ICC-ES Evaluation Report

ESR-3577*

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

DIVISION: 05 00 00—METALS
Section: 05 05 19—Post-Installed Concrete Anchors

REPORT HOLDER:

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EVALUATION SUBJECT:

ITW RED HEAD EPCON C6+ ADHESIVE ANCHORING SYSTEM FOR CRACKED AND UNCRACKED CONCRETE

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2009, 2006, 2003 *International Building Code®* (IBC)
- 2009, 2006, 2003 *International Residential Code®* (IRC)

Property evaluated:

Structural

2.0 USES

The Red Head Epcon C6+ Adhesive Anchoring System is used to resist static, wind or earthquake (Seismic Design Categories A through F) tension and shear loads in cracked and uncracked, normal-weight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

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

3.0 DESCRIPTION

3.1 General:

The Red Head Epcon C6+ Anchoring System is comprised of the following:

- Red Head Epcon C6+ adhesive packaged in cartridges
- Adhesive mixing and dispensing equipment
- Equipment for cleaning holes

Red Head Epcon C6+ adhesive is used with continuously threaded steel rods or deformed steel reinforcing bars. Installation information, guidelines and parameters are shown in Figures 1, 2, and 3 of this report.

The manufacturer's printed installation instructions (MPII), included with each adhesive cartridge unit, are shown in Figure 4 of this report.

3.2 Materials:

3.2.1 Red Head Epcon C6+ Adhesive: Red Head Epcon C6+ adhesive is a two-component (resin and hardener) epoxy-based adhesive, supplied in dual chamber cartridges separating the adhesive components, which are combined in a 1:1 ratio by volume when dispensed through the system static mixing nozzle. The Red Head Epcon C6+ is available in 8.5 fl. oz. (250 mL) and 20 fl. oz. (600 mL) cartridges. The shelf life of the Red Head Epcon C6+ adhesive is two years, when stored in the manufacturer's unopened containers at temperatures between 50°F (10 °C) and 77°F (25°C).

3.2.2 Dispensing Equipment: Red Head Epcon C6+ Adhesive must be dispensed using pneumatic or manual actuated dispensing tools as shown in Figures 1 and 2 of this report.

3.2.3 Hole Preparation Equipment: The holes must be cleaned with hole-cleaning brushes and air nozzles. The brush must be the appropriate size brush shown in Figure 3 of this report and the air nozzle must be equipped with an extension capable of reaching the bottom of the drilled hole and having an inside bore diameter of not less than $^1/_4$ inch (6 mm). The holes must be prepared in accordance with the installation instructions shown in Figure 4 of this report.

3.2.4 Steel Anchor Elements:

3.2.4.1 Threaded Steel Rod: Threaded anchor rods must be clean, continuously threaded rods (all-thread) in diameters and types as described in Tables 1 and 3 of this report. Steel design information for the common grades of threaded rod is provided in Tables 1 and 3. Carbon steel threaded rods may be furnished with a zinc electroplated coating or hot-dipped galvanized, or may be uncoated. Threaded steel rods must be straight and free of indentations or other defects along their length.

3.2.4.2 Steel Reinforcing Bars: Steel reinforcing bars must be deformed bars (rebar). Tables 2 and 3 summarize reinforcing bar size ranges, specifications, and grades. The embedded portions of reinforcing bars must be straight, and free of mill scale, rust and other coatings or

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substances that may impair the bond with the adhesive. Reinforcing bars must not be bent after installation except as set forth in Section 7.3.2 of ACI 318, with the additional condition that the bars must be bent cold, and heating of reinforcing bars to facilitate field bending is not permitted.

3.2.4.3 Ductility: In accordance with ACI 318 D.1, in order for a steel element to be considered ductile, the tested elongation must be at least 14 percent and the reduction of area must be at least 30 percent. Steel elements that with a tested elongation of less than 14 percent or a reduction of area less than 30 percent, or both, are considered brittle. Values for various steel materials are provided in Tables 1 through 3 of this report. Where values are nonconforming or unstated, the steel must be considered brittle.

3.3 Concrete:

Normal-weight concrete must comply with Sections 1903 and 1905 of the IBC, as applicable. The specified compressive strength of the concrete must be from 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

4.0 DESIGN AND INSTALLATION

4.1 Strength Design:

4.1.1 General: The design strength of anchors under the 2009, 2006 and 2003 IBC, as well as the 2009, 2006 and 2003 IRC, must be determined in accordance with ACI 318-11 (ACI 318) and this report.

The strength design of anchors must comply with ACI 318 D.4.1, except as required in ACI 318 D.3.3.

A design example in accordance with the 2009 IBC is given in Figure 5 of this report.

Design parameters are provided in Tables 1 through 9 of this report. Strength reduction factors, ϕ, as described in ACI 318 Section D.4.3 must be used for load combinations calculated in accordance with Section 1605.2 of the IBC or Section 9.2 of ACI 318-11. Strength reduction factors, ϕ, described in ACI 318 Section D.4.4 must be used for load combinations calculated in accordance with Appendix C of ACI 318.

4.1.2 Static Steel Strength in Tension: The nominal steel strength of a single anchor in tension, N_{sa}, in accordance with ACI 318 D.5.1.2 and the associated strength reduction factor, ϕ, in accordance with D.4.3 are provided in Tables 1, 2 and 3 for the anchor element types included in this report.

4.1.3 Static Concrete Breakout Strength in Tension: The nominal static concrete breakout strength of a single anchor or group of anchors in tension, N_{cb} or N_{cbg}, must be calculated in accordance with ACI 318 D.5.2, with the following addition:

The basic concrete breakout strength of a single anchor in tension, N_b, must be calculated in accordance with ACI 318 D.5.2.2 using the selected values of $k_{c,cr}$ and $k_{c,uncr}$ as described in this report. Where analysis indicates no cracking in accordance with ACI 318 D.5.2.6, N_b must be calculated using $k_{c,uncr}$ and $\Psi_{c,N}$ = 1.0. For anchors in lightweight concrete see ACI 318-11 D.3.6. The value of f'_c used for calculation must be limited to 8,000 psi (55 MPa) in accordance with ACI 318 D.3.7. Additional information for the determination of nominal bond strength in tension is given in Section 4.1.4 of this report.

4.1.4 Static Bond Strength in Tension: The nominal static bond strength of a single adhesive anchor or group of adhesive anchors in tension, N_a or N_{ag}, must be calculated in accordance with ACI 318-11 D.5.5. Bond strength values are a function of the concrete condition, whether the concrete is cracked or uncracked, the concrete temperature range, and the installation conditions (dry, water-saturated concrete, water-filled holes). The resulting characteristic bond strength shall be multiplied by the associated strength reduction factor ϕ_{nn} as follows corresponsing to the level of special inspection provided:

CONCRETE STATE	DRILLING METHOD	PERMISSIBLE INSTALLATION CONDITIONS	BOND STRENGTH	ASSOCIATED STRENGTH REDUCTION FACTOR
Cracked	Hammer-drill	Dry concrete	$\tau_{k,cr}$	ϕ_d
		Water-saturated concrete	$\tau_{k,cr}$	ϕ_{ws}
		Water-filled hole (flooded)	$\tau_{k,cr}$	ϕ_{wf}
Uncracked	Hammer-drill	Dry concrete	$\tau_{k,uncr}$	ϕ_d
		Water-saturated concrete	$\tau_{k,uncr}$	ϕ_{ws}
		Water-filled hole (flooded)	$\tau_{k,uncr}$	ϕ_{wf}

Figure 1 of this report presents a bond strength design selection flowchart. Strength reduction factors for determination of the bond strength are given in Tables 7 through 10 of this report.

4.1.5 Static Steel Strength in Shear: The nominal static strength of a single anchor in shear as governed by the steel, V_{sa}, in accordance with ACI318 D.6.1.2 and strength reduction factors, ϕ, in accordance with ACI 318 D.4.3 given in Tables 1 through 3 for the anchor element types included in this report.

