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ESR-2691*

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DIVISION: 03 00 00—CONCRETE
Section: 03 16 00—Concrete Anchors

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EVALUATION SUBJECT:

fischer FH II CARBON STEEL HEAVY DUTY SLEEVE ANCHOR FOR ANCHORING IN CRACKED AND UNCRACKED CONCRETE

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)
- 1997 *Uniform Building Code*™ (1997 UBC)

Property evaluated:

Structural

2.0 USES

The fischer FH II Carbon Steel Heavy Duty Sleeve 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, f'_c of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

The fischer FH II anchors comply as anchors installed in hardened concrete in accordance with Section 1912 of the 2009 and 2006 IBC. The anchor system is an alternative to cast-in-place anchors described in Section 1911 of the 2009 and 2006 IBC and Sections 1923.1 and 1923.2 of the UBC. The anchors may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the 2009 and 2006 IRC.

3.0 DESCRIPTION

3.1 FH II Carbon Steel Heavy Duty Sleeve Anchor:

3.1.1 General: The fischer FH II Carbon Steel Heavy Duty Sleeve Anchor, designated as the FH II, is a torque-controlled, sleeve-type mechanical expansion anchor. The components, dimensions and installation criteria are set forth in Tables 1, 2 and 4, and Figures 1, 2 and 3 of this report. Four head configurations are available: Version S, Version B, Version H and Version SK. The head configurations are illustrated in Figure 3. All carbon steel parts have a minimum 0.0002 inch (5 μm) thick galvanized zinc coating according to DIN EN ISO 4042.

Application of torque at the head of the anchor causes the cone to be drawn into the expansion sleeve. This cone movement in turn causes the expansion sleeve to expand against the wall of the drilled hole. The ribs on the collapsible sleeve prevent rotation of the expansion sleeve and cone during application of torque. Application of the specified installation torque induces a tension force in the concrete acting through the component being fastened. Telescopic deformation of the collapsible sleeve prevents buildup of pre-compression in the expansion sleeve in cases where the steel 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 pre-compression force in the anchor will cause the cone to displace further into the expansion sleeve (follow-up expansion), generating additional expansion force.

3.1.2 FH II S (Hexagonal Screw Version): The anchor consists of an ISO 898-1, Class 8.8 hexagonal screw, 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:

- Hexagonal screw: Carbon steel complying with ISO 898-1, Class 8.8
- Washer: Carbon steel complying with EN 10139.
- Expansion cone: Carbon steel complying with EN 10277.
- Expansion sleeve: Carbon steel complying with EN 10305.
- Steel sleeve: Carbon steel complying with EN 10305-1.
- Collapsible sleeve: Plastic blend of polymer complying with ISO 527-1 and ISO 527-2.

***Revised April 2014**

3.1.3 FH II B (Bolt Version with Threaded Rod): The FH II B has the same components and material specifications as the FH II S (hexagonal screw) except that the hexagonal screw is replaced by a carbon steel threaded rod complying with ISO 898-1 Class 8.8 and a carbon steel hexagonal nut complying with ISO 898-2.

3.1.4 FH II H (Hexagonal Cap Nut Version): The FH II H has the same components and material specifications as the FH II B (bolt) except that a carbon steel hexagonal cap nut complying with ISO 898-2 replaces the nut.

3.1.5 FH II SK (Countersunk Screw Version): The FH II SK has the same components and material specifications as the FH II S (hexagonal screw) except that the hexagonal screw head is configured for countersunk applications, is configured to accept a hexagonal Allen wrench, and is provided with a conical washer. The screw is formed from carbon steel complying with ISO 898-1 and the conical washer is formed from carbon steel complying with EN 10277.

3.2 Concrete:

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

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: Design strength of anchors in accordance with the 2006 IBC and 2006 IRC must be in accordance with ACI 318-05 Appendix D and this report.

Design strength of anchors in accordance with the 2009 IBC and 1997 UBC as well as Section 301.1.3 of the 2009 IRC must be determined in accordance with ACI 318-08 Appendix D and this report. Design examples according to the 2006 IBC are given in Figures 4 through 7 of this report. Design parameters are based on the 2009 IBC (ACI 318-08) unless noted otherwise in Section 4.1.1 through 4.1.12 of this report. The strength design of anchors must comply with ACI 318 D.4.1, except as required in ACI 318 D.3.3.

Strength reduction factors, ϕ, as given in ACI 318 D.4.4 must be used for load combinations calculated in accordance with Section 1605.2.1 of the IBC and Section 9.2 of ACI 318 or Section 1612.2 of the UBC. Strength reduction factors, ϕ, as given in ACI 318 D.4.5 must be used for load combinations calculated in accordance with ACI 318 Appendix C or Section 1909.2 of the UBC.

The value of f'_c used in the calculations must be limited to 8,000 psi (55.2 MPa) maximum, in accordance with ACI 318 D.3.5. Strength reduction factors, Φ, corresponding to ductile steel elements may be used for the FH II.

4.1.2 Requirements for Static Steel Strength in Tension, N_{sa}: The nominal steel strength of a single anchor in tension in accordance with ACI 318 D.5.1.2, N_{sa} is given in Table 3 of this report. Strength reduction factors, Φ, corresponding to ductile steel elements may be used for the FH II.

4.1.3 Requirements for Concrete Breakout Strength in Tension, N_{cb} and N_{cbg}: The nominal concrete breakout strength of a single anchor or group of anchors in tension, N_{cb} and N_{cbg}, respectively must be calculated in accordance with ACI 318 D.5.2, with modifications as described in this section. The basic concrete breakout strength of a single anchor in tension, N_b, must be calculated according to ACI 318 D.5.2, using the values of k_{cr} and h_{ef} and as given in Table 3 of this report. The value of f'_c is limited to 8,000 psi (55.2 MPa), maximum, in accordance with ACI 318 D.3.5. The nominal concrete breakout strength in tension in regions where analysis indicates no cracking at service loads in accordance with ACI 318 D.5.2.6 shall be calculated with Ψ_{cN} = 1.0 and using the value of k_{uncr} as given in Table 3 of this report.

4.1.4 Requirements for Critical Edge Distance, Splitting: 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 $\Psi_{cp,N}$ according to ACI 318 D.5.2.7 (Eq-1 of this report). In lieu of ACI 318 D.8.6, values of c_{ac} provided in Table 4 of this report must be used.

$$\Psi_{cp,N} = \frac{c}{c_{ac}} \qquad \text{(Eq-1)}$$

whereby the factor $\Psi_{cp,N}$ need not to be taken as less than $\frac{1.5h_{ef}}{c_{ac}}$

For all other cases $\Psi_{cp,N}$ = 1.0.

4.1.5 Requirements for pullout strength in tension, N_{pn}: The nominal pullout strength of a single anchor in tension in accordance with ACI 318 D.5.3 in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, do not need to be evaluated.

