ES REPORT™

ESR-1545

Reissued March 1, 2008

This report is subject to re-examination in two years.

ICC Evaluation Service, Inc.
www.icc-es.org

Business/Regional Office ■ 5360 Workman Mill Road, Whittier, California 90601 ■ (562) 699-0543
Regional Office ■ 900 Montclair Road, Suite A, Birmingham, Alabama 35213 ■ (205) 599-9800
Regional Office ■ 4051 West Flossmoor Road, Country Club Hills, Illinois 60478 ■ (708) 799-2305

DIVISION: 03—CONCRETE
Section: 03151—Concrete Anchoring

REPORT HOLDER:

HILTI, INC.
5400 SOUTH 122ND EAST AVENUE
TULSA, OKLAHOMA 74146
(800) 879-8000
www.us.hilti.com
HiltiTechEng@us.hilti.com

EVALUATION SUBJECT:

HILTI HSL-3 CARBON STEEL HEAVY DUTY EXPANSION ANCHORS FOR CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

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

Property evaluated:

Structural

2.0 USES

The Hilti HSL-3 Heavy Duty Expansion Anchor is used to resist static, wind, and seismic tension and shear loads in cracked and uncracked normal-weight and structural sand-lightweight concrete having a specified compressive strength 2,500 psi $\leq f'_c \leq$ 8,500 psi (17.2 MPa $\leq f'_c \leq$ 58.6 MPa). The anchoring system is an alternative to cast-in-place anchors described in Sections 1911 and 1912 of the IBC and Section 1923 of the UBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

3.0 DESCRIPTION

3.1 HSL-3 Metric:

3.1.1 General: The Hilti HSL-3 Carbon Steel Heavy Duty Expansion Concrete Anchor, designated as the HSL-3, is a torque-set, sleeve-type mechanical expansion anchor. The HSL-3 is comprised of seven components which vary slightly according to anchor diameter, as shown in Figure 1 of this report. It is available in five head configurations, illustrated in Figure 2 of this report.

All carbon steel parts receive a minimum 5 µm thick galvanized zinc coating.

Dimensions and installation criteria are set forth in Tables 1 and 2 of this report. Strength design information is provided in Tables 3 and 4 of this report. This anchor is manufactured using metric units.

Allowable loads for selected cases, derived using the strength design procedures of ACI 318-05 Appendix D and Section 4.2 of this report, are provided in Tables 5 through 9. An example calculation is provided in Figure 4 of this report.

3.1.2 HSL-3 (Bolt): The anchor consists of a stud bolt, steel washer, steel sleeve, collapsible plastic sleeve, steel expansion sleeve and steel cone. This anchor is available in carbon steel only. The material specifications are as follows:

- Bolt: Carbon steel per DIN EN ISO 898-1, Grade 8.8
- Washer: Carbon steel per DIN EN 10025.
- Expansion cone: Carbon steel per DIN 1654-4.
- Expansion sleeve: Carbon steel , M8-M16 per DIN 10139, M20-M24 per DIN 2393-2.
- Steel sleeve: Carbon steel per DIN 2393-1.
- Collapsible sleeve: Acetal polyoxymethylene (POM) resin.

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

3.1.3 HSL-3-G (Stud): The anchor has the same components and material specifications as the HSL-3 (bolt) with the exception that the bolt is replaced by a threaded rod of carbon steel per DIN EN ISO 898-1 Grade 8.8 and a nut of carbon steel per DIN 934 Grade 8. A screwdriver slot is provided on the exposed end of the threaded rod.

3.1.4 HSL-3-B (Torque-Indicator Bolt): The anchor has the same components and material specifications as the HSL-3 (bolt) with the addition of a torque cap nut that permits the proper setting of the anchor without a torque-indicator wrench. The torque cap is zinc alloy complying with DIN 1743. A hexagonal nut is fastened to the bolt head by three countersunk rivets. When the anchor is tightened, the torque is transmitted to the cap. When the torque corresponding to correct anchor expansion is attained, the three countersunk rivets shear off, leaving the torque cap to rotate freely.

3.1.5 HSL-3-SH: The anchor has the same components and material specifications as the HSL-3 (bolt) with the exception that the bolt head is configured to accept a hexagonal Allen wrench.

3.1.6 HSL-3-SK: The anchor has the same components and material specifications as the HSL-3 (bolt) except that the bolt head is configured for countersunk applications, is configured to accept a hexagonal Allen wrench and is provided with a conical washer. The bolt is carbon steel per DIN ISO 4759-1 and DIN EN ISO 898-1, Grade 8.8.

3.2 Concrete:

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

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Design strengths are determined in accordance with ACI 318-05 Appendix D and this report. Design parameters are provided in Tables 3 and 4 of this report. 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 or Section 1612.2.1 of the UBC. 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 318-05 and Section 1909.2 of the UBC. Strength reduction factors ϕ corresponding to ductile steel elements may be used.