4.1.6 Static Concrete Breakout Strength in Shear: The nominal concrete breakout strength of a single anchor or group of anchors in shear, V_{cb} or V_{cbg}, must be calculated in accordance with ACI 318 D.6.2 based on information given in Tables 4 and 5 of this report. 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 values of d given in Tables 4 and 5 for the corresponding anchor steel in lieu of d_a (2009 IBC) and d_o (IBC 2006). In addition, h_{ef} must be substituted for ℓ_e. In no case shall ℓ_e exceed $8d_o$. The value of f'_c must be limited to a maximum of 8,000 psi (55 MPa), in accordance with ACI 318 Section D.3.7.

4.1.7 Static Concrete Pryout Strength in Shear: The nominal static pryout strength of a single anchor or group of anchors in shear, V_{cp} or V_{cpg}, shall be calculated in accordance with ACI 318 D.6.3.

4.1.8 Interaction of Tensile and Shear Forces: For designs that include combined tension and shear forces, the interaction of the tension and shear loads must be calculated in accordance with ACI 318 Section D.7.

4.1.9 Minimum Member Thickness, h_{min}, Anchor Spacing, s_{min}, and Minimum Edge Distance, c_{min}: In lieu of ACI 318 D.8.3, values of c_{min} and s_{min} described in this report must be observed for anchor design and installation. In lieu ofACI 318 D.8.5, the minimum member thickness, h_{min}, described in this report must be observed for anchor design and installation. For adhesive anchors that will remain untorqued, ACI 318 D.8.4 applies.

4.1.10 Critical Edge Distance c_{ac}: In lieu of ACI 318 D.8.6, c_{ac} must be determined as follows:

$$c_{ac}=h_{ef}\cdot\left(\frac{\tau_{uncr}}{1160}\right)^{0.4}\cdot\left[3.1-0.7\frac{h}{h_{ef}}\right] \quad \text{(D-43)}$$

where

$\left[\frac{h}{h_{ef}}\right]$ need not be taken as larger than 2.4; and

$\tau_{k,uncr}$ = the characteristic bond strength stated in the table of this report where by τ_{uncr} need not be taken as larger than:

$$\tau_{uncr}=\frac{k_{uncr}\sqrt{h_{ef}f'_c}}{\pi\cdot d_a}$$

4.1.11 Design Strength in Seismic Design Categories C, D, E and F: In structures assigned to Seismic Design Category C, D, E or F under the IBC or IRC, the design must be performed according to ACI 318 Section D.3.3.

The nominal steel shear strength, V_{sa}, must be adjusted by $\alpha_{V,seis}$ as given in Tables 1 through 3 of this report for the corresponding anchor steel. An adjustment to the nominal bond strength, $\tau_{k,cr}$ by $\alpha_{N,seis}$ is not required since $\alpha_{N,seis}$ = 1.0 for all cases.

Modify ACI 318 Sections D.3.3.4.2, D.3.3.4.3(d) and D.3.3.5.2 to read as follows:

D.3.3.4.2 - Where the tensile component of the strength-level earthquake force applied to anchors exceeds 20 percent of the total factored anchor tensile force associated with the same load combination, anchors and their attachments shall be designed in accordance with D.3.3.4.3. The anchor design tensile strength shall be determined in accordance with D.3.3.4.4

Exception:

1. Anchors designed to resist wall out-of-plane forces with design strengths equal to or greater than the force determined in accordance with ASCE 7 Equation 12.11-1 or 12.14-10 shall be deemed to satisfy Section D.3.3.4.3(d).

D.3.3.4.3(d) – The anchor or group of anchors shall be designed for the maximum tension obtained from design load combinations that include E, with E increased by Ω_0. The anchor design tensile strength shall be calculated from D.3.3.4.4.

D.3.3.5.2 – Where the shear component of the strength-level earthquake force applied to anchors exceeds 20 percent of the total factored anchor shear force associated with the same load combination, anchors and their attachments shall be designed in accordance with D.3.3.5.3. The anchor design shear strength for resisting earthquake forces shall be determined in accordance with D.6.

Exceptions:

1. For the calculation of the in-plane shear strength of anchor bolts attaching wood sill plates of bearing or non-bearing walls of light-frame wood structures to foundations or foundation stem walls, the in-plane shear strength in accordance with D.6.2 and D.6.3 need not be computed and D.3.3.5.3 need not apply provided all of the following are satisfied:

1.1. The allowable in-plane shear strength of the anchor is determined in accordance with AF&PA NDS Table 11E for lateral design values parallel to grain.

1.2. The maximum anchor nominal diameter is $^5/_8$ inch (16 mm).

1.3. Anchor bolts are embedded into concrete a minimum of 7 inches (178 mm).

1.4. Anchor bolts are located a minimum of $1^3/_4$ inches (45 mm) from the edge of the concrete parallel to the length of the wood sill plate.

1.5. Anchor bolts are located a minimum of 15 anchor diameters from the edge of the concrete perpendicular to the length of the wood sill plate.

1.6. The sill plate is 2-inch or 3-inch nominal thickness.

2. For the calculation of the in-plane shear strength of anchor bolts attaching cold-formed steel track of bearing or non-bearing walls of light-frame construction to foundations or foundation stem walls, the in-plane shear strength in accordance with D.6.2 and D.6.3 need not be computed and D.3.3.5.3 need not apply provided all of the following are satisfied:

2.1. The maximum anchor nominal diameter is $^5/_8$ inch (16 mm).

2.2. Anchors are embedded into concrete a minimum of 7 inches (178 mm).

2.3. Anchors are located a minimum of $1^3/_4$ inches (45 mm) from the edge of the concrete parallel to the length of the track.

2.4. Anchors are located a minimum of 15 anchor diameters from the edge of the concrete perpendicular to the length of the track.

2.5. The track is 33 to 68 mil designation thickness.

Allowable in-plane shear strength of exempt anchors, parallel to the edge of concrete shall be permitted to be determined in accordance with AISI S100 Section E3.3.1.

3. In light-frame construction, bearing or nonbearing walls, shear strength of concrete anchors less than or equal to 1 inch [25 mm] in diameter attaching a sill plate or track to foundation or foundation stem wall need not satisfy D.3.3.5.3(a) through (c) when the design strength of the anchors is determined in accordance with D.6.2.1(c).

4.2 Allowable Stress Design (ASD):

4.2.1 General: For anchors designed using load combinations calculated in accordance with IBC Section 1605.3 (Allowable Stress Design), allowable loads must be established using the following relationships:

$$T_{allowable,ASD} = \phi N_n/\alpha \quad \textit{Eq. (4-2)}$$

$$V_{allowable,ASD} = \phi V_n/\alpha \quad \textit{Eq. (4-3)}$$

where

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

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

ϕN_n = The lowest design strength of an anchor or anchor group in tension as determined in accordance with ACI 318 Appendix D as amended in this report and 2009 IBC Sections 1908.1.9 and 1908.1.10 or 2006 IBC Section 1908.1.16, as applicable.

ϕV_n = The lowest design strength of an anchor or anchor group in shear as determined in accordance with ACI 318 Appendix D as amended in this report and 2009 IBC Sections 1908.1.9 and 1908.1.10 or 2006 IBC Section 1908.1.16, as applicable.

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

Table 10 provides an illustration of calculated Allowable Stress Design (ASD) values for each anchor diameter at minimum embedment depth.

The requirements for member thickness, edge distance and spacing, as described in Tables 4 and 5 of this report, must apply. An example of allowable stress design values for illustrative purposes is shown in Figure 5 of this report.

4.2.2 Interaction of Tensile and Shear Forces: In lieu of ACI Sections D.7.1, D.7.2 and D.7.3, interaction of tension and shear loads must be calculated as follows:

For tension loads $T \le 0.2 \cdot T_{allowable,ASD}$, the full allowable strength in shear, $V_{allowable,ASD}$, shall be permitted.

For shear loads $V \le 0.2 \cdot V_{allowable,ASD}$, the full allowable strength in tension, $T_{allowable,ASD}$, shall be permitted.