4.1.6 Requirements for Static Steel Strength in Shear, V_{sa}: In lieu of the value of the nominal steel strength values of V_{sa} as given in ACI 318, D.6.1.2 in shear, the values of V_{sa} for single anchor given in Table 3 of this report shall be used and not derived by calculation. Strength reduction factors, Φ, corresponding to ductile elements may be used for the FH II.

4.1.7 Requirements for Static Concrete Breakout Strength in Shear V_{cb} or V_{cbg}: The nominal concrete breakout strength of a single anchor or group of anchors in shear, V_{cb} or V_{cbg}, respectively must be calculated in accordance with ACI 318 D.6.2, with modifications as described in this section. The basic concrete breakout strength of a single anchor in shear, V_b, must be calculated in accordance with ACI 318 D.6.2.2 using the value of l_e and d_a given in Table 3 of this report.

4.1.8 Requirements for Static Concrete Pryout Strength in Shear V_{cp} or V_{cpg}: The nominal concrete pryout strength of a single anchor or group of anchors in shear, V_{cp} or V_{cpg}, must be calculated in accordance with ACI 318 D.6.3, modified by using the value of k_{cp} provided in Table 3 of this report and the value of N_{cb} or N_{cbg} as calculated in accordance with Section 4.1.3 of this report.

4.1.9 Requirements for Minimum Member Thickness, Minimum Anchor Spacing and Minimum Edge Distance: In lieu of ACI 318 D.8.5, minimum member thickness, $h_{a,min}$, must comply with Table 4 of this report. In lieu of ACI 318 D.8.3, minimum edge distance and minimum spacing, $c_{a,min}$ and $s_{a,min}$ must comply with Table 4 of this report. Intermediate values between s_{min} and c_{min} can be calculated by linear interpolation. Figures 4 through 7 of this report provide more detail.

4.1.10 Requirements for Seismic Design:

4.1.10.1 General: For load combinations including seismic, the design must be performed according to ACI 318 D.3.3, as modified by Section 1908.1.9 of the 2009 IBC or Section 1908.1.16 of the 2006 IBC, or the following:

CODE	ACI 318 SECTION D3.3 SEISMIC REGION	CODE EQUIVALENT DESIGNATION
UBC	Moderate or high seismic risk	Seismic Zones 2B, 3 and 4

The nominal steel strength and the nominal concrete breakout strength for anchors in tension, and the nominal concrete breakout strength and pryout strength for anchors in shear, must be calculated according to ACI 318 Sections D.5 and D.6, respectively, taking into account the corresponding values in Table 3 and 4 of this report. The anchors comply with ACI 318 Section D.1 as ductile steel elements and must be designed in accordance with ACI 318-05 Section D.3.3.4 or D.3.3.5 or ACI 318-08 Section D.3.3.4, D.3.3.5 or D.3.3.6.

4.1.10.2 Seismic Tension: The nominal steel strength and nominal concrete breakout strength for anchors in tension must be calculated according to ACI 318 D.5.1 and D.5.2, as described in Sections 4.1.2 and 4.1.3 of this report and in accordance with ACI 318 Section D.5.3.2. The value for pullout strength in tension for seismic loads, N_{eq}, does not need to be evaluated.

4.1.10.3 Seismic Shear: The nominal concrete breakout strength and pryout strength for anchors in shear must be calculated according to ACI 318 Section D.6.2 and D.6.3, as described in Sections 4.1.7 and 4.1.8 of this report. In accordance with ACI 318 D.6.1.2. the appropriate value for nominal steel strength in shear for seismic loads, V_{eq}, described in Table 3 of this report must be used in lieu of V_{sa}. Strength reduction factors, Φ, corresponding to ductile elements must be used for the FH II.

4.1.11 Requirements for Interaction of Tensile und Shear Forces: For loadings that include combined tension and shear, the design must be performed in accordance with ACI 318 D.7.

4.1.12 Structural Sand-lightweight Concrete: For ACI 318-08, when anchors are used in structural sand-lightweight concrete, the modification factor λ for concrete breakout strength must be taken as 0.6.

For ACI 318-05, the values N_b *and* V_b determined in accordance with this report must be multiplied by 0.60, in lieu of ACI 318 D.3.4.

4.2 Allowable Stress Design (ASD):

4.2.1 General: Design values for use with allowable stress design load combinations calculated in accordance with Section 1605.3 of the IBC and Section 1612.3 of the UBC, shall be established using Eq-2 and Eq-3:

$$T_{allowable,ASD} = \frac{\phi N_n}{\alpha} \qquad \text{(Eq-2)}$$

and

$$V_{allowable,ASD} = \frac{\phi V_n}{\alpha} \qquad \text{(Eq-3)}$$

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 and 2009 IBC Section 1908.1.9, or 2006 IBC Section 1908.1.16, as applicable (lbf or kN).

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

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

An example of allowable stress design values for illustrative purposes is shown in Table 5 of this report.

4.2.2 Interaction of Tensile and Shear Forces: The interaction must be calculated in accordance and consistent with ACI 318 Section D.7 as follows:

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

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

For all other cases Eq-4 applies:

$$\frac{T}{T_{allowable,ASD}} + \frac{V}{V_{allowable,ASD}} \leq 1.2 \qquad \text{(Eq-4)}$$

4.3 Installation:

Installation parameters are provided in Tables 2 and 4 and in Figure 2 of this report. Anchor locations must be in accordance with this report and the plans and specifications approved by the code official. The FH II anchors must be installed according to the manufacturer's published instructions and this report. Anchors must be installed in holes drilled into the concrete using carbide-tipped masonry drill bits complying with the requirements of Table 2 of this report. The minimum drilled hole depth is given in Table 2. The predrilled hole must be cleaned free of dust and debris using a hand pump, compressed air or vacuum. The anchor must be hammered into the predrilled hole until the proper nominal embedment depth is achieved. The anchor must be tightened against the washer until the torque values T_{inst} specified in Table 2 of this report are achieved.

4.4 Special Inspection:

Special inspection is required, in accordance with Section 1701.5.2 of the UBC and Section 1704.13 of the IBC. The special inspector must make periodic inspections during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, hole cleaning procedures, anchor spacing(s), edge distance(s), slab thickness, anchor embedment depth, tightening torque and adherence to manufacturer's published 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 FH II 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 Anchor sizes, dimensions and minimum embedment depths are as set forth in this report.

5.2 The anchors must be installed in accordance with the manufacturer‘s published installation instructions and this report. In case of a conflict, this report governs.

5.3 Anchors must be installed in cracked and uncracked normal-weight or structural sand-lightweight concrete having a specified compressive strength, f'_c of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

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

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

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

5.7 Anchor spacing(s) and edge distance(s) 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, FH II 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 tire-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 Special inspection must be provided in accordance with Section 4.4 of this report.