4.1.2 Requirements for Steel Strength in Tension: The static steel strength in tension must be calculated in accordance with ACI 318 Section D 5.1.2. The values used to calculate steel strengths are described in Table 3 of this report.

4.1.3 Requirements for Concrete Breakout Strength in Tension: The basic concrete breakout strength in tension must be calculated according to ACI 318 D.5.2.2 using the values of $h_{ef,min}$ and k_{cr} as given in Table 3 of this report in lieu of h_{ef} and k, respectively. The nominal concrete breakout strength in tension, in regions where analysis indicates no cracking in accordance with ACI 318 Section D.5.2.6, must be calculated with $\Psi_{c,N}$ as given in Table 3 of this report.

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

$$\Psi_{cp,N} = \frac{c}{c_{ac}} \tag{1}$$

whereby the factor $\Psi_{cp,N}$ need not be taken as less than $\frac{1.5h_{ef}}{c_{ac}}$. For all other cases, $\Psi_{cp,N}$= 1.0. Values for the critical edge distance c_{ac} must be taken from Table 4 of this report. The values $c_{ac,A}$ are valid for a member thickness $h \geq h_{min,A}$ and the values $c_{ac,B}$ for $h_{min,B} \leq h < h_{min,A}$.

4.1.5 Requirements for Pullout Strength in Tension: The pullout strength of the anchor in cracked concrete, where given in Table 3 of this report, is governed by anchor displacement. In accordance with ACI 318 D.5.3.2, the nominal pullout strength in tension must be calculated according to the following equation:

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

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

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

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

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

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

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 D.6.1.2(b), the values of V_s given in Table 3 of this report must be used.

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

4.1.8 Requirements for Static Concrete Pryout Strength of Anchor in Shear, V_{cp} or V_{cpg}: Static concrete pryout strength shear capacity must be calculated in accordance with ACI 318 Section D.6.3 based on the values described in Table 3.

4.1.9 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

4.1.10 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: In lieu of ACI 318 Section D.8.3, values of c_{min} and s_{min} as given in Table 4 of this report must be used. In lieu of ACI 318 D.8.5, minimum member thicknesses h_{min} as given in Table 4 of this report must be used. Additional combinations for minimum edge distance c_{min} and spacing s_{min} may be derived by linear interpolation between the given boundary values. (See example in Table 4 of this report.)

4.1.11 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.

4.1.12 Requirements for Seismic Design: For load combinations including earthquake the design must be performed according to ACI 318 D.3.3 as modified by Section 1908.1.16 of the IBC. The nominal steel strength and the nominal concrete breakout strength for anchors in tension and the nominal concrete breakout strength and pryout strength for anchors in shear must be calculated according to ACI 318 D.5 and D.6, respectively, taking into account the corresponding values given in Table 3 of this report. The nominal pullout strength $N_{p,seismic}$ and the nominal steel strength for anchors in shear $V_{s,seismic}$ must be evaluated with the values given in Table 3 of this report. The values of $N_{p,seismic}$ must be adjusted for concrete strength as follows:

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

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

If no values for $N_{p,seismic}$ are given in Table 3, the static design strength values govern. (See Section 4.1.5 of this report.)

4.2 Allowable Stress Design:

Design values for use with allowable stress design (working stress design) must be established as follows:

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

where $R_d = \phi R_k$ represents the limiting design strength in tension (ϕN_n) or shear (ϕV_n) as calculated according to ACI 318 D.4.1.1 and D.4.1.2 and Section 4.1 of this report. Limits on edge distance, anchor spacing and member thickness as given in Section 4.1.5 of this report must apply. An example allowable stress design values for illustrative purposes are shown in Table 5.

Correction factor α is 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.

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

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

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

For all other cases:

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

4.3 Installation:

Installation parameters are provided in Tables 1 and 2 and in Figure 3 of this report. Anchors must be installed per the manufacturer's published instructions and this report.

4.4 Special Inspection:

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

5.0 CONDITIONS OF USE

The Hilti HSL-3 anchors described in this report comply with the codes specifically listed in Section 1.0 of this report, subject to the following conditions:

5.1 Anchor sizes, dimensions and minimum embedment depths are as set forth in the tables of this report.

5.2 The anchors are installed in accordance with the manufacturer's published installation instructions and this report, in concrete with a specified strength of f'_c= 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

5.3 The values of f'_c used for calculation purposes must not exceed 8,000 psi (55.1 MPa).

5.4 Loads applied to the anchors are adjusted in accordance with Section 1605.2.1 of the IBC and Sections 1612.3 or 1909.2 of the UBC for strength design and in accordance with Section 1605.3 of the IBC and Section 1612.3 of the UBC for allowable stress design.

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

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

5.7 Anchor spacing and edge distance as well as minimum member thickness must comply with Table 4 of this report.

5.8 Prior to installation, calculations and details demonstrating compliance with this report must be submitted to the code official. The calculations and details must be prepared by a registered design professional where required by the statues of the jurisdiction in which the project is to be constructed.

