



NORTH AMERICAN PROFIS ENGINEERING ANCHORING TO CONCRETE DESIGN GUIDE

ACI 318-14 Provisions

2021



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PROFIS ENGINEERING REPORT TENSION LOAD



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Equations N_a

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$	17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$	ACI 318 anchoring-to-concrete provisions for the nominal bond strength of a single anchor (N_a) require calculation of various modification factors corresponding to area of influence (A_{Na}/A_{Na0}), edge distance ($\psi_{ed,Na}$), and splitting ($\psi_{cp,Na}$); and then multiplying these factors by what is termed the “basic bond strength in tension” (N_{ba}) to obtain a “nominal bond strength in tension” (N_a). Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic bond strength in tension Reference the Results section of the PROFIS Engineering report for more information on N_a.

Equations ϕN_a

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi N_a \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Bond Strength of Adhesive Anchor in Tension Single Anchor $\phi N_a \geq N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_a) against a factored tension load (N_{ua}). The parameter ϕN_a corresponds to the design bond strength for a single anchor in tension. The parameter N_{ua} corresponds to the factored tension load acting on the anchor. If $\phi N_a > N_{ua}$ for the application being modeled, the provisions of Section 17.3.1.1 are satisfied for bond failure. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_a: Nominal bond strength in tension ϕ_{bond}: Strength reduction factor for bond failure $\phi_{seismic}$: Strength reduction factor for seismic tension ϕN_a: Design bond strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

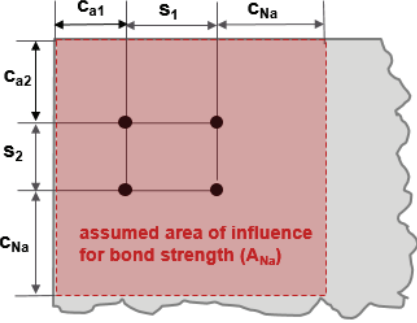
Equations N_{ag}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$	17.4.5.1 The nominal bond strength in tension, ... N_{ag} of a group of adhesive anchors, shall not exceed: (b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$	ACI 318 anchoring-to-concrete provisions for the nominal bond strength of a group of adhesive anchors (N_{ag}) require calculation of various modification factors corresponding to area of influence (A_{Na}/A_{Na0}), eccentricity ($\psi_{ec,Na}$), edge distance ($\psi_{ed,Na}$), and splitting ($\psi_{cp,Na}$); and then multiplying these factors by what is termed the “basic bond strength in tension” (N_{ba}) to obtain a “nominal bond strength in tension” (N_{ag}). Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ec,Na}$: Tension modification factor for eccentricity $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic bond strength in tension Reference the Results section of the PROFIS Engineering report for more information on N_{ag}.

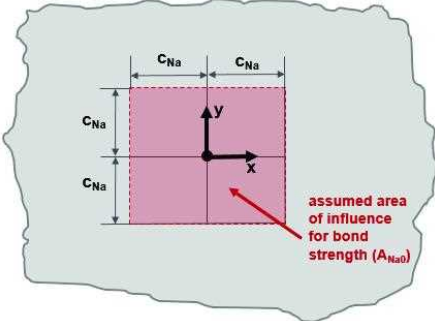
Equations ϕN_{ag}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi N_{ag} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Bond Strength in Tension Single Anchor $\phi N_{ag} \geq N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{ag}) against a factored tension load (N_{ua}). The parameter ϕN_{ag} corresponds to the design bond strength for a group of anchors in tension. The parameter N_{ua} corresponds to the factored tension load acting on the anchor group. If $\phi N_{ag} > N_{ua}$ for the application being modeled, the provisions of Section 17.3.1.1 are satisfied for bond failure. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{ag}: Nominal bond strength in tension ϕ_{bond}: Strength reduction factor for bond failure $\phi_{seismic}$: Strength reduction factor for seismic tension ϕN_{ag}: Design bond strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Equations A_{Na}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Na}	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors.....	A_{Na} is a modification factor that accounts for the area of influence assumed to develop in concrete, with respect to bond failure, when a tension load is applied to a single adhesive anchor or a group of adhesive anchors. A_{Na} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Na} is defined by projected distances from the anchors that are in tension. The maximum projected distance from an anchor that is considered when calculating A_{Na} is limited to c_{Na}, where c_{Na} is defined by Equation (17.4.5.1d) in Section 17.4.5.1. Therefore, the maximum edge distance parameter used to calculate A_{Na} equals c_{Na} and the maximum spacing parameter used to calculate A_{Na} equals $2.0c_{Na}$. The figure below illustrates how A_{Na} is calculated for a group of four anchors in tension with fixed edge distances equal to c_{a1} and c_{a2}, and spacing parameters equal to s_1 and s_2. Note that the maximum edge distance parameter used to calculate A_{Na} equals c_{Na}. Anchors spaced greater than $2.0c_{Na}$ from one another would not be considered to act as a group with respect to that spacing.  $A_{Na} = (c_{a1} + s_1 + c_{Na})(c_{a2} + s_2 + c_{Na})$ where: c_{a1} and c_{a2} are $< c_{Na}$ s_1 and s_2 are $< 2.0c_{Na}$ Reference the Equations and Calculations section of the PROFIS Engineering report for more information on c_{Na}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Na}.