5.15 Anchors are manufactured by fischerwerke, under an approved quality control program with inspections by ICC-ES.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Mechanical

Anchors in Concrete Elements (AC193), dated March 2010, for use in cracked and uncracked concrete and quality control documentation.

7.0 IDENTIFICATION

The anchors can be identified on the packaging label with the manufacturer‘s name (fischer) and address, anchor name, anchor size and evaluation report number (ICC-ES ESR-2691). The “fish” symbol, the letters FH II, the anchor diameter and the maximum fixing thickness are stamped on each anchor.

Example: (“fish”) FH II 24/25 S, means 24 mm outer anchor diameter, 25 mm maximum thickness of fixture, S stands for Hexagonal Screw Version.

TABLE 1—ANCHOR DIMENSIONAL CHARACTERISTICS[1]

Anchor Version[2]	Nominal Bolt Diameter (mm)	d_{bit} (mm)	d_s (mm)	L_1 (mm)	t_{fix}[3] (mm)		l_1 (mm)	l_2 (mm)	l_3 (mm)	l_4 (mm)	t_{washer} (mm)
					Min.	**Max.**					
FH II S	M8	12	12.0	74	0	250	11	30	10	22	≥1.8
	M10	15	14.8	89	0	300	13	35.5	10.5	26.5	≥2.3
	M12	18	17.8	99	0	350	16	41	15	26.5	≥2.7
	M16	24	23.7	124	0	400	19	46	20	38	≥2.7
	M20	28	27.5	148	0	600	22.4	50	17.5	61.5	≥3.4
	M24	32	31.5	168	0	600	22.4	55	25	74	≥4.0
FH II B	M8	12	12.0	74	0	250	11	30	10	22	≥1.8
	M10	15	14.8	89	0	300	13	35.5	10.5	26.5	≥2.3
	M12	18	17.8	99	0	350	16	41	15	26.5	≥2.7
	M16	24	23.7	124	0	400	19	46	20	38	≥2.7
	M20	28	27.5	148	0	600	22.4	50	17.5	61.5	≥3.4
	M24	32	31.5	168	0	600	22.4	55	25	74	≥4.0
FH II H	M10	15	14.8	89	0	300	13	35.5	10.5	26.5	≥2.3
	M12	18	17.8	99	0	350	16	41	15	26.5	≥2.7
	M16	24	23.7	124	0	400	19	46	20	38	≥2.7
FH II SK	M10	15	14.8	89	6	300	13	35.5	10.5	26.5	0
	M12	18	17.8	99	6	350	16	41	15	26.5	0

For pound-inch units: 1 mm = 0.03937 inches

[1] Figure 1 describes location of dimensions. All dimensions are nominal excluding manufacturing tolerances.
[2] Figure 3 illustrates the available anchor versions.
[3] Thickness applies to the attached fixture.

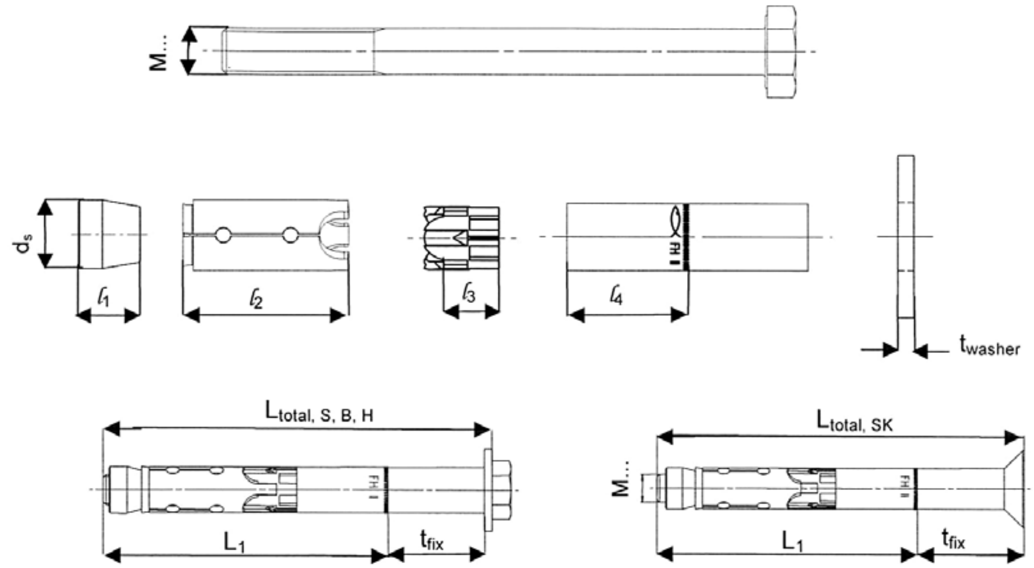


FIGURE 1—ANCHOR DIMENSIONAL CHARACTERISTICS

TABLE 2—INSTALLATION INFORMATION[1]

Characteristic		Symbol	Units	Anchor Designation and Size					
				FH II 12 M8	**FH II 15 M10**	**FH II 18 M12**	**FH II 24 M16**	**FH II 28 M20**	**FH II 32 M24**
Nominal drill hole diameter[2]		d_{bit}	mm	12	15	18	24	28	32
Cutting diameter of drill bit		$d_{bit,min}$	mm	12.10	15.10	18.10	24.10	28.10	32.15
		$d_{bit,max}$	mm	12.50	15.50	18.50	24.55	28.55	32.70
Minimum drill hole depth		$h_{1,min} \geq$	mm	80	90	105	125	155	180
			in.	3.15	3.54	4.13	4.92	6.10	7.09
Diameter of clearance hole in the fixture[4]		$d_{f,S,H,B} \leq$	mm	14	17	20	26	31	35
			in.	0.55	0.67	0.79	1.02	1.22	1.38
Diameter of countersunk hole in the fixture		$d_{f,SK}$	mm	-	24.5	31.6	-	-	-
			in.	-	0.97	1.25	-	-	-
Required installation torque	**Type S**	T_{inst}	Nm	22.5	40	80	160	180	200
	Type SK			-	40	80	-	-	-
	Type H			-	40	80	90	-	-
	Type B			17.5	38	80	120	180	200
	Type S		ft-lbf	16.6	29.5	59.0	118.0	132.8	147.5
	Type SK			-	29.5	59.0	-	-	-
	Type H			-	29.5	59.0	66.4	-	-
	Type B			12.9	28.0	59.0	88.5	132.8	147.5
Wrench size[3]	**Type S**	-	mm	13	17	19	24	30	36
	Type SK			-	6	8	-	-	-
	Type H			-	17	19	24	-	-
	Type B			13	17	19	24	30	36
Washer Diameter		d_w	mm	≥20	≥24	≥28	≥36	≥40	≥46
			in.	≥0.79	≥0.95	≥1.10	≥1.42	≥1.57	≥1.81