5.9 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.

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

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

5.12 Where not otherwise prohibited in the code, anchors are permitted for use with fire-resistance-rated construction provided that at least one of the following conditions is fulfilled:

- Anchors are used to resist wind or seismic forces only.
- Anchors that support a fire-resistance-rated envelope or a fire-resistance-rated membrane, are protected by approved fire-resistance-rated materials, or have been evaluated for resistance to fire exposure in accordance with recognized standards.
- Anchors are used to support nonstructural elements.

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

5.14 Anchors are manufactured for Hilti, Inc., by Frigo Zerspanungstechnik, GmbH, Nüziders, Austria, 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 February 2008.

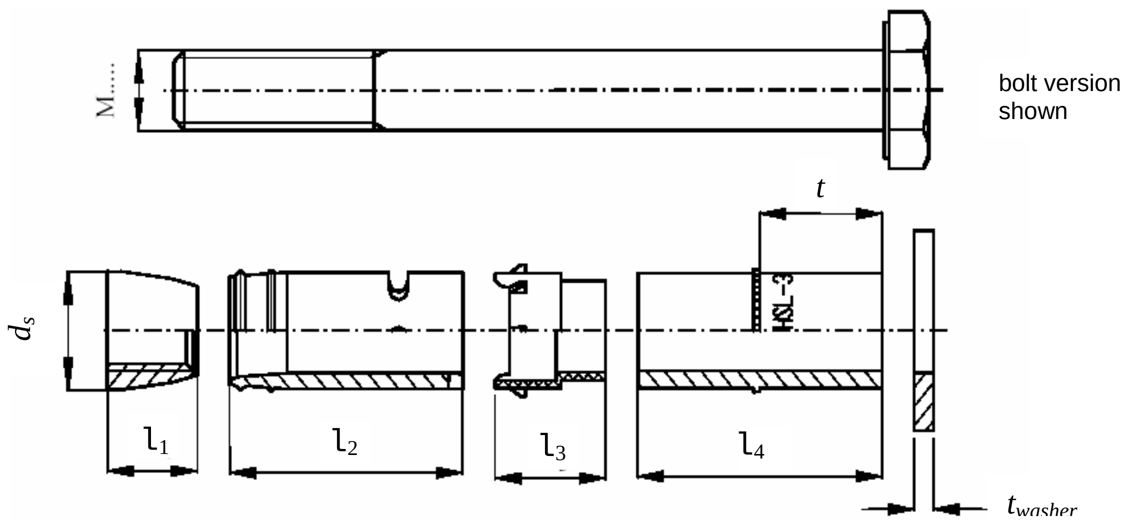
7.0 IDENTIFICATION

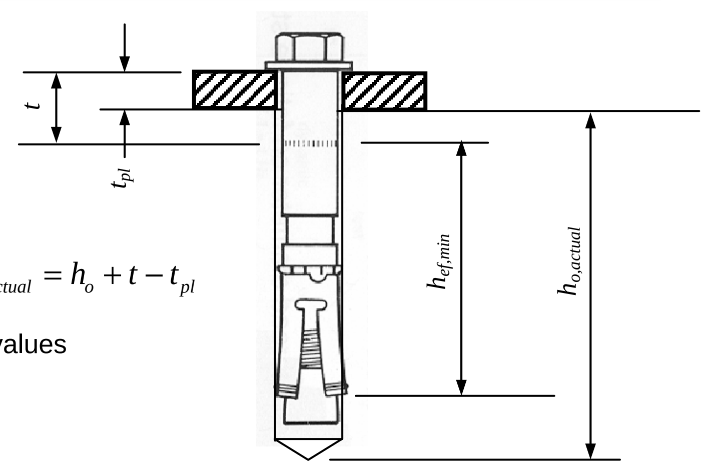
The anchors are identified by packaging labeled with the evaluation report holder's name (Hilti, Inc.) and address, anchor name, anchor size, evaluation report number (ICC-ES ESR-1545), and the name of the inspection agency (Underwriters Laboratories Inc.). The anchors have the letters HSL-3 and the anchor size embossed on the sleeve.

TABLE 1—ANCHOR DIMENSIONAL CHARACTERISTICS (mm)

