
<p>Step 3. Calculate concrete breakout strength of anchor in tension $N_{cbg} = \frac{A_N}{A_{No}} \psi_1 \psi_2 \psi_3 N_b$</p>		<p>B.5.2.1</p>	
<p>Step 4. Verify minimum spacing and edge distance: Table 4 Case A: $h_{min} = 5-1/2$ in. < 6 in. okay $\text{slope} = \frac{9.5 - 2.75}{2.75 - 5} = -3.0$ For $c_{min} = 4$ in. \Rightarrow $s_{min} = 9.5 - [(4 - 2.75)(-3.0)] = 5.75$ [in.] < 6 [in.] \therefore okay</p>		<p>B.8</p>	<p>Table 1 Table 2</p>
<p>Step 5. Calculate A_{No} and A_N for the anchorage: $A_{No} = 9h_{ef}^2 = 9(2.76 \text{ in.})^2 = 68.6 \text{ in}^2$ $A_N = (1.5h_{ef} + c)(3h_{ef} + s) = [1.5(2.76) + 4][3(2.76) + 6] = 116.2 \text{ [in}^2\text{]} < 2A_{No} \therefore$ okay</p>		<p>B.5.2.1</p>	<p>Table 1</p>
<p>Step 6. Calculate $N_b = k_{cr} \sqrt{f'_c} h_{ef}^{1.5} = 21 \sqrt{3,000} (2.76)^{1.5} = 5,274$ [lb]</p>		<p>B.5.2.2</p>	<p>Table 1</p>
<p>Step 7. Modification factor for eccentricity \rightarrow no eccentricity $e'_N = 0 \therefore \psi_1 = 1.0$</p>		<p>B.5.2.4</p>	<p>-</p>
<p>Step 8. Modification factor for edge $1.5h_{ef} = 1.5(2.76 \text{ in.}) = 4.13 \text{ in.} > c \therefore \psi_2$ must be calculated $\psi_2 = 0.7 + 0.3 \frac{4}{1.5(2.76)} = 0.99$</p>		<p>B.5.2.5</p>	<p>Table 1</p>
<p>Step 9. Modification factor for cracked concrete $\psi_3 = 1.0$</p>		<p>B.5.2.2 B.5.2.8</p>	<p>Table 1</p>
<p>Step 10. Calculate $N_{cbg} = \frac{116.2}{68.6} \times 1.0 \times 0.99 \times 1.0 \times 5,274 \text{ lb} = 8,844$ lb</p>		<p>B.5.2.1</p>	<p>-</p>
<p>Step 11. $\phi N_{cbg} = 0.75 \times 8,844 \text{ lb} = 6,633$ lb controls</p>		<p>B.4.4.c</p>	<p>Table 1</p>
<p>Step 12. Calculate pullout strength: $\phi N_{p,cr}$ $\phi N_{p,cr} = 0.75 \times 4,496 \text{ lb} = 3,372$ lb/anchor $\times 2$ anchors = 6,744 lb</p>		<p>B.5.3.2</p>	<p>Table 1</p>
<p>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 $\phi = 0.85$ $0.85 (8,844 \text{ lb}) < 20,880 \text{ lb} \Rightarrow$ ductility not met B.3.6.3 requires an additional reduction factor of 0.6 for non-ductile anchors $\phi N_{cbg} = 0.6 \times 6,633 = 3,980$ lb</p>		<p>B.3.6.1 B.3.6.3 B.4.1</p>	<p>Table 1</p>
<p>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.</p>			