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

[1] All specifications excluding manufacturing tolerances.
[2] Only metric drill bits must be used.
[3] For Type SK Allen wrench size.
[4] Tolerances complying with ISO 273

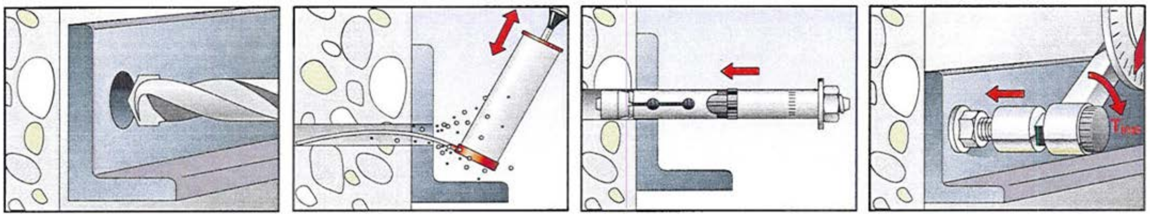
Installation:

Step 1: Using the correct metric bit diameter, d_{bit} (Table 2), drill hole to minimum required hole depth $h_{1,min}$ (Table 2) or deeper.

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

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 prior to installation.

Step 4: Using a torque wrench, apply the specified installation torque T_{inst} (Table 2).



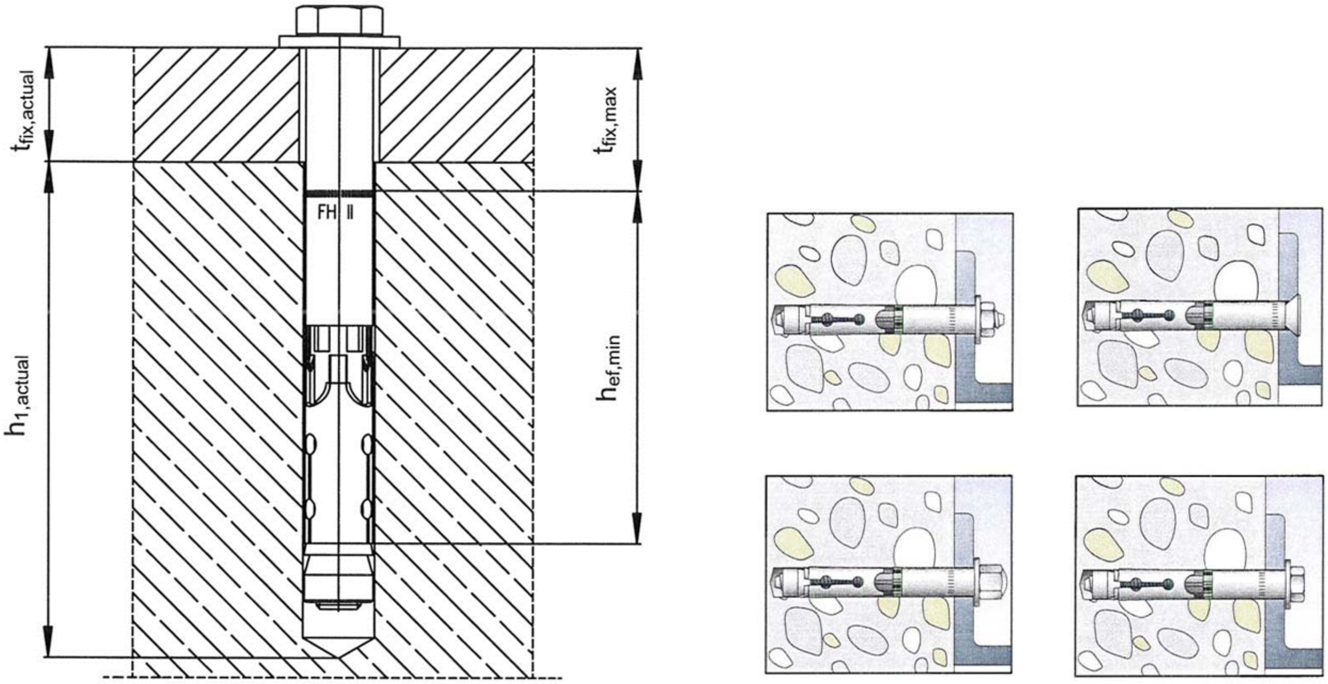
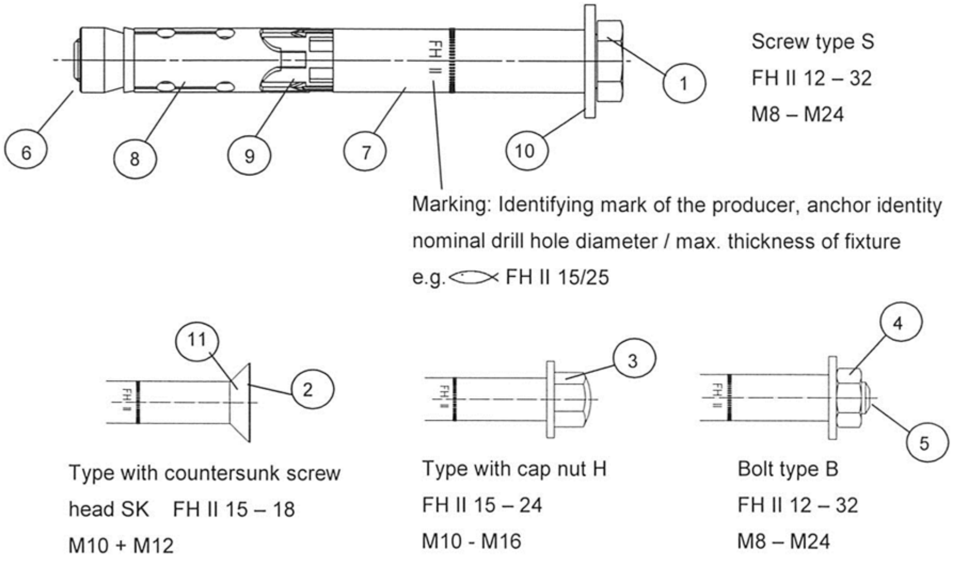


FIGURE 2—CORRECT INSTALLED ANCHOR



①	Hexagon screw	⑥	Conical nut
②	Countersunk screw	⑦	Spacer sleeve
③	Cap nut	⑧	Expansion sleeve
④	Hexagon nut	⑨	Plastic sleeve
⑤	Threaded rod	⑩	Washer
		⑪	Conical washer