ANCHOR VERSION (see Fig.2)	Nom. bolt dia.	Max. thickness of fastened part, t, corresponding to anchor length options			d_s	l_1	l_2	l_3	l_4 min.	l_4 max.	t_{washer}
HSL-3 (bolt) HSL-3-G	M8	20	40	5 < t ≤ 200 [1]	11.9	12.0	32.0	15.2	19.0	214.0	2.0
	M10	20	40	5 < t ≤ 200 [1]	11.9	14.0	36.0	17.2	23.0	218.0	3.0
HSL-3 (bolt) HSL-3-G HSL-3-B	M12	25	50	5 < t ≤ 200 [1]	17.6	17.0	40.0	20.0	28.0	223.0	3.0
	M16	25	50	5 < t ≤ 200 [1]	23.6	20.0	54.4	24.4	34.5	224.5	4.0
	M20	30	60	10 < t ≤ 200 [1]	27.6	20.0	57.0	31.5	51.0	241.0	4.0
HSL-3 (bolt) HSL-3-B	M24	30	60	10 < t ≤ 200 [1]	31.6	22.0	65.0	39.0	57.0	247.0	4.0
HSL-3-SH	M8	5			11.9	12.0	32.0	15.2	19.0		2.0
	M10	20			14.8	14.0	36.0	17.2	38.0		3.0
	M12	25			17.6	17.0	40.0	20.0	48.0		3.0
HSL-3-SK	M8	10		20	11.9	12.0	32.0	15.2	18.2	28.2	2.0
	M10	20			14.8	14.0	36.0	17.2	32.2		3.0
	M12	25			17.6	17.0	40.0	20.0	40.0		3.0

For pound-inch units: 1 mm = 0.03937 inches. [1] custom anchor lengths





For determination of required hole depth: $h_{o,actual} = h_o + t - t_{pl}$

See Tables 2 and 3 for values of h_o and $h_{ef,min}$.

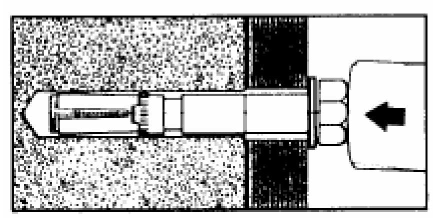
TABLE 2—SETTING INFORMATION

		Nominal anchor diameter							
Parameters		**Symbol**	**Units**	**M8**	**M10**	**M12**	**M16**	**M20**	**M24**
Nominal drill bit diameter[1]		**d_{bit}**	**mm**	**12**	**15**	**18**	**24**	**28**	**32**
Hilti matched-tolerance carbide-tipped drill bit		-	-	TE-CX 12/22 TE-YX 12/35	TE-CX 15/27 TE-YX 15/35	TE-C 18/22 TE-YX 18/32	TE-C-T 24/27 TE-YX 24/32	TE-C-T 28/27 TE-YX 28/32	TE-YX 32/37
Minimum hole depth	HSL-3, HSL-3-G, HSL-3-B, HSL-3-SK	h_o	mm (in.)	80 (3.15)	90 (3.54)	105 (4.13)	125 (4.92)	155 (6.10)	180 (7.09)
	HSL-3-SH	h_o	mm (in.)	85 (3.35)	95 (3.74)	110 (4.33)			
Clearance hole diameter in part being fastened		d_h	mm (in.)	14 (0.55)	17 (0.67)	20 (0.79)	26 (1.02)	31 (1.22)	35 (1.38)
Max. cumulative gap between part(s) being fastened and concrete surface		-	mm (in.)	4 (0.16)	5 (0.20)	8 (0.31)	9 (0.35)	12 (0.47)	16 (0.63)
Washer diameter HSL-3, HSL-3-G, HSL-3-B		d_w	mm (in.)	20 (0.79)	25 (0.98)	30 (1.18)	40 (1.57)	45 (1.77)	50 (1.97)
Installation torque HSL-3		T_{inst}	Nm (ft-lb)	25 (18)	50 (37)	80 (59)	120 (89)	200 (148)	250 (185)
Wrench size HSL-3, HSL-3-G		-	mm	13	17	19	24	30	36
Wrench size HSL-3-B		-	mm			24	30	36	41
Installation torque HSL-3-G		T_{inst}	Nm (ft-lb)	20 (15)	35 (26)	60 (44)	80 (59)	160 (118)	
Allen wrench size for HSL-3-SH		-	mm	6	8	10			
Installation torque HSL-3-SH		T_{inst}	Nm (ft-lb)	20 (15)	35 (26)	60 (44)			
Allen wrench size for HSL-3-SK		-	mm	5	6	8			
Installation torque HSL-3-SK		T_{inst}	Nm (ft-lb)	25 (18)	50 (37)	80 (59)			
Diameter of countersunk hole HSL-3-SK		d_{sk}	mm (in.)	22.5 (0.89)	25.5 (1.00)	32.9 (1.29)			

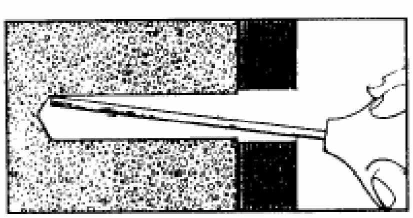
For pound-inch units: 1 mm = 0.03937 inches, 1 Nm = 0.7376 ft-lbf.

[1]Use metric bits only.

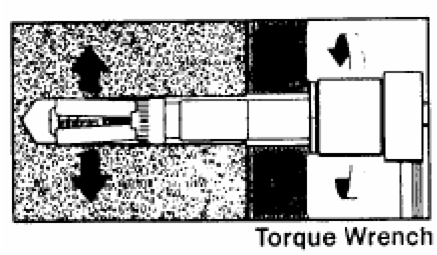
Step 1:
Using the correct diameter metric bit, drill hole to minimum required hole depth or deeper.