Equations A_{Na0}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$A_{Na0} = (2c_{Na})^2$	17.4.5.1 A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$	A_{Na0} is a modification factor that accounts for the area of influence assumed to develop in concrete, with respect to bond failure, when a tension load is applied to a single anchor without the influence of any fixed edges. A_{Na0} is calculated with the parameter "c_{Na}", which is defined in ACI 318-14 Chapter 2 as the "projected distance from the center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor." c_{Na} is a calculated value, and is calculated per ACI 318-14 Equation (17.4.5.1d). The geometry for A_{Na0} is defined by a projected distance of c_{Na} from the anchor in the x and y directions. The figure below illustrates how A_{Na0} is calculated.  $A_{Na0} = (c_{Na} + c_{Na})(c_{Na} + c_{Na})$ $= (2.0c_{Na})^2$ Reference the Equations and Calculations section of the PROFIS Engineering report for more information on c_{Na}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Na0}.

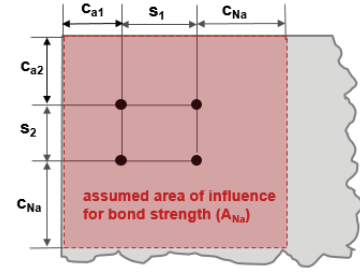
Equations c_{Na}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}}$	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors.....A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in².	ACI 318-14 Chapter 17 bond strength calculations are predicated on the parameter “c_{Na}”, which is defined in Chapter 2 as the “projected distance from the center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor.” c_{Na} is calculated per Equation (17.4.5.1d). The parameter “d_a” corresponds to the diameter of the anchor element selected for the PROFIS Engineering application being modeled. The parameter “T_{uncr}” corresponds to the characteristic bond stress in uncracked concrete of the adhesive product selected for the PROFIS Engineering application being modeled. The modification factor A_{Na} accounts for the area of influence assumed to develop with respect to bond failure, for the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. Per the provisions for A_{Na} given in Section 17.4.5.1, PROFIS Engineering limits the geometry used to define A_{Na} to a maximum projected distance from an anchor of c_{Na}. A_{Na0} is a modification factor that accounts for the area of influence assumed to develop in concrete, with respect to bond failure, when a tension load is applied to a single anchor without the influence of any fixed edges. Per the provisions for A_{Na0} given in Section 17.4.5.1, PROFIS Engineering defines the geometry for A_{Na0} as a projected distance of “c_{Na}” from the anchor in the +x, -x, +y and -y directions. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: d_a: Diameter of anchor element T_{uncr}: Characteristic bond stress of an adhesive anchor in uncracked concrete Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence modification factor A_{Na0}: Idealized area of influence modification factor for a single anchor c_{Na}: Projected distance from the center of an adhesive anchor

Equations $\psi_{ec,Na}$

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \leq 1.0$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as: $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	$\psi_{ec,Na}$ is a modification factor that is used to account for a resultant tension load that is eccentric with respect to the centroid of anchors that are loaded in tension. $\psi_{ec,Na}$ is only considered when calculating the nominal bond strength in tension for an anchor group (N_{ag}). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: c_{Na}: Projected distance from an adhesive anchor $\psi_{ec1,N}$: Modification factor for tension eccentricity with respect to the x direction $\psi_{ec2,N}$: Modification factor for tension eccentricity with respect to the y direction

Equations $\psi_{ed,Na}$

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \leq 1.0$	17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) If $c_{a,min} < c_{Na}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b)	$\psi_{ed,Na}$ is a modification factor that is used to account for fixed edge distances less than c_{Na}, where c_{Na} corresponds to a projected distance from the center of the adhesive anchor element being modeled in PROFIS Engineering. The illustration below shows how the assumed area of influence (A_{Na}) would be defined for an adhesive anchoring application being modeled with two fixed edges (c_{a1} and c_{a2}) that are both less than c_{Na}, and with c_{a1} being less than c_{a2}. The smallest edge distance (c_{a1}) corresponds to the parameter $c_{a,min}$, and would be used to calculate the modification factor $\psi_{ed,Na}$.  $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a1}}{c_{Na}} \right)$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameter: $c_{a,min}$: Parameter for the smallest fixed edge being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the following parameter: c_{Na}: Projected distance from an adhesive anchor

Equations $\psi_{cp,Na}$

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering								
$\psi_{cp,Na} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}} \right) \leq 1.0$	17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}}$ (17.4.5.5b) but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0. 17.4.5.2 For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors</td><td>2h_{ef}</td></tr><tr><td>Undercut anchors</td><td>2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors</td><td>4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchors</td><td>4h_{ef}</td></tr></table>	Adhesive anchors	2h_{ef}	Undercut anchors	2.5h_{ef}	Torque-controlled expansion anchors	4h_{ef}	Displacement-controlled expansion anchors	4h_{ef}	$\psi_{cp,Na}$ is a modification factor that considers splitting failure when calculating the nominal bond strength in tension (N_a or N_{ag}) for an adhesive anchor system. Since ACI 318 anchoring-to-concrete provisions do not specifically consider concrete splitting as a failure mode, splitting is addressed through the $\psi_{cp,Na}$ modification factor. The parameter $\psi_{cp,Na}$ is only considered when designing adhesive anchors installed in uncracked concrete. Splitting failure will typically not occur for cast-in-place anchors; therefore, a splitting modification factor is not calculated in PROFIS Engineering when modeling cast-in-place anchors. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels.” The parameter c_{ac} that is used to calculate $\psi_{cp,Na}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” $\psi_{cp,Na}$ does not need to be calculated if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}, or if cracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR ACI 318-14 Section 17.7.6 provides c_{ac} values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the c_{ac}-value that is given in the ICC-ES evaluation report for an adhesive anchor system to calculate $\psi_{cp,Na}$. The value for $\psi_{cp,Na}$ that PROFIS Engineering calculates will be limited to: MAXIMUM { $c_{a,min}/c_{ac}$: c_{Na}/c_{ac} } where $c_{a,min}$ is the smallest fixed edge distance being modeled in the application and c_{Na} corresponds to an assumed projected distance from the center of the adhesive anchor element calculated per Equation (17.4.5.1d). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled c_{ac}: Value derived from testing per AC308/ACI 355.4 for the adhesive anchor system being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter c_{Na}.
Adhesive anchors	2h_{ef}									
Undercut anchors	2.5h_{ef}									
Torque-controlled expansion anchors	4h_{ef}									
Displacement-controlled expansion anchors	4h_{ef}									