FIGURE 3—FH II HEAD CONFIGURATIONS

TABLE 3—DESIGN INFORMATION

Design parameter	Symbol	Units	Nominal anchor diameter FH II					
			M8	M10	M12	M16	M20	M24
Outside diameter of anchor	d_a (d_o)[8,9]	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 [4,5]	ϕ	Cond.A	0.75					
		Cond.B	0.65					
Strength reduction factor for shear, concrete failure modes [4,5]	ϕ	Cond.A	0.75					
		Cond.B	0.70					
Yield strength of anchor steel	f_{ya}	N/mm^2	640					
		lbf/in.^{2}	92,824					
Ultimate strength of anchor steel	f_{uta}	N/mm^2	800					
		lbf/in.^{2}	116,030					
Tensile stress area	A_{se}	mm^2	36.6	58.0	84.3	156.7	244.8	352.5
		in.^{2}	0.057	0.090	0.131	0.243	0.379	0.546
Steel strength in tension	N_{seN} (N_{sa})[9]	kN	29	46	67	125	196	282
		lbf	6,516	10,337	15,056	28,090	44,045	63,370
Effectiveness factor cracked concrete	k_{cr}	SI	7.1	8.8	8.8	10	10	10
		Imp	17	21	21	24	24	24
Effectiveness factor cracked concrete	k_{uncr}	SI	11.3	11.3	11.3	12.6	12.6	12.6
		Imp	27	27	27	30	30	30
Additional effectiveness factor for uncracked concrete [6]	$\Psi_{c,N}$	-	1.0	1.0	1.0	1.0	1.0	1.0
Pullout strength uncracked concrete[7]	$N_{p,uncr}$	not decisive						
Pullout strength cracked concrete [7]	$N_{p,cr}$	not decisive						
Tension pullout strength seismic [7]	N_{eq}	not decisive						
Steel strength in shear S, SK	V_{sa}	kN	33	59	76	146	174	217
		lbf	7,419	13,264	17,085	32,822	39,117	48,784
Steel strength in shear B, H		kN	27	41	62	119	146	169
		lbf	6,070	9,217	13,938	26,752	32,822	37,993
Steel strength in shear, seismic S,SK	V_{eq}	kN	25	38	57	110	143	174
		lb	5,620	8,543	12,814	24,729	32,148	39,117
Steel strength in shear, seismic B,H		kN	17	31	46	98	119	169
		lb	3,822	6,969	10,341	22,031	26,752	37,993
Coefficient for pryout strength	k_{cp}	[-]	1	2				
Effective length of anchor in shear loading	l_e	mm	24	30	36	48	56	64
		in.	0.94	1.18	1.42	1.88	2.20	1.56
Axial stiffness in service load range cracked concrete	β_m	kN/mm	21	24	27	33	39	45
		10^3lbf/in	120	137	154	188	223	257
uncracked concrete	β_m	kN/mm	65	91	118	171	224	277
		10^3lbf/in	371	520	674	976	1,279	1,582

[1] Figure 2 illustrates the location of $h_{ef,min}$.

[2] Sections ACI 318 Section D.4.4 and D.4.5 set forth the permitted strength reduction factor ϕ based on anchor category.

[3] The FH II anchors are considered as ductile steel element as defined by ACI 318 D.1.

[4] Condition A requires supplemental reinforcement, while Condition B applies where supplemental reinforcement is not provided or where pullout or pryout governs, as set forth in ACI 318 D.4.4. The tabulated value of ϕ applies when the load combinations of Section 1605.2.1 of the IBC, Section 1612.2.1 of the UBC, or ACI 318 9.2 are used. If the load combinations of ACI 318 Appendix C or Section 1909.2 of the UBC are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.5.

[5] Anchors are permitted to be used in structural sand-lightweight concrete provided that the provisions in accordance with Section 4.1.12 of this report are taken into account.

[6] The value $\Psi_{c,N}$ = 1.0 for all design cases.

[7] As described in Section 4.1.5 of this report, pullout resistance is not decisive.

[8] All dimensions are nominal excluding manufacturing tolerances.

[9] The notation in brackets is for the 2006 IBC.

TABLE 4—EDGE DISTANCE, SPACING AND MEMBER THICKNESS REQUIREMENTS[1,2]

Dimension	Symbol	Units	**FH II 12 M8**	**FH II 15 M10**	**FH II 18 M12**	**FH II 24 M16**	**FH II 28 M20**	**FH II 32 M24**
Minimum thickness of concrete member	$h_{a,min}$	**[mm]**	120	140	160	200	250	300
		[in.]	4.75	5.50	6.25	7.88	9.88	11.88
Minimum spacing[1,3]	$s_{a,min}$	[mm]	60	70	80	100	120	160
	for $c_a \geq$	[mm]	100	120	160	220	240	380
Minimum spacing[1,3]	$s_{a,min}$	[in.]	2.36	2.76	3.15	3.94	4.72	6.30
	for $c_a \geq$	[in.]	3.94	4.72	6.30	8.66	9.45	14.96
Minimum edge distance[1,3]	$c_{a,min}$	[mm]	60	70	80	100	120	180
	for $s_a \geq$	[mm]	120	140	200	240	260	400
Minimum edge distance[1,3]	$c_{a,min}$	[in.]	2.36	2.76	3.15	3.94	4.72	7.09
	for $s_a \geq$	[in.]	4.72	5.51	7.87	9.45	10.24	15.75
Critical edge distance[2]	c_{ac}	[mm]	155	165	170	225	265	285
		[in.]	6.10	6.50	6.69	8.86	10.43	11.22

[1] According to section 4.1.9 of this report.
[2] According to section 4.1.4 of this report.
[3] Intermediate values by linear interpolation.

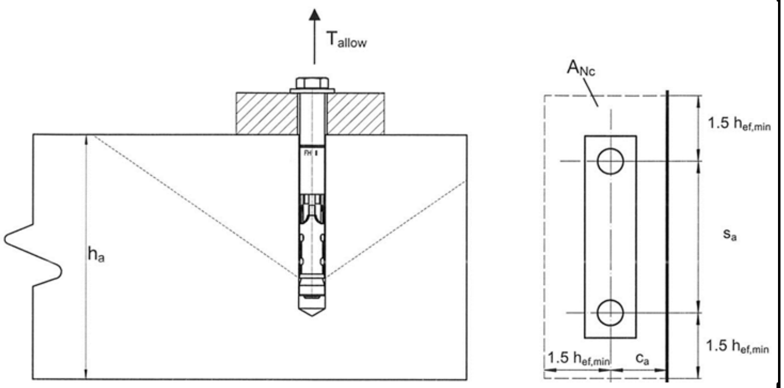
TABLE 5—EXAMPLE ALLOWABLE STRESS DESIGN VALUES FOR ILLUSTRATIVE PURPOSES

Anchor type FH II S, SK, B, H	**Effective Embedment depth h_{ef}**	**Allowable Tension Load**
FH II 12 M8	2.36 in	2,150 lbf
	60 mm	9.57 kN
FH II 15 M10	2.76 in	2,719 lbf
	70 mm	12.05 kN
FH II 18 M12	3.15 in	3,315 lbf
	80 mm	14.73 kN
FH II 24 M16	3.94 in	5,152 lbf
	100 mm	22.77 kN
FH II 28 M20	4.92 in	7,189 lbf
	125 mm	31.82 kN
FH II 32 M24	5.91 in	9,465 lbf
	150 mm	41.83 kN

Design Assumptions:
[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 1.2 D + 1.6 L.
[5] Calculation of weighted average for = 0.3 x 1.2 + 0.7 x 1.6 = 1.48.
[6] f'_c = 2,500 psi (17.2 MPa) (normal weight concrete).
[7] $c_{a1} = c_{a2} \geq c_{ac}$
[8] $h \geq h_{min}$.
[9] Condition B according to ACI 318 Appendix D, Section 4.4, no supplementary reinforcement is present.