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



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



Step 4:
Using a torque wrench, apply the specified installation torque. HSL-3-B does not require use of a torque wrench.

TABLE 3—DESIGN INFORMATION

Design parameter		Symbol	Units	Nominal anchor diameter					
				M8	M10	M12	M16	M20	M24
Anchor O.D.		d_0	mm	12	15	18	24	28	32
			in.	0.47	0.59	0.71	0.94	1.10	1.26
Effective min. embedment depth[1]		$h_{ef,min}$	mm	60	70	80	100	125	150
			in.	2.36	2.76	3.15	3.94	4.92	5.91
Anchor category[2]		*1,2 or 3*	-	1	1	1	1	1	1
Strength reduction factor for tension, steel failure modes[3]		ϕ	-	0.75					
Strength reduction factor for shear, steel failure modes[3]		ϕ	-	0.65					
Strength reduction factor for tension, concrete failure modes[3]		ϕ	Cond.A	0.75					
			Cond.B	0.65					
Strength reduction factor for shear, concrete failure modes[3]		ϕ	Cond.A	0.75					
			Cond.B	0.70					
Yield strength of anchor steel		f_y	lb/in^2	92,800					
Ultimate strength of anchor steel		f_{ut}	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[4]		k_{cr}	-	17	24	24	24	24	24
k_{uncr}/k_{cr}[5]		$\psi_{C,N}$	-	1.41	1.00	1.00	1.00	1.00	1.00
Pullout strength uncracked concrete[6]		$N_{p,uncr}$	lb	4,204	-	-	-	-	-
Pullout strength cracked concrete[6]		$N_{p,cr}$	lb	2,810	4,496	-	-	-	-
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	
Tension pullout strength seismic[7]		$N_{p,seismic}$	lb	-	-	-	-	-	14,320
Steel strength in shear, seismic[7] HSL-3,-B,-SH,-SK		$V_{s,seismic}$	lb	4,609	8,453	11,892	24,796	29,135	38,173
Steel strength in shear, seismic[7] HSL-3-G			lb	3,777	6,924	9,824	21,065	24,459	
Axial stiffness in service load range[8]	uncracked concrete	β_{uncr}	10^3 lb/in.	300					
	cracked concrete	β_{cr}		30	70	130	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 Table 1.

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

[3]For use with the load combinations of ACI 318-05 9.2. Condition A applies where the potential concrete failure surfaces are crossed by supplementary reinforcement proportioned to tie the potential concrete failure prism into the structural member. Condition B applies where such supplementary reinforcement is not provided, or where pullout or pryout strength governs.

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

[5]See ACI 318-05 D.5.2.6.

[6]See Section 4.1.5 of this report.

[7]See Section 4.1.12 of this report.

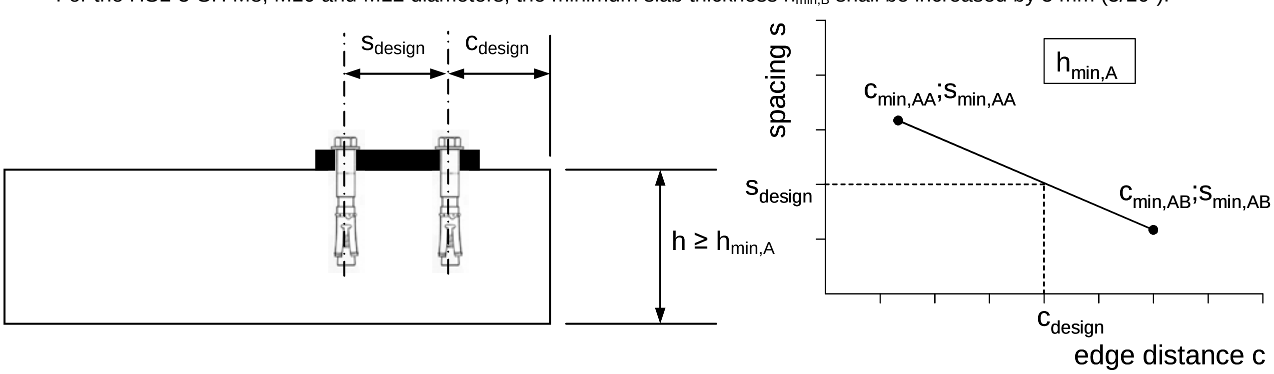
[8]Minimum axial stiffness values, maximum values may be 3 times larger (e.g., due to high-strength concrete) .

TABLE 4—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]See Section 4.1.10 of this report.
[2]See Section 4.1.4 of this report.
[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 $h_{min,B}$ shall be increased by 5 mm (3/16").