Equations N_{ba}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering															
$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. Where analysis indicates cracking at service load levels, adhesive anchors shall be shown compliance for use in cracked concrete in accordance with ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{uncr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age of 21 days (e) Concrete temperature at time of installation shall be at least 50°F Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1] [2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	ACI 318 anchoring-to-concrete provisions for bond strength in tension require calculation of various modification factors corresponding to area of influence (A_{Na}/A_{Na0}), eccentricity (ψ_{ec,N_a}), edge distance (ψ_{ed,N_a}), and splitting (ψ_{cp,N_a}); and then multiplying these factors by what is termed the “basic bond strength in tension” (N_{ba}) to obtain a “nominal bond strength in tension” (N_a or N_{ag}). The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), and the anchor element geometry (πd_a and h_{ef}), where d_a corresponds to the nominal diameter of the anchor element and h_{ef} corresponds to the effective embedment depth that has been input into PROFIS Engineering for the selected anchor element. Equation (17.4.5.2) also includes a modification factor for lightweight concrete (λ_a). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist. Concrete is typically assumed to crack under normal service load conditions. If cracked concrete conditions are assumed, the characteristic bond stress for cracked concrete (τ_{cr}) is used to calculate N_{ba}. If uncracked concrete conditions are assumed, the characteristic bond stress for uncracked concrete (τ_{uncr}) is used to calculate N_{ba}. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR and are designated “$\tau_{k,cr}$”, corresponding to the characteristic bond stress in cracked concrete, and “$\tau_{k,uncr}$”, corresponding to the characteristic bond stress in uncracked concrete. The values given in Table 17.4.5.2 for “τ_{cr}” or “τ_{uncr}” are intended to be used as guide values in the absence of product-specific data. PROFIS Engineering uses the $\tau_{k,cr}$ and $\tau_{k,uncr}$ values given in the ICC-ES evaluation report for the adhesive anchor that has been selected to calculate N_{ba}. Although noted in the ICC-ESR as a “strength”, $\tau_{k,cr}$ and $\tau_{k,uncr}$ are stress parameters having units of psi. The parameter “$\alpha_{N,seis}$” is a seismic reduction factor derived from testing per AC308/ACI 354, and is also given in the anchor ICC-ESR. The PROFIS Engineering report includes $\alpha_{N,seis}$ as a parameter used to calculate N_{ba}. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxxx}$: Characteristic bond stress for cracked or uncracked concrete. $\alpha_{N,seis}$: Seismic modification factor d_a: Anchor element diameter h_{ef}: Effective embedment depth that has been selected for the anchor being modeled
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi													
Outdoor	Dry to fully saturated	175	200	650													
Indoor	Dry	110	300	1000													

Equations N_{ba} (continued)

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																		
$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$	Example: Example of a table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,cr}$ and $\tau_{k,uncl}$) and the seismic reduction value $\alpha_{N,seis}$. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncl}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncl}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncl}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_{ba} .
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in.)																																																																																																												
		3/8	1/2	5/8	3/4			7/8	1	1-1/4																																																																																																										
Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127																																																																																																										
Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)																																																																																																										
Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)																																																																																																										
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																										
Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)																																																																																																										
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																										
Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)																																																																																																										
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)																																																																																																										
Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0																																																																																																										

Variables $\tau_{k,c,unscr}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering															
$\tau_{k,c,unscr}$	17.4.5.1 where $c_{Na} = 10d_a \sqrt{\frac{\tau_{unscr}}{1100}} \quad (17.4.5.1d)$ and the constant 1100 carries the unit of lb/in². 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{unscr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age of 21 days (e) Concrete temperature at time of installation shall be at least 50°F Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1] [2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{unscr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> ^[1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{unscr} by 0.4. ^[2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{unscr} by 0.4.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{unscr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	The parameter “τ_{unscr}” corresponds to the characteristic bond stress in uncracked concrete. It is used to calculate the parameter “c_{Na}”, which is defined in ACI 318-14 Equation (17.4.5.1d). If uncracked concrete conditions are assumed, τ_{unscr} is also used to calculate the parameter “N_{ba}”, which is defined in ACI 318-14 Equation (17.4.5.2). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist; however, c_{Na} is always calculated using τ_{unscr} regardless of whether cracked or uncracked concrete conditions are assumed. N_{ba} can be calculated for either cracked or uncracked concrete conditions. PROFIS Engineering calculates c_{Na} and N_{ba} using the characteristic bond stress values given in the ICC-ESR for the adhesive anchor system. The ICC-ESR designates the ACI 318 parameter “τ_{unscr}” as “$\tau_{k,unscr}$” and the PROFIS Engineering report designates “τ_{unscr}” as “$\tau_{k,c,unscr}$”. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR. Values designated “$\tau_{k,unscr}$” in the ICC-ESR correspond to the characteristic bond stress in uncracked concrete. The values designated “τ_{unscr}” in ACI 318-14 Table 17.4.5.2 are intended to be used as guide values in the absence of product-specific data. When uncracked concrete conditions are assumed, PROFIS Engineering uses the $\tau_{k,unscr}$ values given in the ICC-ESR for adhesive anchor bond strength calculations. Although noted in the ICC-ESR as a “strength”, $\tau_{k,unscr}$ is stress parameter having units of psi. $\tau_{k,unscr}$-values in the ICC-ESR are relevant to testing in concrete having a compressive strength of 2500 psi. These values can be increased for compressive strengths 2500 psi < f'_c < 8000 psi using the factor noted in the bond strength table footnotes. PROFIS Engineering increases the $\tau_{k,unscr}$-values by this factor when concrete compressive strengths > 2500 psi are being modeled.
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{unscr} psi													
Outdoor	Dry to fully saturated	175	200	650													
Indoor	Dry	110	300	1000													