For all other cases:

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

4.3 Installation:

Installation parameters are provided in Figure 3. Installation must be in accordance with ACI 318-11 D.9.1 and D.9.2. Anchor locations must comply with this report and the plans and specifications approved by the building official. Installation of the Red Head Epcon C6+ Adhesive Anchoring System must conform to the manufacturer's printed installation instructions (MPII) included in each package unit and as described in Figure 4. The nozzles, brushes, dispensing tools and piston plugs shown in Figures 1 and 2 and listed in Figure 3 supplied by the manufacturer, must be used along with the adhesive cartridges. Installation of anchors may be vertically down (floor), horizontal (walls) and vertically overhead. Use of nozzle extension tubes and piston plugs must be in accordance with the installation parameters provided in Figures 3 and 4.

4.4 Special Inspection:

4.4.1 General: Installations may be made under continuous special inspection or periodic special inspection, as determined by the registered design professional. Tables 6 through 9 of this report provide strength reduction factors, ϕ, corresponding to the type of inspection provided.

Continuous special inspection of adhesive anchors installed in horizontal or upwardly inclined orientations to resist sustained tension loads shall be performed in accordance with ACI 318 D.9.2.4.

Under the IBC, additional requirements as set forth in Sections 1705, 1706, or 1707 must be observed, where applicable.

4.4.2 Continuous Special Inspection: Installations made under continuous special inspection with an on-site proof loading program must be performed in accordance with Sections 1704.4 and 1704.15 of the 2009 IBC, or Sections 1704.4 and 1704.13 of the 2006 or 2003 IBC, whereby continuous special inspection is defined in Section 1702.1 of the IBC, and this report. The special inspector must be on the jobsite continuously during anchor installation to verify anchor type, adhesive expiration date, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, hole cleaning procedures, anchor spacing, edge distances, concrete thickness, anchor embedment, tightening torque, and adherence to the manufacturer's printed installation instructions.

The proof loading program must be established by the registered design professional. As a minimum, the following requirements must be addressed in the proof loading program:

1. Frequency of proof loading based on anchor type, diameter, and embedment.
2. Proof loads by anchor type, diameter, embedment, and location.
3. Acceptable displacements at proof load.
4. Remedial action in the event of a failure to achieve proof load, or excessive displacement.

Unless otherwise directed by the registered design professional, proof loads must be applied as confined tension tests. Proof load levels must not exceed the lesser of 50 percent of expected peak load based on adhesive bond strength, or 80 percent of the anchor yield strength. The proof load must be maintained at the required load level for a minimum of 10 seconds.

4.4.3 Periodic Special Inspection: Periodic special inspection must be performed in accordance with Sections 1704.4 and 1704.15 of the 2009 IBC, or Section 1704.13 of the 2006 or 2003 IBC and this report. The special inspector must be on the jobsite initially during anchor installation to verify anchor type, anchor dimensions, concrete type, concrete compressive strength, adhesive identification and expiration date, hole dimensions, hole cleaning procedures, anchor spacing, edge distances, concrete thickness, anchor embedment, tightening torque, and adherence to the manufacturer's printed installation instructions. The special inspector must verify the initial installations of each type and size of adhesive anchor by construction personnel on the site. Subsequent installations of the same anchor type and size by the same construction personnel are permitted to be performed in the absence of the special inspector. Any change in the anchor product being installed or the personnel performing the installation requires an initial inspection. For ongoing installations over an extended period, the special inspector must make regular inspections to confirm correct handling and installation of the product.

5.0 CONDITIONS OF USE

The Red Head Epcon C6+ Adhesive Anchoring System described in this report is a suitable alternative to what is specified in the codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 Red Head Epcon C6+ adhesive anchors must be installed in accordance with the manufacturer's printed installation instructions (MPII) and as shown in Figure 4 of this report.

5.2 The anchors must be installed in cracked or uncracked normal-weight concrete having a specified compressive strength, 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 Anchors must be installed in concrete base materials in holes predrilled in accordance with the instructions provided in Figure 3 of this report, with carbide-tipped drill bits complying with ANSI B212.15-1994.

5.5 Loads applied to the anchors must be adjusted in accordance with Section 1605.2 of the IBC for strength design, and Section 1605.3 of the IBC for allowable stress design.

5.6 Red Head Epcon C6+ Adhesive Anchors are recognized for use to resist short- and long-term loads, including wind and earthquake, subject to the conditions of this report.

5.7 In structures assigned to Seismic Design Category C, D, E or F under the IBC or IRC, anchor strength must be adjusted in accordance with 2009 IBC Section 1908.1.9 or 2006 IBC Section 1908.1.16.

5.8 Red Head Epcon C6+ Adhesive Anchors are permitted to be installed in concrete that is cracked or that may be expected to crack during the service life of the anchor, subject to the conditions of this report.

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

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

5.11 Minimum anchor spacing and edge distance, as well as minimum member thickness, must comply with the values described in this report.

5.12 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 statutes of the jurisdiction in which the project is to be constructed.

5.13 Anchors are not permitted to support fire-resistive construction. Where not otherwise prohibited by the code, Red Head Epcon C6+ Adhesive Anchors are permitted for installation in fire-resistive construction provided at least one of the following conditions is fulfilled:

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

5.14 Since an ICC-ES acceptance criteria for evaluating data to determine the performance of adhesive 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.

5.15 Use of zinc-plated carbon steel threaded rods or steel reinforcing bars is limited to dry, interior locations.

5.16 Use of hot-dipped galvanized carbon steel and stainless steel rods is permitted for exterior exposure or damp environments.

5.17 Steel anchoring materials in contact with preservative-treated wood and fire-retardant-treated wood must be zinc-coated carbon steel or stainless steel. The minimum coating weights for zinc-coated steel must comply with ASTM A153.

5.18 Special inspection must be provided in accordance with Section 4.4 in this report. Continuous special inspection for anchors installed in horizontal or upwardly inclined orientations to resist sustained tension loads must be provided in accordance with Section 4.4 of this report.

5.19 Installation of anchors in horizontal or upwardly inclined orientations to resist sustained tension loads shall be performed by personnel certified by an applicable certification program in accordance with ACI 318 D.9.2.2 or D.9.2.3.

5.20 Red Head Epcon C6+ Adhesive is manufactured and packaged into cartridges under a quality control program with inspections by ICC-ES.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Post-installed Adhesive Anchors in Concrete (AC308), dated February 2013.

7.0 IDENTIFICATION

7.1 Red Head Epcon C6+ Adhesive is identified in the field by labels on the cartridge and packaging, bearing the company name (ITW Commercial Construction North America), product name (Red Head Epcon C6+), the batch number, the expiration date, and the evaluation report number (ESR-3577).

7.2 Threaded rods, nuts, and washers are standard elements, and must conform to applicable national or international specifications.

TABLE 1—STEEL DESIGN INFORMATION FOR FRACTIONAL CARBON STEEL AND STAINLESS STEEL THREADED ROD[1,2]