Given:
2 x FH II 12 S (M8)
Slab on grade 5,076 psi
No supplementary reinforcement =>
Condition B per ACI 318 D.4.4 c)
Assume cracked concrete
h_a =4.72 in.
h_{ef} = 2.36 in.
s_a = 3.94 in.
c_a = 3.15 in.

Calculate the allowable static tension load for this configuration.



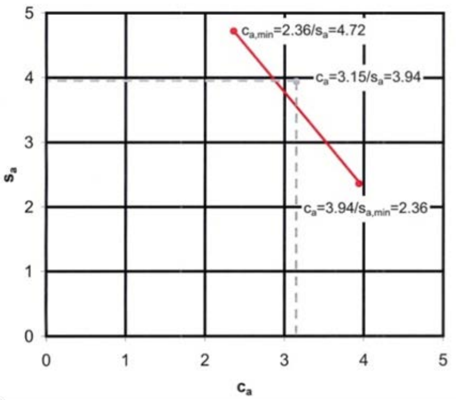
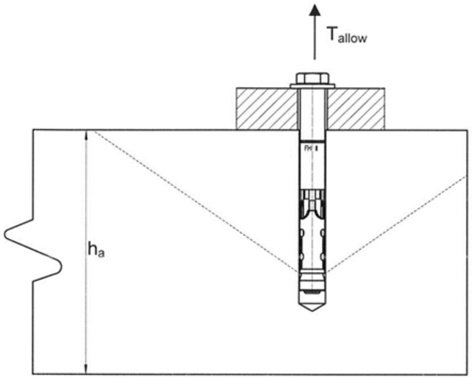
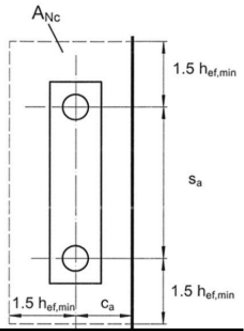
Calculation according to ACI 318-05 Appendix D and this report	ACI 318-05 Ref.	Report Ref.
Step 1. Verify minimum member thickness, spacing and edge distance: Table 4: h_a = 4.72 in. ≥ $h_{a,min}$= 4.72 in. => ok slope: $\frac{4.72-2.36}{2.36-3.94} = -1.5$ For c_a = 3.15 in. $s_{min,calc}$=[(3.15-3.94)x(-1.5)]+2.36=3.54 in. ≤ s_a = 3.94 => ok  	D.8	Table 4
Step 2. Calculate steel strength of anchor in tension N_{sa} = n N_{sa} = 13,032 lbf Calculate steel capacity ϕN_{sa} = 0.75 * 13,032 = 9,774 lbf	D.5.1.2 D.4.4 b)	Table 3
Step 3. Calculate concrete breakout strength of anchor in tension $N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \times \psi_{ec,N} \times \psi_{ed,N} \times \psi_{c,N} \times \psi_{cp,N} \times N_b$	D.5.2.1 b)	§ 4.1.3 § 4.1.5
Step 3a. Check 1.5 h_{ef} = 1.5x2.36=3.54 in. > c_a 3.0 h_{ef} = 3.0x2.36=7.08 in. > s_a	D.5.2.1 b)	Table 4
Step 3b. Calculate A_{Nc0} and A_{Nc} A_{Nc0} = 9x h_{ef}^2 = 9x(2.36)^2 = 50.13 in.² A_{Nc} = (1.5 h_{ef} + c_a) x (3 h_{ef} + s_a) = [1.5x2.36+3.15] x [3x(2.36) + 3.94]=73.72 in.² < 2x A_{Nc0}	D.5.2.1 b)	Table 3
Step 3c. Calculate $\psi_{ec,N}$: e_N\`= 0 => $\psi_{ec,N}$ =1	D.5.2.4	-
Step 3d. Calculate $N_b = k_{cr} \sqrt{f`_c}\ h_{ef}^{1.5}$ = 17 x $\sqrt{5{,}076}$ x 2.36$^{1.5}$ = 4,391 lbf	D.5.2.2	Table 3
Step 3e. Calculate modification factor for edge distance: $\psi_{ed,N} = 0.7 + 0.3\frac{c_{a,min}}{1.5 \times h_{ef}} = 0.7 + 0.3 \times \frac{3.15}{1.5 \times 2.36} = 0.97$ < 1	D.5.2.5	Table 4
Step 3f. $\psi_{c,N}$ = 1.0 (cracked concrete)	D.5.2.6	Table 3
Step 3g. $\psi_{cp,N}$ = 1.0	D.5.2.7	Table 3
Step 3h. Calculate N_{cbg} = (73.72/50.13)x1x0.97x1x4,391= 6,264 lbf	D.5.2.1 b)	§4.1.1 Table 3
Step 4. Controlling strength: ϕN_{cbg} = 0.65 x 6,264 = 4,071 lbf < ϕN_s = 9,774 lbf	D.4.4.c)	Table 3
Step 5. Calculate allowable stress design (30% dead load, 70% live load) α = 1.2x0.3+1.6x0.7=1.48 -> $T_{allowable,ASD}$ = 4,071 / 1.48 = 2,751 lbf	ACI 318 Section 9.2	§4.2

FIGURE 4—EXAMPLE CALCULATION FOR TENSION CAPACITY (IMPERIAL UNITS)

Given:
2 x FH II 12 S (M8)
Slab on grade 35 MPa
No supplementary reinforcement.=>
Condition B per ACI 318 D.4.4 c)
Assume cracked concrete
h_a =120 mm
h_{ef} = 60 mm
s_a = 100 mm
c_a = 80 mm

Calculate the allowable static and seismic tension load for this configuration.