Variables $\tau_{k,c,uncr}$ (continued)

Variables	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																		
$\tau_{k,c,uncr}$	Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,cr}$ and $\tau_{k,uncr}$). 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For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.										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Variables $\tau_{k,c}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering															
$\tau_{k,c}$	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi_{da} h_{ef} \quad (17.4.5.2)$ The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{un-cr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1] [2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{un-cr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{un-cr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{un-cr} by 0.4.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{un-cr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	The parameter “τ_{cr}” corresponds to the characteristic bond stress in cracked concrete. If cracked concrete conditions are assumed, τ_{cr} is used to calculate the parameter “N_{ba}”, which is defined in ACI 318-14 Equation (17.4.5.2). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist. N_{ba} can be calculated for either cracked or uncracked concrete conditions. PROFIS Engineering calculates N_{ba} using the characteristic bond stress values given in the ICC-ESR for the adhesive anchor system. The ICC-ESR designates the ACI 318 parameter “τ_{cr}” as “$\tau_{k,cr}$” and the PROFIS Engineering report designates “τ_{cr}” as “$\tau_{k,c}$”. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR. Values designated “$\tau_{k,cr}$” in the ICC-ESR correspond to the characteristic bond stress in cracked concrete. The values designated “τ_{cr}” in ACI 318-14 Table 17.4.5.2 are intended to be used as guide values in the absence of product-specific data. When cracked concrete conditions are assumed, PROFIS Engineering uses the $\tau_{k,cr}$ values given in the ICC-ESR for adhesive anchor bond strength calculations. Although noted in the ICC-ESR as a “strength”, $\tau_{k,cr}$ is stress parameter having units of psi. $\tau_{k,cr}$-values in the ICC-ESR are relevant to testing in concrete having a compressive strength of 2500 psi. These values can be increased for compressive strengths 2500 psi < f'_c < 8000 psi using the factor noted in the bond strength table footnotes. PROFIS Engineering increases the $\tau_{k,cr}$-values by this factor when concrete compressive strengths > 2500 psi are being modeled.
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{un-cr} psi													
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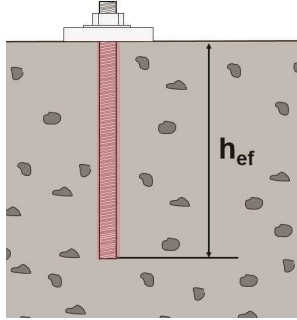
Variables $\tau_{k,c}$ (continued)

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Variables d_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																			
d_a	17.4.5.1 where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad (17.4.5.1d)$ and the constant 1100 carries the unit of lb/in². 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a T_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ Example: Example of a bond strength table in an ICC-ESR showing parameters that are dependent on the anchor element diameter. 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Therefore, d_a corresponds to the external diameter of an anchor element. d_a is used to calculate the parameter “c_{Na}”, which is defined in ACI 318-14 Equation (17.4.5.1d); and the parameter “N_{ba}”, which is defined in ACI 318-14 Equation (17.4.5.2). Other parameters such as effective embedment depth (h_{ef}), characteristic bond stress (τ_k) and $\alpha_{N,seis}$, which are used in bond strength calculations, are also dependent on the diameter of the anchor element being used. The PROFIS Engineering adhesive anchor portfolio permits bond strength calculations with the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Specialty anchor elements Information about these anchor element types is given in the ICC-ESR for an adhesive anchor system. PROFIS Engineering uses the anchor diameter parameter referenced in the ICC-ESR bond strength tables for an adhesive anchor system to calculate c_{Na} and N_{ba} for a specific anchor element. When design with a threaded rod or reinforcing bar is selected, PROFIS Engineering uses the nominal diameter of the anchor element to calculate c_{Na} and N_{ba}. When design with Hilti HIS-N and HIS-RN internally threaded inserts is selected, PROFIS Engineering uses the outside diameter of the insert to calculate c_{Na} and N_{ba}. Below are illustrations showing how the parameter d_a for calculating c_{Na} and N_{ba} can be defined for various anchor elements. The parameter “d_{hole}” noted in the illustrations corresponds to the diameter of the drilled hole into which the adhesive product and anchor element are inserted. reinforcing bar threaded rod internally threaded element Reference the Variables section of the PROFIS Engineering report for more information on: h_{ef}: Effective embedment depth $T_{k,c,uncr}$: Characteristic bond stress in uncracked concrete $T_{k,c}$: Characteristic bond stress in cracked concrete $\alpha_{N,seis}$: Seismic reduction factor Reference the Calculations section of the PROFIS Engineering report for more information on: c_{Na}: Projected distance from an adhesive anchor N_{ba}: Basic bond strength for a single adhesive anchor
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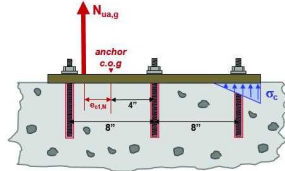
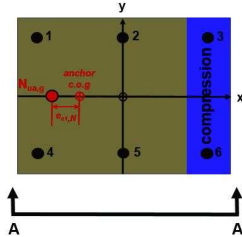
Variables h_{ef}