Characteristic		Symbol	Units	Nominal Rod Diameter, d_o						
Nominal Size		d_o	inch	3/8	1/2	5/8	3/4	7/8	1	1 1/4
Stress Area[1]		A_{se}	in.^{2}	0.0775	0.1419	0.226	0.334	0.462	0.606	0.969
Carbon Steel Threaded Rod	Strength Reduction Factor for Tension Steel Failure[2]	ϕ	-	0.75						
	Strength Reduction Factor for Shear Steel Failure[2]	ϕ	-	0.65						
	Reduction for Seismic Tension	$\alpha_{N,seis}$	-	1.00						
	Reduction for Seismic Shear	$\alpha_{V,seis}$	-	0.58	0.57	0.57	0.57	0.42	0.42	0.42
	Tension Resistance of Carbon Steel ASTM F1554 Grade 36	N_{sa}	lb (kN)	4,495 (20.0)	8,230 (36.6)	13,110 (58.3)	19,370 (86.2)	26,795 (119.2)	35,150 (156.4)	56,200 (250.0)
	Tension Resistance of Carbon Steel ASTM A193 B7	N_{sa}	lb (kN)	9,690 (43.1)	17,740 (78.9)	28,250 (125.7)	41,750 (185.7)	57,750 (256.9)	75,750 (337.0)	121,125 (538.8)
	Shear Resistance of Carbon Steel ASTM F1554 Grade 36	V_{sa}	lb (kN)	2,250 (10.0)	4,940 (22.0)	7,865 (35.0)	11,625 (51.7)	16,080 (71.5)	21,090 (93.8)	33,720 (150.0)
	Shear Resistance of Carbon Steel ASTM A193 B7	V_{sa}	lb (kN)	4,845 (21.6)	10,645 (47.4)	16,950 (75.4)	25,050 (111.4)	34,650 (154.1)	45,450 (202.2)	72,675 (323.3)
Stainless Steel Threaded Rod	Strength Reduction Factor for Tension Steel Failure[2]	ϕ	-	0.65						
	Strength Reduction Factor for Shear Steel Failure[2]	ϕ	-	0.60						
	Reduction for Seismic Tension	$\alpha_{N,seis}$	-	1.00						
	Reduction for Seismic Shear	$\alpha_{V,seis}$	-	0.51	0.50	0.49	049	0.43	0.43	0.43
	Tension Resistance of Stainless Steel ASTM F593 CW1	N_{sa}	lb (kN)	7,750 (34.5)	14,190 (63.1)	22,600 (100.5)	--	--	--	--
	Tension Resistance of Stainless Steel ASTM F593 CW2	N_{sa}	lb (kN)	--	--	--	28,390 (126.3)	39,270 (174.7)	51,510 (229.1)	82,365 (366.4)
	Tension Resistance of Stainless Steel ASTM F593 SH1	N_{sa}	lb (kN)	8,915 (39.7)	16,320 (72.6)	25,990 (115.6)	--	--	--	--
	Tension Resistance of Stainless Steel ASTM F593 SH2	N_{sa}	lb (kN)	--	--	--	35,070 (156.0)	48,510 (215.8)	63,630 (283.0)	--
	Tension Resistance of Stainless Steel ASTM F593 SH3	N_{sa}	lb (kN)	--	--	--	--	--	--	92,055 (409.5)
	Shear Resistance of Stainless Steel ASTM F593 CW1	V_{sa}	lb (kN)	3,875 (17.2)	7,095 (31.6)	11,300 (50.3)	--	--	--	--
	Shear Resistance of Stainless Steel ASTM F593 CW2	V_{sa}	lb (kN)	--	--	--	14,195 (63.1)	19,635 (87.3)	25,755 (114.6)	41,185 (183.2)
	Shear Resistance of Stainless Steel ASTM F593 SH1	V_{sa}	lb (kN)	4,455 (19.8)	9,790 (43.5)	15,595 (69.4)	--	--	--	--
	Shear Resistance of Stainless Steel ASTM F593 SH2	V_{sa}	lb (kN)	--	--	--	17,535 (78.0)	24,255 (107.9)	31,815 (141.5)	--
	Shear Resistance of Stainless Steel ASTM F593 SH3	V_{sa}	lb (kN)	--	--	--	--	--	--	46,030 (204.8)

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Values provided for steel threaded rod are based on minimum specified strengths and calculated in accordance with ACI 318-11 Eq. (D-2) and Eq. (D-29).

[2]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 2—STEEL DESIGN INFORMATION FOR FRACTIONAL STEEL REINFORCING BAR[1,2]

	Characteristic	Symbol	Units	Nominal Reinforcing Bar size, d_o						
				No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 10
Reinforcing bar	Nominal bar diameter	d_o	inch	0.375	0.500	0.625	0.750	0.875	1.000	1.250
	Stress Area	A_{se}	in.^{2}	0.11	0.20	0.31	0.44	0.60	0.79	1.27
	Strength Reduction Factor for Tension Steel Failure	ϕ	-	0.65						
	Strength Reduction Factor for Shear Steel Failure	ϕ	-	0.60						
	Reduction for Seismic Tension	$\alpha_{N,seis}$	-	1.00						
	Reduction for Seismic Shear	$\alpha_{V,seis}$	-	0.70	0.70	0.82	0.82	0.42	0.42	0.42
	Tension Resistance of Carbon Steel ASTM A615 Grade 40	N_{sa}	lb (kN)	6,600 (29.4)	12,000 (53.4)	18,600 (82.7)	26,400 (117.4)	36,000 (160.1)	47,400 (210.8)	76,200 (339.0)
	Tension Resistance of Carbon Steel ASTM A615 Grade 60	N_{sa}	lb (kN)	9,900 (44.0)	18,000 (80.1)	27,900 (124.1)	39,600 (176.1)	54,000 (240.2)	71,100 (316.3)	114,300 (508.4)
	Shear Resistance of Carbon Steel ASTM A615 Grade 40	V_{sa}	lb (kN)	3,960 (17.6)	7,200 (32.0)	11,160 (49.6)	15,840 (70.5)	21,600 (96.1)	28,440 (126.5)	45,720 (203.4)
	Shear Resistance of Carbon Steel ASTM A615 Grade 60	V_{sa}	lb (kN)	5,940 (26.4)	10,800 (48.0)	16,740 (74.5)	23,760 (105.7)	32,400 (144.1)	42,660 (189.8)	68,580 (305.1)

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Values provided for steel threaded rod are based on minimum specified strengths and calculated in accordance with ACI 318-11 Eq. (D-2) and Eq. (D-29).
[2]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 3—STEEL DESIGN INFORMATION FOR METRIC THREADED ROD AND REINFORCING BAR[1,2]

	Characteristic	Symbol	Units	Nominal Rod Diameter, d_o					
Metric Threaded Rod	Nominal Size	d_o	mm	M10	M12	M16	M20	M24	M30
	Stress Area	A_{se}	mm^2	58	84	157	245	353	561
	Strength Reduction Factor for Tension Steel Failure	ϕ	-	0.65					
	Strength Reduction Factor for Shear Steel Failure	ϕ	-	0.60					
	Reduction for Seismic Tension	$\alpha_{N,seis}$	-	1.00					
	Reduction for Seismic Shear	$\alpha_{V,seis}$	-	0.58	0.57	0.57	0.42	0.42	0.42
	Tension Resistance of Carbon Steel ISO 898-1 Class 5.8	N_{sa}	kN lb	29.0 (6,519)	42.2 (9,476)	78.5 (17,648)	122.5 (27,539)	176.5 (39,679)	280.5 (63,059)
	Tension Resistance of Carbon Steel ISO 898-1 Class 8.8	N_{sa}	kN lb	46.4 (10,431)	67.4 (15,161)	125.6 (28,236)	196.0 (44,063)	282.4 (63,486)	448.8 (100,894)
	Tension Resistance of Carbon Steel ISO 898-1 Class 12.9	N_{sa}	kN lb	50.0 (11,240)	72.7 (16,336)	135.3 (30,424)	211.2 (47,477)	304.3 (68,406)	483.6 (108,714)
	Tension Resistance of Stainless Steel ISO 3506-1 A4-70	N_{sa}	kN lb	40.6 (9,127)	59.0 (13,266)	109.9 (24,707)	171.5 (38,555)	247.1 (55,550)	392.7 (88,282)
	Tension Resistance of Stainless Steel ISO 3506-1 A4-80	N_{sa}	kN lb	46.4 (10,431)	67.4 (15,161)	125.6 (28,236)	196.0 (44,063)	282.4 (63,486)	448.8 (100,894)
	Shear Resistance of Carbon Steel ISO 898-1 Class 5.8	V_{sa}	kN lb	17.4 (3,912)	25.3 (5,685)	47.1 (10,589)	73.5 (16,523)	105.9 (23,807)	168.3 (37,835)
	Shear Resistance of Carbon Steel ISO 898-1 Class 8.8	V_{sa}	kN lb	27.8 (6,259)	40.5 (9,097)	75.4 (16,942)	117.6 (26,438)	169.4 (38,092)	269.3 (60,537)
	Shear Resistance of Carbon Steel ISO 898-1 Class 12.9	V_{sa}	kN lb	30.0 (6,744)	43.6 (9,802)	81.2 (18,255)	126.7 (28,486)	182.6 (41,044)	290.1 (65,228)
	Shear Resistance of Stainless Steel ISO 3506-1 A4-70	V_{sa}	kN lb	24.4 (5,476)	35.4 (7,960)	65.9 (14,824)	102.9 (23,133)	148.3 (33,330)	235.6 (52,969)
	Shear Resistance of Stainless Steel ISO 3506-1 A4-80	V_{sa}	kN lb	27.8 (6,259)	40.5 (9,097)	75.4 (16,942)	117.6 (26,438)	169.4 (38,092)	269.3 (60,537)