Example of allowable interpolation of minimum edge distance and minimum spacing

TABLE 5—Example Allowable Stress Design Values for Illustrative Purposes[1,2,3,4,5,6,7,8]

Nominal Anchor Diameter	Effective Embedment		Allowable Tension (lbs)
	mm	**inches**	***f'c* = 2500 psi**
M8	60	2.36	1,846
M10	70	2.76	2,417
M12	80	3.15	2,946
M16	100	3.94	4,122
M20	125	4.92	5,751
M24	150	5.91	7,572

[1] Single anchor 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 + 1.6L
[5] Calculation of 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] $h \geq h_{min}$
[9] ø factor is 0.65

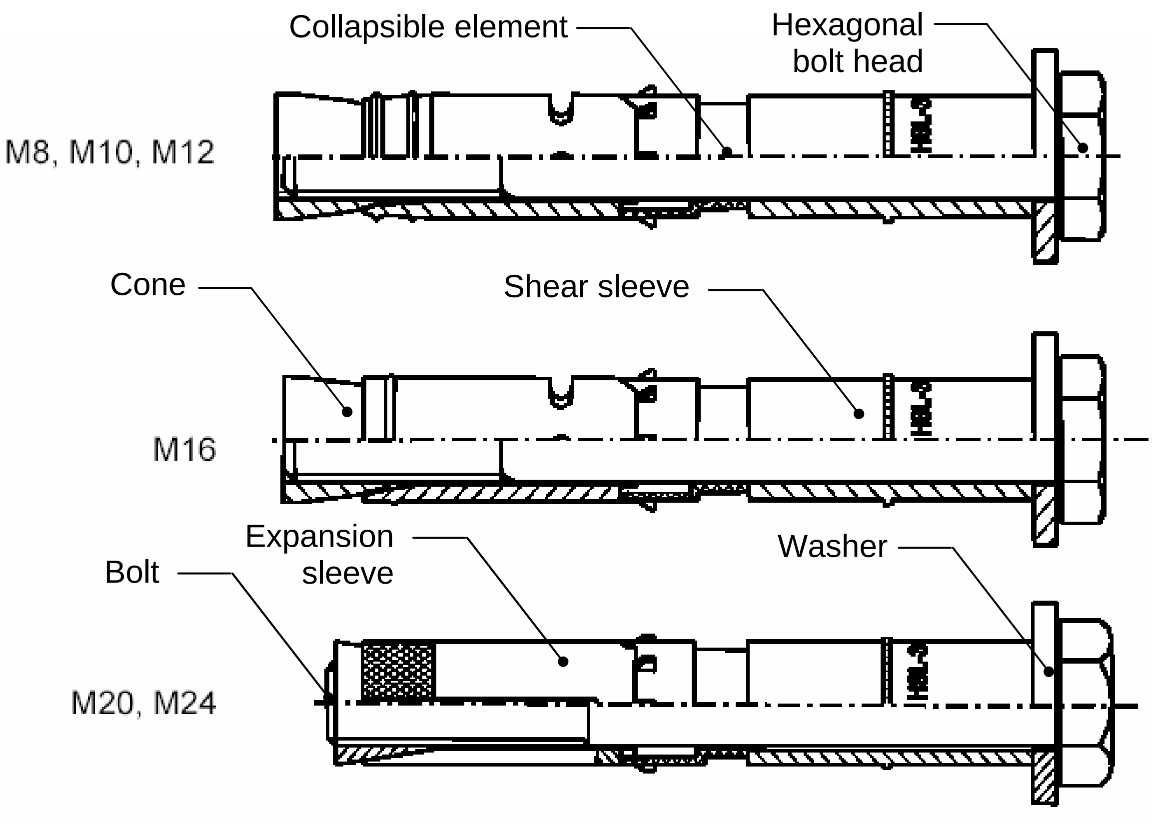


FIGURE 1—HSL-3 (BOLT VERSION SHOWN)