Variables	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																																	
h_{ef}	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi_{da} h_{ef} \quad (17.4.5.2)$ Example: Example of a table in an ICC-ESR showing effective embedment depth values ($h_{ef,min}$ and $h_{ef,max}$) for threaded rod elements used with an adhesive anchor system. 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Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), the anchor element geometry (π_{da} and h_{ef}), and a modification factor for lightweight concrete (λ_a). Adhesive anchor systems tested per the ICC-ES acceptance criteria AC308 can also include an additional seismic modification factor ($\alpha_{N,seis}$) when calculating N_{ba}. h_{ef} is defined as the "effective embedment depth of an anchor." This parameter corresponds to the embedded portion of the anchor that is "effective" in transferring tension load from the anchor into the concrete. ACI 318-14 Equation (17.4.5.2) includes h_{ef} for calculating N_{ba}. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive product-specific data that is used in ACI 318-14 bond strength calculations for an adhesive anchor system. Data derived from this testing, as well as some of the parameters used to develop this data, are provided in an ICC-ESR. The minimum effective embedment depth ($h_{ef,min}$) derived from this testing is specific to the anchor element (e.g. threaded rod, rebar, internally threaded insert), and to the adhesive product. AC308 limits the maximum effective embedment depth ($h_{ef,max}$) for adhesive anchor systems to a value of 20 times the anchor diameter ($20d_a$). For post-installed adhesive anchors, PROFIS Engineering permits users to input h_{ef} values that are within the embedment depth range given in the ICC-ESR for a specific anchor element, diameter, and adhesive product. post-installed adhesive anchor $h_{ef,min} < h_{ef} < h_{ef,max}$ where $h_{ef,min}$ and $h_{ef,max} (=20d_a)$ are given in the anchor ICC-ESR 
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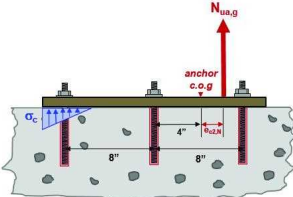
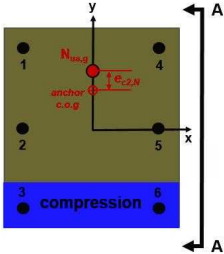
Variables $c_{a,min}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{a,min}$	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors..... 17.4.5.1 A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ 17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as $\text{If } c_{a,min} \geq c_{Na}, \text{ then } \psi_{ed,Na} = 1.0 \quad (17.4.5.4a)$ $\text{If } c_{a,min} < c_{Na}, \text{ then } \psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \quad (17.4.5.4b)$ 17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: $\text{If } c_{a,min} \geq c_{ac}, \text{ then } \psi_{cp,Na} = 1.0 \quad (17.4.5.5a)$ $\text{If } c_{a,min} < c_{ac}, \text{ then } \psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}} \quad (17.4.5.5b)$ but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0.	$c_{a,min}$ is defined as the “minimum distance from the center of an anchor shaft to the edge of concrete.” When one or more fixed edges are modeled in PROFIS Engineering, the report will show the smallest fixed edge as “$c_{a,min}$” in the Variables section. Excerpted ACI 318-14 anchoring-to-concrete provisions and equations that include $c_{a,min}$ for calculating bond strength in tension are shown to the left. Reference the parameters A_{Na} and A_{Na0} in the Equations section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Distance from the center of an anchor shaft to the edge of concrete in one direction (e.g. the x+ direction). For tension calculations, c_{a1} is the smallest fixed edge distance c_{a2}: Distance from the center of an anchor shaft to the edge of concrete in a direction perpendicular to c_{a1} (e.g. the y+ direction) Reference the parameters $\psi_{ed,Na}$ and $\psi_{cp,Na}$ in the Equations and Calculations sections of the PROFIS Engineering report for more information on how $c_{a,min}$ is used to calculate these parameters.

Variables $e_{c1,N}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c1,N}$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\Psi_{ec,Na}$ shall be calculated as: $\Psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\Psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\Psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\Psi_{ec,Na}$ in Eq. (17.4.5.1b).	$e_{c1,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the x direction. The value for $e_{c1,N}$ corresponds to the distance in the x direction of a resultant tension load from the centroid of anchors that are loaded in tension. PROFIS Engineering uses $e_{c1,N}$ to calculate the ACI 318 modification factor for tension eccentricity ($\Psi_{ec,Na}$), and designates this modification factor $\Psi_{ec1,Na}$ to indicate eccentricity is being considered in the x direction. PROFIS Engineering calculations for tension eccentricity with respect to the x direction are as follows: • Calculate a resultant tension load acting on the anchors • Calculate the distance in the x direction ($e_{c1,N}$) between this load and the centroid of the anchors loaded in tension • Calculate a modification factor for tension eccentricity ($\Psi_{ec1,Na}$) with respect to the x direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions, PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\Psi_{ec,N}$ modification factor for each direction ($\Psi_{ec1,Na}$ for eccentricity with respect to the x direction and $\Psi_{ec2,Na}$ for eccentricity with respect to the y direction). $\Psi_{ec1,Na}$ and $\Psi_{ec2,Na}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.5.3 Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the x direction when calculating bond strength in tension.  Section A-A $N_{u,ag}$ = resultant tension load $e_{c1,N} = 2.75"$ $c_{Na} = 10.65"$ $\Psi_{ec1,Na} = \frac{1}{\left(1 + \frac{2.75"}{10.65"}\right)} = 0.795$