Metric Reinforcing bar	Nominal Size	d_o	mm	T10	T12	T16	T20	T25	-
	Stress Area	A_{se}	mm^2	78.5	113	201	314	491	-
	Strength Reduction Factor for Tension Steel Failure	ϕ	-	0.65					
	Strength Reduction Factor for Shear Steel Failure	ϕ	-	0.60					
	Reduction for Seismic Tension	$\alpha_{N,seis}$	-	1.00					
	Reduction for Seismic Shear	$\alpha_{V,seis}$	-	0.70	0.70	0.82	0.42	0.42	-
	Tension Resistance of DIN 488 BSt 500	N_{sa}	kN lb	43.2 (9,706)	62.2 (13,972)	110.6 (24,853)	172.7 (38,825)	270.1 (60,710)	-
	Shear Resistance of DIN 488 BSt 500	V_{sa}	kN lb	25.9 (5,824)	37.3 (8,383)	66.3 (14,912)	103.6 (23,295)	162.0 (36,426)	-

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Values provided for steel threaded rod are based on minimum specified strengths and calculated in accordance with ACI 318-11 Eq. (D-2) and Eq. (D-29).
[2]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 4—CONCRETE BREAKOUT STRENGTH DESIGN INFORMATION FOR FRACTIONAL THREADED ROD AND REINFORCING BAR

Characteristic		Symbol	Units	Nominal Anchor Element Diameter						
US Threaded Rod	Size	d_o	inch	$^3/_8$	$^1/_2$	$^5/_8$	$^3/_4$	$^7/_8$	1	$1^1/_4$
	Drill Size	d_{hole}	inch	$^7/_{16}$	$^9/_{16}$	$^3/_4$	$^7/_8$	1	$1^1/_8$	$1^3/_8$
US Rebar	Size	d_o	inch	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 10
	Drill Size	d_{hole}	inch	$^7/_{16}$	$^5/_8$	$^3/_4$	$^7/_8$	1	$1^1/_8$	$1^3/_8$
Embedment Depth Range		$h_{ef,min}$	inch	$2^3/_8$	$2^3/_4$	$3^1/_8$	$3^3/_4$	4	4	5
		$h_{ef,max}$	inch	$7^1/_2$	10	$12^1/_2$	15	$17^1/_2$	20	25
Minimum Anchor Spacing		s_{min}	inch	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^7/_8$	2	2	$2^1/_2$
Minimum Edge Distance		c_{min}	inch	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^7/_8$	2	2	$2^1/_2$
Minimum Concrete Thickness		h_{min}	inch	$1.5 \cdot h_{ef}$						
Critical Edge Distance		c_{ac}	-	See Section 4.1.10 of this report						
Effectiveness Factor for Uncracked Concrete, Breakout		$k_{c,uncr}$	-- (SI)	24 (10)						
Effectiveness Factor for Cracked Concrete, Breakout		$k_{c,cr}$	-- (SI)	17 (7.1)						
$k_{c,uncr}$ / $k_{c,cr}$		--	--	1.41						
Strength Reduction Factor for Tension, Concrete Failure Modes, Condition B[1]		ϕ	--	0.65						
Strength Reduction Factor for Shear, Concrete Failure Modes, Condition B[1]		ϕ	--	0.70						

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Condition B applies where supplemental reinforcement is not provided as set forth in ACI 318 D.4.3. The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 5—CONCRETE BREAKOUT STRENGTH DESIGN INFORMATION FOR METRIC THREADED ROD AND REINFORCING BAR

Characteristic		Symbol	Units	Nominal Anchor Element Diameter					
SI Threaded Rod	Size	d_o	mm	M10	M12	M16	M20	M24	M30
	Drill Size	d_{hole}	mm	12	14	18	22	26	35
SI Rebar	Size	d_o	mm	T10	T12	T16	T20	T25	-
	Drill Size	d_{hole}	mm	14	16	20	25	32	-
Embedment Depth Range		$h_{ef,min}$	inch	$2^3/_8$	$2^3/_4$	$3^1/_8$	$3^3/_4$	4	5
		$h_{ef,max}$	inch	$7^1/_2$	10	$12^1/_2$	15	20	25
Minimum Anchor Spacing		s_{min}	inch	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^7/_8$	2	$2^1/_2$
Minimum Edge Distance		c_{min}	inch	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^7/_8$	2	$2^1/_2$
Minimum Concrete Thickness		h_{min}	inch	$1.5 \cdot h_{ef}$					
Critical Edge Distance		--	-	See Section 4.1.10 of this report					
Effectiveness Factor for Uncracked Concrete, Breakout		k_{uncr}	-- (SI)	24 (10)					
Effectiveness Factor for Cracked Concrete, Breakout		k_{cr}	-- (SI)	17 (7.1)					
k_{uncr} / k_{cr}		--	--	1.41					
Strength Reduction Factor for Tension, Concrete Failure Modes, Condition B		ϕ	--	0.65					
Strength Reduction Factor for Shear, Concrete Failure Modes, Condition B		ϕ	--	0.70					

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Condition B applies where supplemental reinforcement is not provided as set forth in ACI 318 D.4.3. The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 6—BOND STRENGTH DESIGN INFORMATION FOR FRACTIONAL THREADED ROD[1]

Design Information		Symbol	Units	Nominal Threaded Rod Diameter						
				3/8"	**1/2"**	**5/8"**	**3/4"**	**7/8"**	**1"**	**1 1/4"**
Minimum Effective Installation Depth		$h_{ef,min}$	in.	2 3/8	2 3/4	3 1/8	3 1/2	4	4	5
			mm	60	70	79	89	102	102	127
Maximum Effective Installation Depth		$h_{ef,max}$	in.	7 1/2	10	12 1/2	15	17 1/2	20	25
			mm	191	254	318	381	445	508	635
Temperature Range A[2,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	1,820						
			N/mm[2]	12.6						
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	1,550	1,465	1,380	1,300	1,215	1,130	965
			N/mm[2]	10.7	10.1	9.5	9.0	8.4	7.8	6.6
Temperature Range B,[3,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	735						
			N/mm[2]	5.1						
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	625	590	560	525	490	455	390
			N/mm[2]	4.3	4.1	3.9	3.6	3.4	3.1	2.7
Temperature Range C[,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	530						
			N/mm[2]	3.7						
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	450	425	400	375	350	330	280
			N/mm[2]	3.1	2.9	2.8	2.6	2.4	2.3	1.9
Permissible Installation Conditions[6]	Dry Concrete	ϕ_d	Periodic Inspection	0.65						
	Water-saturated Concrete	ϕ_{ws}		0.55			0.65			
	Water-filled Hole	ϕ_{wf}		0.55						
	Dry Concrete	ϕ_d	Continuous Inspection	0.65						
	Water-saturated Concrete	ϕ_{ws}		0.65						
	Water-filled Hole	ϕ_{wf}		0.65						

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi. Bond strength values must not be increased for increased concrete compressive strength.
[2]Temperature Range A = Maximum Long Term Temperature: 70°F (21`°C); Maximum Short Term Temperature: 110°F (43°C)
[3]Temperature Range B = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 162°F (72°C)
[4]Temperature Range C = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 176°F (80°C)
[5]Short-term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long-term concrete temperatures are roughly constant over significant periods of time.
[6]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 7—BOND STRENGTH DESIGN INFORMATION FOR FRACTIONAL REINFORCING BAR[1]