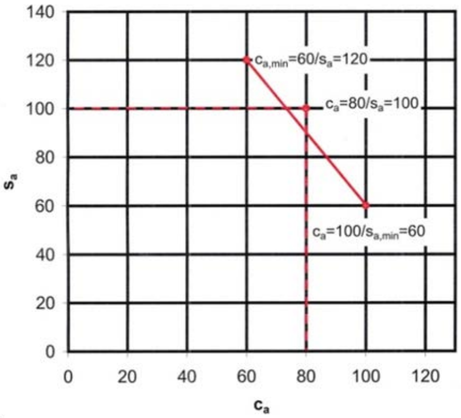
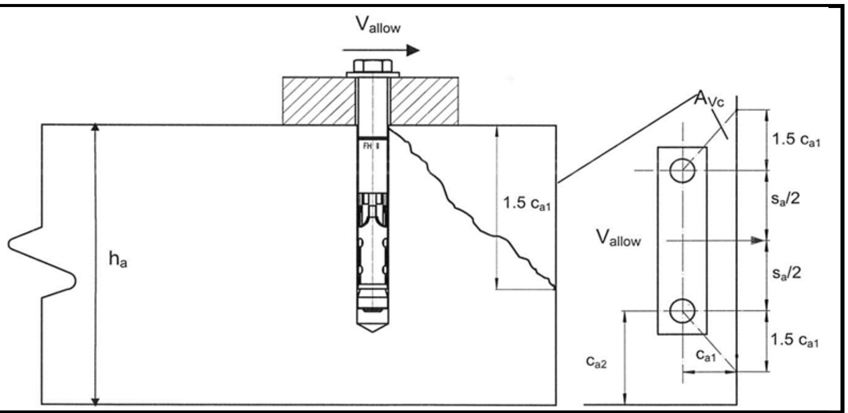
Calculation according to ACI 318-05 Appendix D and this report	ACI 318-05 Ref.	Report Ref.
Step 1. Verify minimum spacing and edge distance: Table 4: h_a = 120 mm ≥ $h_{a,min}$= 120 mm => ok slope: $\frac{120-60}{60-100} = -1.5$ For c_a = 80 mm $s_{min,calc}$=[(80-100)x(-1.5)]+60=90 mm ≤ s_a => ok  	D.8	Table 4
Step 2. Calculate steel strength of anchor in tension N_{sa} = n N_{sa} = 58 kN Calculate steel capacity ϕN_{sa} = 0.75 * 58 = 43.5 kN	D.5.1.2 D.4.4 b)	Table 3
Step 3. Calculate concrete breakout strength of anchor in tension $N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \times \psi_{ec,N} \times \psi_{ed,N} \times \psi_{c,N} \times \psi_{cp,N} \times N_b$	D.5.2.1 b)	§ 4.1.1 § 4.1.2
Step 3a. Check 1.5 h_{ef} = 1.5x60=90 mm > c_a 3.0 h_{ef} = 3.0x60=180 mm > s_a	D.5.2.1 b)	Table 4
Step 3b. Calculate A_{Nc0} and A_{Nc} A_{Nc0} = 9x h_{ef}^2 = 9x$(60)^2$ = 32,400 mm² A_{Nc} = (1.5 h_{ef} + c) x (3 h_{ef} + s) = [1.5x60+80] x [3x(60) + 100]=47,600mm² < 2x A_{Nc0}	D.5.2.1 b)	Table 3
Step 3c. Calculate $\psi_{ec,N}$: e_N' = 0 => $\psi_{ec,N}$ =1	D.5.2.4	-
Step 3d. Calculate $N_b = k_c \sqrt{f'_c}\ h_{ef}^{1.5} = 7 \times \sqrt{35} \times 60^{1.5}$ = 19,246 N = 19.25 kN	D.5.2.2	Table 3
Step 3e. Calculate modification factor for edge distance: $\psi_{ed,N} = 0.7 + 0.3\frac{c_{a,min}}{1.5 \times h_{ef}} = 0.7 + 0.3 \times \frac{80}{1.5 \times 60} = 0.97 < 1$	D.5.2.5	Table 4
Step 3f. $\psi_{c,N}$ = 1.0 (cracked concrete)	D.5.2.6	Table 3
Step 3g. $\psi_{cp,N}$ = 1.0	D.5.2.7	Table 3
Step 3h. Calculate N_{cbg} = (47,600/32,400)x1x0.97x1x19.246= 27.33 kN	D.5.2.1 b)	§4.1.1 Table 3
Step 4. Controlling strength: ϕN_{cbg} = 0.65 x 27.33 = 17.77 kN < ϕN_s = 43.5 kN	D.4.4.c)	Table 3
Step 5. Calculate allowable stress design (30% dead load, 70% live load) α = 1.2x0.3+1.6x0.7=1.48 -> $T_{allowable,ASD}$ = 17.77 / 1.48 = 12,01 kN	ACI 318 Section 9.2	§4.2

FIGURE 5—EXAMPLE CALCULATION FOR TENSION CAPACITY (SI UNITS)

Given:
2 x FH II 12 S (M8)
Slab on grade = 5,076 psi
No supplementary reinforcement. =>
Condition B per ACI 318 D.4.4 c)
Assume cracked concrete
h_a =4.72 in.
h_{ef} =2.36 in.
s_a =3.94 in.
c_{a1} =3.15 in.
c_{a2} =7.87 in.

Calculate the allowable static shear load for this configuration.