Variables $e_{c2,N}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c2,N}$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\Psi_{ec,Na}$ shall be calculated as: $\Psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\Psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\Psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\Psi_{ec,Na}$ in Eq. (17.4.5.1b).	$e_{c2,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the y direction. The value for $e_{c2,N}$ corresponds to the distance in the y direction of a resultant tension load from the centroid of anchors that are loaded in tension. PROFIS Engineering uses $e_{c2,N}$ to calculate the ACI 318 modification factor for tension eccentricity ($\Psi_{ec,Na}$), and designates this modification factor $\Psi_{ec2,Na}$ to indicate eccentricity is being considered in the y direction. PROFIS Engineering calculations for tension eccentricity with respect to the y direction are as follows: • Calculate a resultant tension load acting on the anchors • Calculate the distance in the y direction ($e_{c2,N}$) between this load and the centroid of the anchors loaded in tension • Calculate a modification factor for tension eccentricity ($\Psi_{ec2,Na}$) with respect to the y direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions, PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\Psi_{ec,N}$ modification factor for each direction ($\Psi_{ec1,Na}$ for eccentricity with respect to the x direction and $\Psi_{ec2,Na}$ for eccentricity with respect to the y direction). $\Psi_{ec1,Na}$ and $\Psi_{ec2,Na}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.5.3 Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the y direction when calculating bond strength in tension.  Section A-A $N_{u,ag}$ = resultant tension load $e_{c2,N} = 1.67"$ $c_{Na} = 10.65"$ $\Psi_{ec2,Na} = \frac{1}{\left(1 + \frac{1.65"}{10.65"}\right)} = 0.864$

Variables c_{ac}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering								
c_{ac}	17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,Na} = \frac{c_{a,min}}{c_{Na}}$ (17.4.5.5b) but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0. 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors</td><td>.2h_{ef}</td></tr><tr><td>Undercut anchors</td><td>.2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors</td><td>.4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchors</td><td>.4h_{ef}</td></tr></table> Example of critical edge distance requirements given in an adhesive anchor approval. Reference ICC-ESR-3187 Section 4.1.10.2. 4.1.10.2 Threaded Rod, Steel Reinforcing Bars, and Hilti HIS-N and HIS-RN Inserts: The modification factor $\psi_{cp,Na}$ must be determined in accordance with ACI 318-14 17.4.5.5 or ACI 318-11 D.5.5 as applicable, except as noted below. For all cases where $c_{Na}/c_{ac} < 1.0$, $\psi_{cp,Na}$ determined from ACI 318-14 Eq. 17.4.5.5b or ACI 318-11 Eq. D-27, as applicable, need not be taken less than c_{Na}/c_{ac}. For all other cases $\psi_{cp,Na}$ shall be taken as 1.0. The critical edge distance c_{ac} must be calculated according to Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11, in lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6 as applicable. $c_{ac} = h_{ef} \left(\frac{\tau_{k,uncr}}{1160} \right)^{0.4} * \left[3.1 - 0.7 \frac{h}{h_{ef}} \right]$ (Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11) where $\left[\frac{h}{h_{ef}} \right]$ need not be taken as larger than 2.4; and $\tau_{k,uncr}$ is the characteristic bond strength in uncracked concrete, h is the member thickness, and h_{ef} is the embedment depth. $\tau_{k,uncr}$ need not be taken greater than: $\tau_{k,uncr} = \frac{k_{uncr}}{\pi_d} \sqrt{\frac{h_{ef} f'_c}{c}} \quad \text{Eq. (4-1)}$	Adhesive anchors	.2h_{ef}	Undercut anchors	.2.5h_{ef}	Torque-controlled expansion anchors	.4h_{ef}	Displacement-controlled expansion anchors	.4h_{ef}	$\psi_{cp,Na}$ is a modification factor that considers splitting failure when calculating the nominal bond strength in tension (N_a or N_{ag}) for an adhesive anchor system. $\psi_{cp,Na}$ is only considered when designing adhesive anchors installed in uncracked concrete. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing anchors. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels.” The parameter c_{ac} that is used to calculate $\psi_{cp,Na}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” The c_{ac}-values for post-installed anchors noted in ACI 318-14 Section 17.7.6 are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 includes provisions for deriving the characteristic bond stress in uncracked concrete ($\tau_{k,uncr}$), which can be used in an equation to calculate c_{ac}. This equation is typically given in the adhesive anchor ICC-ESR. The equation shown to the left is given in ICC-ESR-3187 and is used to calculate c_{ac}. Key parameters included in the equation are: - Anchor effective embedment depth (h_{ef}) for the application - Characteristic bond stress in uncracked concrete ($\tau_{k,uncr}$) derived from the AC308/ACI 355.4 testing. $\tau_{k,uncr}$ is specific to the anchor element and concrete conditions being modeled. $\tau_{k,uncr}$-values are given in the ICC-ESR bond strength tables - Concrete thickness (h) being modeled for the application The c_{ac} provisions in an ICC-ESR can also include a limiting value for $\tau_{k,uncr}$. PROFIS Engineering calculates this limiting value and checks it against the relevant $\tau_{k,uncr}$-value from the ICC-ESR bond strength table. PROFIS Engineering uses the smaller of (a) the limiting $\tau_{k,uncr}$-value or (b) the $\tau_{k,uncr}$-value from the bond strength table to calculate c_{ac}. PROFIS Engineering always uses the provisions given in the adhesive anchor ICC-ESR to determine the c_{ac}-value that will be used to calculate $\psi_{cp,Na}$. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter $\psi_{cp,Na}$. Reference the Variables section of the PROFIS Engineering report for more information on the parameter h_{ef}. Reference the Variables section for bond strength in the PROFIS Engineering report for more information on the parameter $\tau_{k,uncr}$.
Adhesive anchors	.2h_{ef}									
Undercut anchors	.2.5h_{ef}									
Torque-controlled expansion anchors	.4h_{ef}									
Displacement-controlled expansion anchors	.4h_{ef}									