Design Information		Symbol	Units	Nominal Reinforcing Bar Diameter						
				No. 3	**No. 4**	**No. 5**	**No. 6**	**No. 7**	**No. 8**	**No. 10**
Minimum Effective Installation Depth		$h_{ef,min}$	in.	$2^3/_8$	$2^3/_4$	$3^1/_8$	$3^1/_2$	4	4	5
			mm	60	70	79	89	102	102	127
Maximum Effective Installation Depth		$h_{ef,max}$	in.	$7^1/_2$	10	$12^1/_2$	15	$17^1/_2$	20	25
			mm	191	254	318	381	445	508	635
Temperature Range A[2,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	1,820						
			N/mm^2	12.6						
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	1,550	1,465	1,380	1,300	1,215	1,130	965
			N/mm^2	10.7	10.1	9.5	9.0	8.4	7.8	6.6
Temperature Range B[3,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	735						
			N/mm^2	5.1						
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	625	590	560	525	490	455	390
			N/mm^2	4.3	4.1	3.9	3.6	3.4	3.1	2.7
Temperature Range C[4,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	530						
			N/mm^2	3.7						
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	450	425	400	375	350	330	280
			N/mm^2	3.1	2.9	2.8	2.6	2.4	2.3	1.9
Permissible Installation Conditions[6]	Dry Concrete	ϕ_d	Periodic Inspection	0.65						
	Water-saturated Concrete	ϕ_{ws}		0.55			0.65			
	Water-filled Hole	ϕ_{wf}		0.65						
	Dry Concrete	ϕ_d	Continuous Inspection	0.65						
	Water-saturated Concrete	ϕ_{ws}		0.65						
	Water-filled Hole	ϕ_{wf}		0.65						

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi. Bond strength values must not be increased for increased concrete compressive strength.
[2]Temperature Range A = Maximum Long Term Temperature: 70°F (21°C); Maximum Short Term Temperature: 110°F (43°C)
[3]Temperature Range B = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 162°F (72°C)
[4]Temperature Range C = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 176°F (80°C)
[5]Short-term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long-term concrete temperatures are roughly constant over significant periods of time.
[6]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 8—BOND STRENGTH DESIGN INFORMATION FOR METRIC THREADED ROD[1]

Design Information		Symbol	Units	Nominal Threaded Rod Diameter					
				M10	M12	M16	M20	M24	M30
Minimum Effective Installation Depth		$h_{ef,min}$	in.	2.4	2.8	3.1	3.5	3.8	4.7
			mm	60	70	80	90	96	120
Maximum Effective Installation Depth		$h_{ef,max}$	in.	7.9	9.4	12.6	15.7	18.9	23.6
			mm	200	240	320	400	480	600
Temperature Range A[2,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	1,820					
			N/mm²	12.6					
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	1,540	1,485	1,380	1,275	1,165	1,010
			N/mm²	10.6	10.2	9.5	8.8	8.1	7.0
Temperature Range B[3,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	735					
			N/mm²	5.1					
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	620	600	555	515	470	405
			N/mm²	4.3	4.1	3.8	3.5	3.3	2.8
Temperature Range C[4,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	530					
			N/mm²	3.7					
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	445	430	400	370	340	295
			N/mm²	3.1	3.0	2.8	2.5	2.3	2.0
Permissible Installation Conditions[6]	Dry Concrete	ϕ_d	Periodic Inspection	0.65					
	Water-saturated Concrete	ϕ_{ws}		0.55			0.65		
	Water-filled Hole	ϕ_{wf}		0.65					
	Dry Concrete	ϕ_d	Continuous Inspection	0.65					
	Water-saturated Concrete	ϕ_{ws}		0.65					
	Water-filled Hole	ϕ_{wf}		0.65					

For **SI:** 1 inch = 25.4 mm, 1 in.^{2} = 645.16 mm^2, 1 lb = 0.004448 kN

[1]Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi. Bond strength values must not be increased for increased concrete compressive strength.
[2]Temperature Range A = Maximum Long Term Temperature: 70°F (21°C); Maximum Short Term Temperature: 110°F (43°C)
[3]Temperature Range B = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 162°F (72°C)
[4]Temperature Range C = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 176°F (80°C)
[5]Short-term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long-term concrete temperatures are roughly constant over significant periods of time.
[6]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

TABLE 9—BOND STRENGTH DESIGN INFORMATION FOR METRIC REBAR[1]

Design Information		Symbol	Units	Nominal Reinforcing Bar Diameter				
				T10	T12	T16	T20	T25
Minimum Effective Installation Depth		$h_{ef,min}$	in.	2.4	2.8	3.1	3.5	3.9
			mm	60	70	80	90	100
Maximum Effective Installation Depth		$h_{ef,max}$	in.	7.9	9.4	12.6	15.7	19.7
			mm	200	240	320	400	500
Temperature Range A[2,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	1,820				
			N/mm²	12.6				
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	1,540	1,485	1,380	1,275	1,140
			N/mm²	10.6	10.2	9.5	8.8	7.9
Temperature Category B, Range B[3,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	735				
			N/mm²	5.1				
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	620	600	555	515	460
			N/mm²	4.3	4.1	3.8	3.5	3.2
Temperature Category B, Range C[4,5]	Characteristic Bond Strength in Uncracked Concrete	$\tau_{k,uncr}$	psi	530				
			N/mm²	3.7				
	Characteristic Bond Strength in Cracked Concrete	$\tau_{k,cr}$	psi	445	430	400	370	330
			N/mm²	3.1	3.0	2.8	2.5	2.3
Permissible Installation Conditions[6,7]	Dry Concrete	ϕ_d	Periodic Inspection	0.65				
	Water-saturated Concrete	ϕ_{ws}		0.55			0.65	
	Water-filled Hole	ϕ_{wf}		0.65				
	Dry Concrete	ϕ_d	Continuous Inspection	0.65				
	Water-saturated Concrete	ϕ_{ws}		0.65				
	Water-filled Hole	ϕ_{wf}		0.65				

For **SI:** 1 inch = 25.4 mm, 1 in.² = 645.16 mm², 1 lb = 0.004448 kN

[1]Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi. Bond strength values must not be increased for increased concrete compressive strength.
[2]Temperature Range A = Maximum Long Term Temperature: 70°F (21°C); Maximum Short Term Temperature: 110°F (43°C)
[3]Temperature Range B = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 162°F (72°C)
[4]Temperature Range C = Maximum Long Term Temperature: 110°F (43°C); Maximum Short Term Temperature: 176°F (80°C)
[5]Short-term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long-term concrete temperatures are roughly constant over significant periods of time.
[6]The tabulated value of ϕ applies when the load combinations of Section 1605.2 of the IBC, or ACI 318 Section 9.2 are used in accordance with ACI 318 D.4.3. If the load combinations of ACI 318 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318 D.4.4.

FIGURE 1—RED HEAD EPCON C6+ ADHESIVE ANCHORING SYSTEM

Cox 300 mL (9 fl. oz.) manual tool

Newborn 600 mL (20 fl. oz.) manual tool

Newborn 600 mL (20 fl. oz.) pneumatic tool

FIGURE 2—ADDITIONAL DISPENSING TOOLS FOR USE WITH RED HEAD EPCON C6+ ADHESIVE ANCHORING SYSTEM

SPECIFICATIONS FOR INSTALLATION OF EPCON C6+ ADHESIVE ANCHORS IN CONCRETE

Characteristic		Symbol	Units	Nominal Anchor Element Diameter						
Fractional Threaded Rod	Size	d_o	inch	$^3/_8$	$^1/_2$	$^5/_8$	$^3/_4$	$^7/_8$	1	$1^1/_4$
	Drill Size	d_{hole}	inch	$^7/_{16}$	$^9/_{16}$	$^3/_4$	$^7/_8$	1	$1^1/_8$	$1^3/_8$
Fractional Rebar	Size	d_o	inch	#3	#4	#5	#6	#7	#8	#10
	Drill Size	d_{hole}	inch	$^7/_{16}$	$^5/_8$	$^3/_4$	$^7/_8$	1	$1^1/_8$	$1^3/_8$
Metric Threaded Rod	Size	d_o	mm	M10	M12	M16	M20	-	M24	M30
	Drill Size	d_{hole}	mm	12	14	18	22	-	26	35
Metric Rebar	Size	d_o	mm	T10	T12	T16	T20	-	T25	-
	Drill Size	d_{hole}	mm	14	16	20	25	-	32	-
Maximum Tightening Torque		T_{inst}	ft·lb	15	30	60	100	125	150	200
Embedment Depth Range		$h_{ef,min}$	inch	$2^3/_8$	$2^3/_4$	$3^1/_8$	$3^3/_4$	4	4	5
		$h_{ef,max}$	inch	$7^1/_2$	10	$12^1/_2$	15	$17^1/_2$	20	25
Minimum Concrete Thickness		h_{min}	inch	$1.5 \cdot h_{ef}$						
Critical Edge Distance		c_{ac}	inch	See Section 4.1.10 of this report						
Minimum Edge Distance		c_{min}	inch	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^7/_8$	2	2	$2^1/_2$
Minimum Anchor Spacing		s_{min}	inch	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^7/_8$	2	2	$2^1/_2$