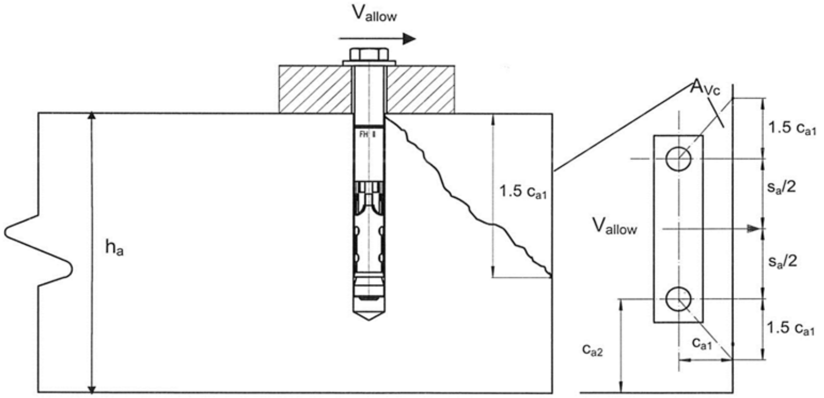
Calculation according to ACI 318-05 Appendix D and this report	ACI 318-05 Ref.	Report Ref.
Step 1. Verify minimum spacing and edge distance according to Figure 4 – Tension	D.8	Figure 4
Step 2. Calculate steel strength of anchor in shear V_{sg} = n V_{sa} = 14,838 lbf Calculate steel capacity ϕV_{sg} = 0.65 * 14,832 = 9,645 lbf	D.6.1 D.4.4 b)	Table 3
Step 3. Calculate concrete breakout strength of anchor in shear $V_{cbg} = \frac{A_{Vc}}{A_{Vc0}} \times \psi_{ec,V} \times \psi_{ed,V} \times \psi_{c,V} \times V_b$	D.6.2.1 b)	§ 4.1.4 § 4.1.6
Step 3a. Check 3 c_{a1} = 3x3.15=9.45 in. > s = 3.94 in. s_a controls 1.5 c_{a1} = 1.5x3.15=4.72 in. < h_a c_{a1} controls 1.5 $c_{a1} < c_{a2}$ c_{a1} controls	D.6.2.2	-
Step 3b. Calculate A_{Vc0} and A_{Vc} A_{Vc} = 4.5 x c_1^2 = 4.5x$(3.15)^2$ = 44.65 in.² A_{vc0} = (1.5 c_{a1}) x (3 c_{a1} + s) = [1.5x3.15] x [3x(3.15) + 3.94]=63.27 in.² < 2x A_{Vc0}	D.6.2.2	-
Step 3c. Calculate $\psi_{ec,v}$: e_V\`= 0 => $\psi_{ec,v}$ =1	D.6.2.5	-
Step 3d. Calculate $V_b = 7 \sqrt{f\grave{}_c} \times \sqrt{d_0} \times c_{a1}^{1.5} \times (\frac{le}{d_0})^{0.2} = 7\sqrt{5{,}076} \times \sqrt{0.47} \times 3.15^{1.5} \times (\frac{0.94}{0.47})^{0.2}$ =2,196 lbf	D.6.2.2	-
Step 3e. Calculate modification factor for edge distance: $c_{a2} = 7.87 \geq 1.5 \text{ x } c_{a1} = 7.2$ $\psi_{ed,V} = 1$	D.6.2.6	-
Step 3f. $\psi_{c,V}$ = 1.0 (cracked concrete)	D.6.2.7	-
Step 3g. Calculate V_{cbg} = (63.27/44.65)x1x1x2,196= 3,112 lbf	D.6.2.1 b)	-
Step 3h. Calculate ϕV_{cbg} = 3,112 lbf x 0.7= 2,178 lbf	D.4.4 c)	Table 3
Step 4. Calculate Pryout: ϕ $V_{cpg} = k_{cp}$ x ϕ N_{cbg} = 1 x 0,7 x 6,264= 4,385 lbf N_{cbg} According to Figure 4 – Tension (c_{a2} > 1,5 h_{ef})	D.6.3.1 b)	Table 3
Step 5. Controlling strength: ϕV_n = min **I** ϕ $\boldsymbol{V_{cpg}}$, ϕV_{cbg}, ϕV_{sg} **I** = 2,178 lbf (static)	D.4.1.2	-
Step 6. Calculate allowable stress design (30% dead load, 70% live load) α = 1.2x0.3+1.6x0.7=1.48 -> $V_{allowable,ASD}$ = 2,178 / 1.48 = 1,471 lbf	ACI 318 Section 9.2	§4.2

FIGURE 6—EXAMPLE CALCULATION FOR SHEAR CAPACITY (IMPERIAL UNITS)

Given:
2 x FH II 12 S (M8)
Slab on grade 35 Mpa

No supplementary reinforcement. =>
Condition B per ACI 318 D.4.4 c)
Assume cracked concrete
h_a =120 mm
h_{ef} = 60 mm
s_a = 100 mm
c_{a1} = 80 mm
c_{a2} = 200 mm.

Calculate the allowable static shear load for this configuration.



Calculation according to ACI 318-05 Appendix D and this report	ACI 318- ef.	Report Ref.
Step 1. Verify minimum spacing and edge distance according to Figure 5 – Tension	D.8	Figure 5
Step 2. Calculate steel strength of anchor in shear V_{sg} = n V_{sa} = 66 kN Calculate steel capacity ϕV_{sg} = 0.65 * 68 = 42.9kN	D.6.1 D.4.4 b)	Table 3
Step 3. Calculate concrete breakout strength of anchor in shear $V_{cbg} = \frac{A_{Vc}}{A_{Vc0}} \times \psi_{ec,V} \times \psi_{ed,V} \times \psi_{c,V} \times V_b$	D.6.2.1 b)	§ 4.1.4 § 4.1.6
Step 3a. Check 3 c_{a1} = 3x80=240 mm > s = 100 mm s controls 1.5 c_{a1} = 1.5x80=120 mm < h_a c_{a1} controls 1.5 c_{a1} < c_{a2} c_{a1} controls	D.6.2.2	-
Step 3b. Calculate A_{Vc0} and A_{Vc} $A_{Vc} = 4.5 \times c_1^2 = 4.5x(80)^2$ = 28,800 mm² A_{vc0} = (1.5 c_{a1}) x (3 c_{a1} + s) = [1.5x80] x [3x(80) + 100]=40,800 mm² < 2x A_{Vc0}	D.6.2.2	-
Step 3c. Calculate $\psi_{ec,v}$: e_V\`= 0 => $\psi_{ec,v}$ =1	D.6.2.5	-
Step 3d. Calculate $V_b = 0.6 \sqrt{f`_c} \times \sqrt{d_0} \times c_{a1}^{1.5} \times (\frac{le}{d_0})^{0.2} = 0.6x\sqrt{35} \times \sqrt{12} \times 80^{1.5} \times (\frac{24}{12})^{0.2}$ = 10.11 kN	D.6.2.2	-
Step 3e. Calculate modification factor for edge distance: $c_{a2} = 200 \geq 1.5 \; x \; c_{a1} = 120$ $\psi_{ed,V} = 1$	D.6.2.6	-
Step 3f. $\psi_{c,V}$ = 1.0 (cracked concrete)	D.6.2.7	-
Step 3g. Calculate V_{cbg} = (40,800/28,800)x1x1x10.11= 14.32 kN	D.6.2.1 b)	-
Step 3h. Calculate ϕV_{cbg} = 14.32 kN x 0.7= 10.02 kN	D.4.4 c)	Table 3
Step 4. Calculate Pryout: $\phi V_{cpg} = k_{cp}$ x ϕN_{cbg} = 1x 0.7 x 27.33= 19.13 kN N_{cbg} According to Figure 5 – Tension ($c_{a2} > 1,5 h_{ef}$)	D.6.3.1 b)	Table 3
Step 5. Controlling strength: ϕV_n = min **I** ϕ ***V_{cpg},*** ϕV_{cbg}, ϕV_{sg} **I** = 10.02 kN (static)	D.4.1.2	-
Step 6. Calculate allowable stress design (30% dead load, 70% live load) α = 1.2x0.3+1.6x0.7=1.48 -> $V_{allowable,ASD}$ = 10.02 / 1.48 = 6.77 kN	ACI 318 Section 9.2	§4.2

FIGURE 7—EXAMPLE CALCULATION SHEAR CAPASITY (SI UNITS)