Variables λ_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure 1.0 λ Expansion and adhesive anchor concrete failure 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2). 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ ^{[1] [2]} <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85 ^[1]</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33</td><td>0.85 to 1 ^[2]</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> 1 Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. 2 Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}}{6.7 / f_{cm}^{1.5}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the work. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ^[1]	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ^[2]	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	ACI 318 anchoring-to-concrete provisions consider the following tension failure modes with respect to adhesive anchor systems: - Steel failure in tension - Concrete breakout failure in tension - Bond failure in tension λ_a is a modification factor for lightweight concrete that is used to calculate various parameters for design with ACI 318 anchoring-to-concrete provisions. ACI 318-14 Section 17.2.6 references how λ_a is calculated for various anchoring-to-concrete failure modes. When considering concrete breakout failure in tension for an adhesive anchor application, the λ_a-value that is calculated equals 0.8λ. This λ_a-value would be used to calculate the basic concrete breakout in tension (N_b) for the adhesive anchor being designed. Per Section 17.2.6, λ_a is also used to calculate the “basic bond strength in tension” (N_{ba}) per Eq. (17.4.5.2), and the λ_a-value calculated for bond failure equals 0.6λ. Generally speaking, with respect to concrete failure modes, ACI 318 applies a multiplier designated “λ” to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete.” The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to “anchoring-to-concrete” calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ, determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the anchor failure mode being considered, to obtain the parameter λ_a. Therefore, when designing adhesive anchors with ACI 318 anchoring-to-concrete provisions, a lightweight concrete multiplier ($\lambda_a = 0.8\lambda$) is applied to the parameter $\sqrt{f'_c}$ when considering concrete breakout failure, and a lightweight concrete multiplier ($\lambda_a = 0.6\lambda$) is applied to the parameter “τ” corresponding to the characteristic bond stress (τ_{cr} for cracked concrete or τ_{unscr} for uncracked concrete) when considering bond failure. Post-installed adhesive anchor systems can be shown compliance to under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a-provisions for a specific adhesive anchor system are derived from this testing and will be given in the ICC-ESR for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. When modeling an adhesive anchor application in PROFIS Engineering, the λ_a-value (or provisions) for concrete breakout failure referenced in the adhesive anchor ICC-ESR is used to calculate N_b, and the λ_a-value (or provisions) for bond failure referenced in the adhesive anchor ICC-ESR is used to calculate N_{ba}. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. Per ACI 318 provisions for determining λ_a, when designing adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.8 to obtain the λ_a-value used to calculate N_b. Per ACI 318 provisions for determining λ_a, when designing adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.6 to obtain the λ_a-value used to calculate N_{ba}. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameters N_b and N_{ba}.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ^[1]																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ^[2]																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