For **SI:** 1 inch = 25.4 mm, 1 ft lb = 1.356 Nm

CURE TIMES AND GEL TIMES FOR EPCON C6+ ADHESIVE

Concrete Temperature (°F)[1,2]	Gel Time[3]	Cure Time[4]
104	3 min	3 hours
95	4 min	4 hours
86	6 min	5 hours
77	8 min	6 hours
72	11 min	7 hours
59	15 min	8 hours
50	20 min	12 hours
40	20 min	24 hours

For **SI:** t° (°F-32) X 0.555 = °C

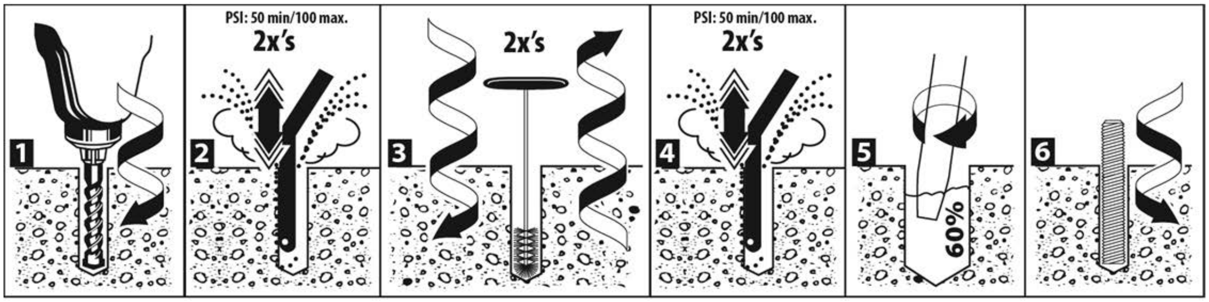
[1] Adhesive must be installed in concrete temperatures within the noted range or artificially maintained at the noted temperature.
[2] For concrete temperatures between 40°F and 50°F, adhesive must be maintained at a minimum of 50°F during installation.
[3] Gel time is the maximum time from the end of mixing to when the insertion of the anchor into the adhesive shall be completed and is based upon the adhesive and the concrete temperatures noted.
[4] Cure time is the minimum time from the end of gel time to when the anchor may be torque or loaded. Anchors are to be undisturbed during the cure time.

BRUSH SPECIFICATIONS

Anchor Diameter – d_o (in)	Anchor Diameter – d_o (mm)	Brush Color	Brush Part No.	Minimum Brush Diameter (in)
$^3/_8$ and No. 3	M10	Grey	SB038	0.563
$^1/_2$ and No. 4	M12 and T10	Brown	SB012	0.675
$^5/_8$ and No. 5	M16 and T12	Green	SB058	0.900
¾ and No. 6	M20 and T16	Yellow	SB034	1.125
$^7/_8$ and No. 7	M24 and T20	Red	SB078	1.350
1 and No. 8	-	Purple	SB010	1.463
1 ¼ and No. 10	M30 and T25	Blue	SB125	1.575

FIGURE 3—RED HEAD EPCON C6+ ADHESIVE INSTALLATION INFORMATION

RED HEAD EPCON C6+ ADHESIVE ANCHOR INSTALLATION INSTRUCTIONS



* Water-saturated concrete and water-filled hole applications require 4x's air, 4x's brushing and 4x's air

1) ▪ Use a rotary hammer drill or pneumatic air drill with a carbide drill bit complying to ANSI B212.15-1994 tolerance requirements. Drill hole to the required embedment depth. See attached table for drill bit specifications and min/maximum embedment depths.
▪ Installations may be used with maximum 1-1/4" diameter rods/rebar for floor, wall and overhead applications.
▪ Per construction specification, adhere to minimum spacing, minimum edge distance, and minimum member thickness.

2) ▪ For dry holes, oscillate a clean air nozzle in and out of the dry hole two times, for a total of two seconds, starting at the bottom of the hole with contaminant-free compressed air, exhausting hole until visually clean (i.e., no dust, debris, etc.)
▪ For water-saturated concrete and water-filled hole applications, oscillate a clean air nozzle in and out of the damp, water-filled or submerged hole four times, for a total of four seconds, starting at the bottom of the hole with contaminant-free compressed air, exhausting hole until visually clean (i.e., no dust, debris, etc.)
▪ If required, use an extension on the end of the air nozzle to reach the bottom of the hole.

3) ▪ Select an appropriately sized Red Head brush for the anchor diameter. Brush must be checked for wear before use. See attached table for brush specifications, including minimum diameter.
▪ Insert the brush into the hole with a clockwise motion. For every ½" forward advancement, complete one full turn until bottom of hole is reached. For faster and more suitable cleaning, attach the brush to a drill.
▪ Using a clockwise motion, for every full turn of the brush, pull the brush ½" out of the hole.
▪ For dry holes, twist/spin the brush two times in/out of the hole.
▪ For water-saturated concrete and water-filled hole applications, twist/spin the brush four times in/out of the hole.
▪ If required, use a wire brush extension (part nos. ESDS-38 or EHAN-38) to reach the bottom of the hole.
▪ Air clean the dust off the brush to prevent clogging of the brush.

4) ▪ For dry holes, oscillate a clean air nozzle in and out of the dry hole two times, for a total of two seconds, starting at the bottom of the hole with contaminant-free compressed air, exhausting hole until visually clean (i.e., no dust, debris, etc.)
▪ For water-saturated concrete and water-filled hole applications, oscillate a clean air nozzle in and out of the damp, water-filled or submerged hole four times, for a total of four seconds, starting at the bottom of the hole with contaminant-free compressed air, exhausting hole until visually clean (i.e., no dust, debris, etc.)

5) ▪ Review the Material Safety Data Sheet (MSDS) before use.
▪ Check the "Use By" date on the cartridge and that the cartridge has been stored in temperatures between 50 and 77 degrees F – out of direct sunlight.
▪ Review the gel time/cure time chart, based on the temperature at time of installation, in order to determine tool, cartridge and nozzle requirements.
▪ Assemble the Red Head supplied cartridge and nozzle. Do not modify or remove mixing elements in nozzle.
▪ For 5/8" diameter rod (#5 rebar, M16 rod, T16 rebar) and larger installed overhead or at embedments greater than 10" in all installation directions, assemble Red Head E916-6 extension tubing and appropriate sized piston plug on end of nozzle:
PL-5834 for $^{5}/_{8}$" & ¾" diameters
PL-7810 for $^{7}/_{8}$" & 1" diameters
PL-1250 for 1-$^{1}/_{4}$" diameter
▪Place the assembly into a hand injection tool or a pneumatic injection tool.
▪ Dispense mixed adhesive outside of hole until uniform color is achieved.
▪ During installations, concrete must be between 40 and 104 degrees F, or artificially maintained. For concrete temperatures of 40F to 50F, adhesive must be maintained at a minimum 50F during installation.
▪ Insert the nozzle to the bottom of the hole and inject the adhesive at an angle, leaving the nozzle tip always slightly below the fill level.
▪ If nozzle does not reach the bottom of the hole, use Red Head E25-6 extension tubing positioned on the end of nozzle or use the S75EXT (nozzle extension) on the end of the S75 nozzle.
▪ In a slow circular direction, work the adhesive into the sides of the hole, filling slowly to ensure proper adhesive distribution, until the hole is approximately 60% filled.
▪ For holes that contain water, keep injecting the adhesive below the water in order to displace the water upward.