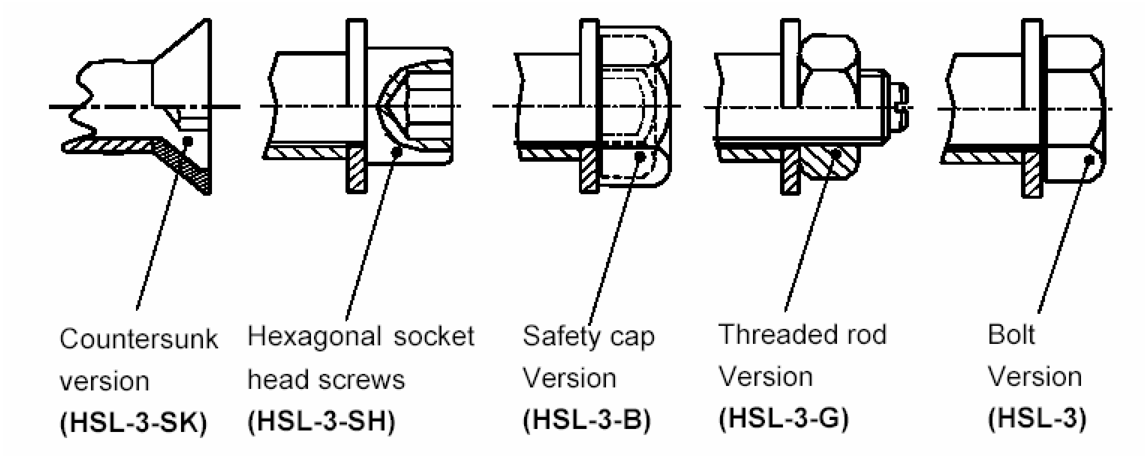


FIGURE 2—HSL-3 HEAD CONFIGURATIONS

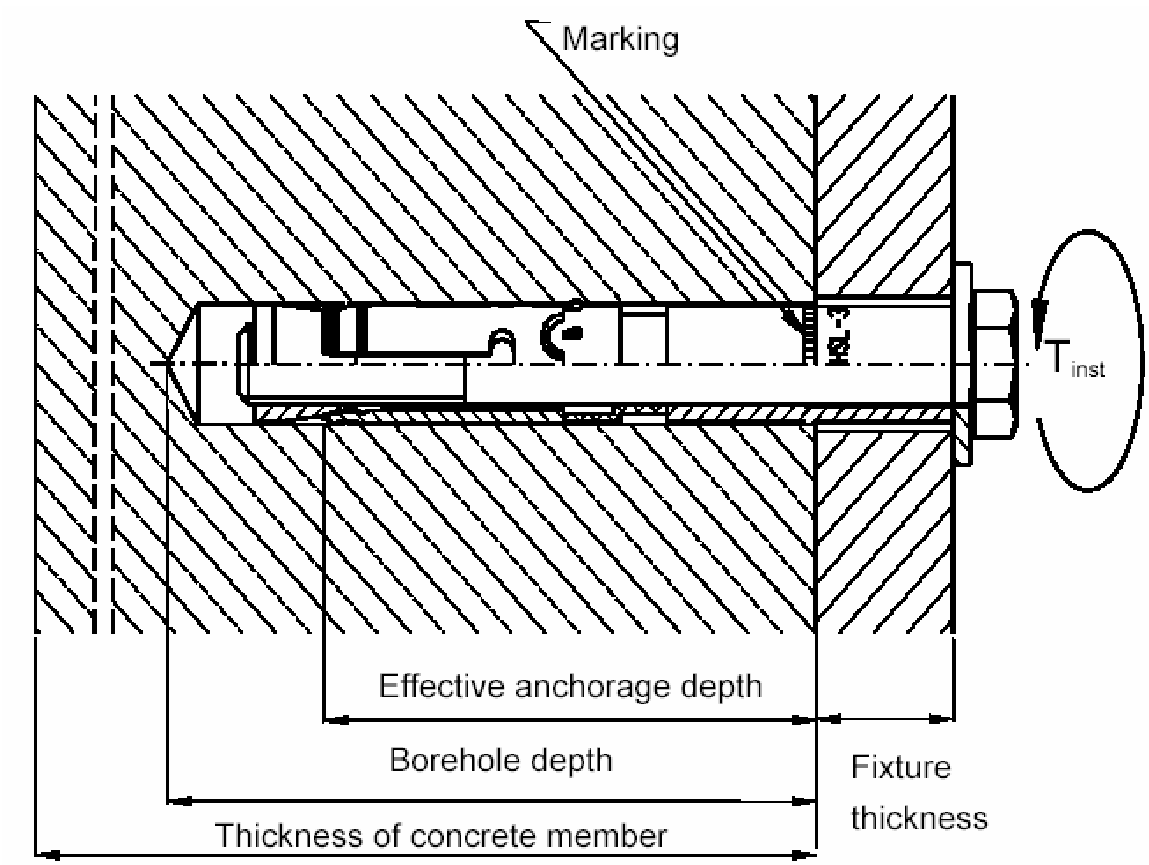


FIGURE 3—CORRECT INSTALLATION OF HSL-3

Given:

2 HSL-3 M10 anchors under static tension load as shown.

h_{ef} = 2.76 in. (70 mm).

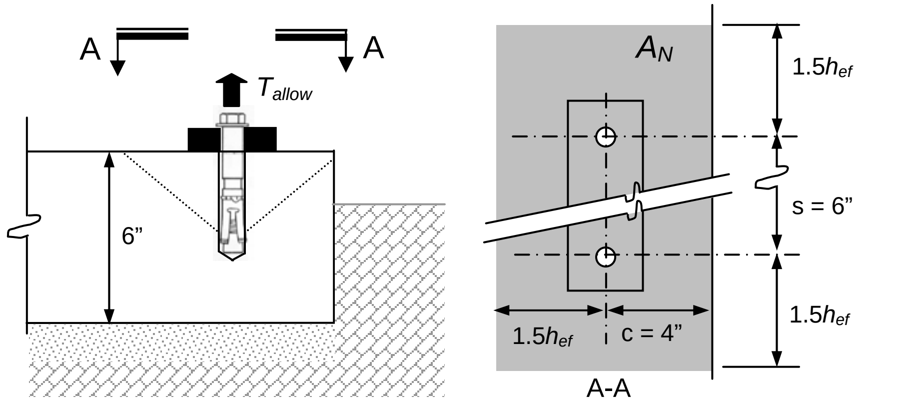
Slab on grade, f'_c = 3,000 psi.