6) ▪ Immediately insert the oil, rust and scale free rod/rebar assembly to the required embedment depth, using a counterclockwise motion to ensure proper adhesive distribution.
▪ The anchor rod/rebar must be marked with the required embedment depth.
▪ After installing the anchor, the gap between the rod and the concrete must be completely filled with adhesive. The adhesive must fill voids, crevices and uniformly coat the rod and concrete.
▪ After installation, do not disturb the anchor until the full cure time has elapsed. Overhead installations must be supported until full cure time has elapsed.
▪ Adhesive must be fully cured before applying any load or torque. Do not over torque the anchor as this could adversely affect its performance.

FIGURE 4—MANUFACTURER'S PRINTED INSTALLATION INSTRUCTIONS (MPII)

TABLE 10—EXAMPLE OF ALLOWABLE STRESS DESIGN (ASD) TENSION VALUES FOR ILLUSTRATIVE PURPOSES

Example Allowable Stress Design (ASD) Calculation for Illustrative Purposes				
Anchor Diameter (in.)	Embedment Depth Max / Min (in.)	Characteristic Bond Strength $\tau_{k,uncr}$ (psi)	Allowable Tension Load (lb) 2,500 psi Concrete	Controlling Failure Mode
$^{3}/_{8}$	$2^{3}/_{8}$	1,820	1,929	Concrete
	$7^{1}/_{2}$		4,910	Steel
$^{1}/_{2}$	$2^{3}/_{4}$		2,403	Concrete
	10		8,990	Steel
$^{5}/_{8}$	$3^{1}/_{8}$		2,911	Concrete
	$12^{1}/_{2}$		14,316	Steel
$^{3}/_{4}$	$3^{1}/_{2}$		3,451	Concrete
	15		21,157	Steel
$^{7}/_{8}$	4		4,216	Concrete
	$17^{1}/_{2}$		29,265	Steel
1	4		4,216	Concrete
	20		38,387	Steel
$1^{1}/_{4}$	4		4,216	Concrete
	25		61,381	Steel

Design Assumptions:

1. Single anchor in static tension only, ASTM A193 Grade B7 threaded rod.
2. Vertical downwards installation.
3. Inspection regimen = Periodic.
4. Installation temperature 70°F to 110°F
5. Long term temperature 70°F
6. Short term temperature 110°F
7. Dry condition (carbide drilled hole).
8. Embedment (h_{ef}) = min / max for each diameter.
9. Concrete determined to remain uncracked for life of anchor.
10. Load combinations from ACI 318 Section 9.2 (no seismic loading).
11. 30% dead load and 70% live load. Controlling load combination 1.2D + 1.6L
12. Calculation of weighted average for $\alpha = 1.2(0.3) + 1.6(0.7) = 1.48$
13. f'_c = 2,500 psi (normal weight concrete)
14. $c_{ac1} = c_{ac2} \geq c_{ac}$
15. $h \geq h_{min}$

Illustrative Procedure to Calculate Allowable Stress Design Tension Value:
Red Head Epcon C6+ Adhesive Anchor ½-inch diameter, using an embedment of 4$^1/_2$ inches, assuming the conditions given in Table 10 (for use with the 2009 IBC, based on ACI 318-11 Appendix D). Applied Tension load, 4,000 lbs.

	PROCEDURE	***CALCULATION***
Step 1	Calculate steel strength of a single anchor in tension per ACI 318 D.5.1.2 and Table 1 of this report.	ϕN_{sa} = 0.75*17,740 = 13,305 lbs steel strength
Step 2	Calculate concrete breakout strength of a single anchor in tension per ACI 318 D.5.2 and Table 4 of this report.	$N_b = k_{c,uncr} * \lambda_a \sqrt{f'_c}\, h_{ef}^{1.5} = 24 * \sqrt{2{,}500} * 4.5^{1.5}$ N_b = 11,455 lbs $\phi N_{cb} = \phi\, A_{NC}/A_{NC0}\, \psi_{ed,N}\, \psi_{c,N}\, \psi_{cp,N}\, N_b$ ϕN_{cb} = 0.65*1.0*1.0*1.0*1.0*11,455 ϕN_{cb} = 7,446 lbs concrete breakout strength
Step 3	Calculate bond strength of a single anchor in tension per ACI 318 D.5.5 and Table 6 of this report.	$N_{ba} = \lambda_a\, \tau_{k,uncr}\, \pi d h_{ef}$ N_{ba} = 1.0*1,820*3.14*0.5*4.5 N_{ba} = 12,858 lbs $\phi N_a = \phi\, A_{Na}/A_{Na0}\, \psi_{ed,Na}\, \psi_{cp,Na}\, N_{ao}$ ϕN_a = 0.55*1.0*1.0*1.0*12,858 ϕN_a = 7,070 lbs bond strength
Step 4	Determine compliance with required anchor strength per ACI 318 D.4.1.	ϕN_{sa} = 13,305 lbs > N_{ua} = 4,000 lbs ϕN_{cb} = 7,446 lbs > N_{ua} = 4,000 lbs ϕN_a = 7,070 lbs > N_{ua} = 4,000 lbs
Step 5	Calculate allowable stress design conversion factor for loading condition per ACI 318 Section 9.2.	α = 1.2*D* + 1.6*L* = 1.2(0.3) + 1.6(0.7) = 1.48
Step 6	Calculate allowable stress design value per Section 4.2 of this report.	$T_{allowable,ASD} = \phi N_n / \alpha$ = 7,446 lbs/1.48 $T_{allowable,ASD}$ = 4,775 lbs allowable stress design

FIGURE 5—EXAMPLE DESIGN CALCULATION

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ESR-3577 FBC Supplement*

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Section: 05 05 19—Post-installed Concrete Anchors

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EVALUATION SUBJECT:

ITW RED HEAD EPCON C6+ ADHESIVE ANCHORING SYSTEM FOR CRACKED AND UNCRACKED CONCRETE

1.0 REPORT PURPOSE AND SCOPE

Purpose:

The purpose of this evaluation report supplement is to indicate that Red Head Epcon C6+ Adhesive Anchoring System for Cracked and Uncracked Concrete, recognized in ICC-ES master evaluation report ESR-3577, has also been evaluated for compliance with the codes noted below.

Applicable code editions:

- 2010 *Florida Building Code—Building*
- 2010 *Florida Building Code—Residential*

2.0 CONCLUSIONS

The Red Head Epcon C6+ Adhesive Anchoring System Adhesive Anchors for Cracked and Uncracked Concrete, described in Sections 2.0 through 7.0 of the master evaluation report ESR-3577, comply with the 2010 *Florida Building Code—Building* and the 2010 *Florida Building Code—Residential*, provided the design and installation are in accordance with the 2009 *International Building Code®* (IBC) provisions noted in the master report and the following provisions apply:

- Design wind loads must be based on Section 1609 of the 2010 *Florida Building Code—Building* or Section 301.2.1.1 of the 2010 *Florida Building Code—Residential*, as applicable.
- Load combinations must be in accordance with Section 1605.2 or Section 1605.3 of the 2010 *Florida Building Code—Building*, as applicable.
- The modifications to ACI 318 as shown in the 2009 IBC Sections 1908.1.9 and 1908.1.10, as noted in 2009 IBC Section 1912.1, do not apply to the 2010 *Florida Building Code*.

Use of the Red Head Epcon C6+ Adhesive Anchoring System for Cracked and Uncracked Concrete for compliance with the High-Velocity Hurricane Zone provisions of the 2010 *Florida Building Code—Building* has not been evaluated, and is outside the scope of this supplemental report.

For products falling under Florida Rule 9N-3, verification that the report holder's quality assurance program is audited by a quality assurance entity approved by the Florida Building Commission for the type of inspections being conducted is the responsibility of an approved validation entity (or the code official when the report holder does not possess an approval by the Commission).

This supplement expires concurrently with the master report issued November 1, 2013, revised January 2014.

***Revised January 2014**

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