No supplementary reinforcing.

Assume uncracked concrete.

Condition B per ACI 318 D.4.4 c)

Calculate the allowable tension load for this configuration.



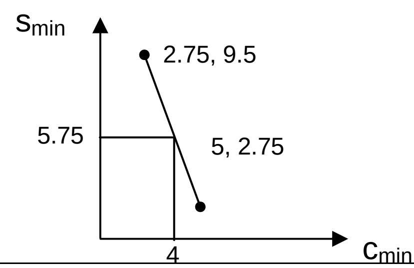
Calculation per ACI 318-05 Appendix D and this report.	Code Ref.	Report Ref.
Step 1. Calculate steel strength of anchor in tension $N_s = nA_{se}f_{ut} = 2 \times 0.090 \times 116,000 = 20,880$ lb	D.5.1.2	Table 3
Step 2. Calculate steel capacity $\phi N_s = 0.75 \times 20,880 = 15,660$ lb	D.4.4 a)	Table 3
Step 3. Calculate concrete breakout strength of anchor in tension $N_{cbg} = \frac{A_n}{A_c}\psi_{ec,N}\psi_{ed,N}\psi_{c,N}\psi_{cp,N}N_b$	D.5.2.1	§4.1.1 §4.1.2
Step 3a. Verify minimum spacing and edge distance: Table 4 Case A: h_{min} = 5-1/2 in. < 6 in. ∴ ok $\text{slope} = \frac{9.5 - 2.75}{2.75 - 5} = -3.0$ For $c_{min} = 4\text{ in} \Rightarrow$ $s_{min} = 9.5 - [(4 - 2.75)(-3.0)] = 5.75\text{ in} < 6\text{ in} \therefore$ ok 	D.8	Table 4
Step 3b. Check $1.5h_{ef} = 1.5(2.76) = 4.13$ in > c $3.0h_{ef} = 3(2.76) = 8.28$ in > s	D.5.2.1	Table 4
Step 3c. Calculate A_{No} and A_N for the anchorage: $A_{No} = 9h_{ef}^2 = 9 \times (2.76)^2 = 68.6\text{ in}^2$ $A_N = (1.5h_{ef} + c)(3h_{ef} + s) = [1.5 \times (2.76) + 4][3 \times (2.76) + 6] = 116.2\text{ in}^2 < 2 \cdot A_{No} \therefore$ ok	D.5.2.1	Table 3
Step 3d. Calculate $\psi_{ec,N}$: $e_{N'} = 0$, $\psi_{ec,N} = 1$	D.5.2.4	Table 3
Step 3e. Calculate N_b: $N_b = k_{cr}\sqrt{f'_c}\,h_{ef}^{1.5} = 24 \times \sqrt{3,000} \times 2.76^{1.5} = 6,027$ lb	D.5.2.2	Table 3
Step 3f. Calculate modification factor for edge distance: $\psi_{ed,N} = 0.8 + 0.3\frac{4}{1.5(2.76)} = 0.99$	D.5.2.5	Table 4
Step 3g. $\psi_{c,N}$ =1.0	D.5.2.6	Table 3
Step 3h. Calculate modification factor for splitting: $\psi_{cp,N} = \frac{\max\lvert c;1.5h_{ef}\rvert}{c_{ac}}$ check: $\frac{4}{4.375} = 0.91$ $\frac{1.5(2.76)}{4.375} = 0.94 \therefore \frac{1.5h_{ef}}{c_{ac}}$ *controls*	-	§ 4.1.2 Table 4
Step 3i. Calculate N_{cbg}: $N_{cbg} = \frac{116.2}{68.6} \times 1 \times 0.99 \times 1 \times 6,027 \times 0.94 = 9,500$ lb	D.5.2.1	§ 4.1.1 Table 3
Step 4. Check pullout strength: Per Table 3, $N_{p,uncr}$ does not govern.	D.5.3.2	§ 4.1.3 Table 3
Step 5. Controlling strength: $\phi N_{cbg} = 0.65 \times 9,500 = 6,175\text{ lb} < \phi N_s \therefore \phi N_{cbg}$ controls	D.4.4 c)	Table 3
Step 6. Convert value to ASD: $T_{allow} = \frac{\phi N_n}{\alpha}$ $T_{allow} = \frac{6,175 * 0.65}{1.48} = 2,690$ lb (assume 30% dead load and 70% live load, controlling load combination 1.2D + 1.6L, α = 0.3*1.2 + 0.7*1.6 = 1.48)	-	§ 4.2

FIGURE 4—EXAMPLE CALCULATION