Variables $\alpha_{N,seis}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																			
$\alpha_{N,seis}$	ACI 318-14 equation for calculating N_{ba}: 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ PROFIS Engineering equation for calculating N_{ba}: $N_{ba} = \lambda_a \tau_{k,c} \alpha_{N,seis} \pi d_a h_{ef}$ Example: Example of a table in an ICC-ESR showing the seismic modification factor $\alpha_{N,seis}$. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 178°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	$\alpha_{N,seis}$ is a seismic modification factor that is used to calculate the basic bond strength of an adhesive anchor (N_{ba}). Values for $\alpha_{N,seis}$ are derived from testing per the ICC-ES acceptance criteria AC308. $\alpha_{N,seis}$-values are specific to the adhesive product, the anchor element being used with that product, and the anchor element diameter. Values for $\alpha_{N,seis}$ are given in the ICC-ESR for an adhesive anchor system. The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), and the anchor element geometry (πd_a and h_{ef}), where d_a corresponds to the nominal diameter of the anchor element and h_{ef} corresponds to the effective embedment depth that has been input into PROFIS Engineering for the selected anchor element. Calculation of N_{ba} also includes a modification factor for lightweight concrete (λ_a). Adhesive anchor systems can be shown compliance to under the International Building Code (IBC) via testing per AC308. AC308 references the ACI test standard for qualifying adhesive anchor systems (ACI 355.4), but ACI 355.4 does not include any provisions for determining $\alpha_{N,seis}$. Since ACI 355.4 does not reference $\alpha_{N,seis}$, ACI 318 anchoring-to-concrete provisions do not reference $\alpha_{N,seis}$. However, since AC308 does include provisions for determining $\alpha_{N,seis}$, adhesive anchor systems shown compliance to per AC308 to receive recognition under the IBC include $\alpha_{N,seis}$ as a parameter for calculating N_{ba}. PROFIS Engineering uses the $\alpha_{N,seis}$-values given in the ICC-ESR for an adhesive anchor system to calculate N_{ba}. The PROFIS Engineering report therefore shows $\alpha_{N,seis}$ in the Variables section, and as a parameter for calculating N_{ba} in the Equations section. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxxx}$: Characteristic bond stress for cracked or uncracked concrete d_a: Anchor element diameter h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
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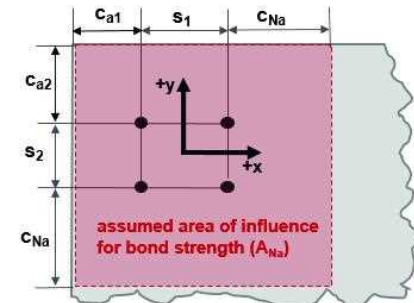
Calculations c_{Na}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}}$	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors.....A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. where $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ $c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². 17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as: $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ 17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as: If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) If $c_{a,min} < c_{Na}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b) 17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}}$ (17.4.5.5b) but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0. Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,uncr}$) that could be used to calculate c_{Na} for a given anchor diameter (d_a) using Eq. (17.4.5.1d).	ACI 318-14 Chapter 17 bond strength calculations are predicated on the parameter "c_{Na}", which is defined in Chapter 2 as the "projected distance from the center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor." c_{Na} is calculated per Equation (17.4.5.1d). The parameter "d_a" corresponds to the diameter of the anchor element selected for the PROFIS Engineering application being modeled. The parameter "τ_{uncr}" corresponds to the characteristic bond stress in uncracked concrete of the adhesive product selected for the PROFIS Engineering application being modeled. The modification factor A_{Na} accounts for the area of influence assumed to develop with respect to bond failure, for the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. Per the provisions for A_{Na} given in Section 17.4.5.1, PROFIS Engineering limits the geometry used to define A_{Na} to a maximum projected distance from an anchor of c_{Na}. c_{Na} is also used to calculate the following bond strength parameters: • A_{Na0}: Modification factor for the idealized area of influence assumed to develop in concrete, with respect to bond failure, for a single anchor without any edge influences. Reference Equation (17.4.5.1c) • $\psi_{ec,Na}$: Modification factor for an eccentric tension load acting on a group of anchors. Reference Section 17.4.5.3 • $\psi_{ed,Na}$: Modification factor for a fixed edge distance less than c_{Na}. Reference Section 17.4.5.4 • $\psi_{cp,Na}$: Modification factor to consider splitting failure. Reference Section 17.4.5.5 Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: d_a: Diameter of anchor element τ_{uncr}: Characteristic bond stress of an adhesive anchor in uncracked concrete Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence modification factor A_{Na0}: Idealized area of influence modification factor for a single anchor $\psi_{ec,Na}$: Modification factor for tension eccentricity $\psi_{ed,Na}$: Modification factor for edge distance $\psi_{ec,Na}$: Modification factor for splitting

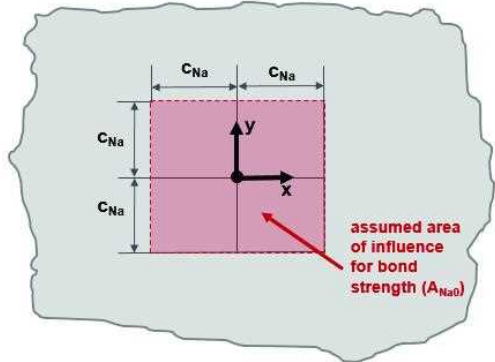
Calculations c_{Na} (continued)

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Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0																																																																																																																														

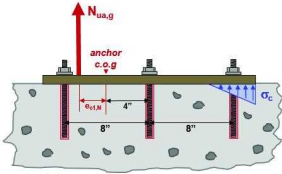
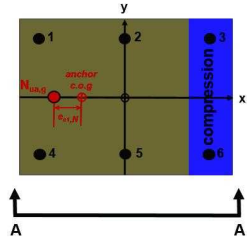
Calculations A_{Na}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																															
A_{Na}	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors..... where and the constant 1100 carries the unit of lb/in². $c_{Na} = 10d_a \sqrt{\frac{T_{unconf}}{1100}} \quad 17.4.5.1d$ Example: Example of minimum edge distance and spacing requirements given in an adhesive anchor system approval. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal Rod Diameter (in).</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th></tr><tr><td>Min. anchor spacing</td><td>s_{min}</td><td>in.</td><td>1-7/8</td><td>2-1/2</td><td>3-1/8</td><td>3-3/4</td><td>4-3/8</td><td>5</td><td>5-5/8</td></tr><tr><td>Min. edge distance (Threaded rods)</td><td>c_{min}</td><td>in.</td><td>1-3/4</td><td>1-3/4</td><td>2</td><td>2-1/8</td><td>2-1/4</td><td>2-3/4</td><td>n/a</td></tr><tr><td>Min. edge distance (Reinforcing bars)</td><td>c_{min}</td><td>-</td><td colspan="7">5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in).							3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	Min. anchor spacing	s_{min}	in.	1-7/8	2-1/2	3-1/8	3-3/4	4-3/8	5	5-5/8	Min. edge distance (Threaded rods)	c_{min}	in.	1-3/4	1-3/4	2	2-1/8	2-1/4	2-3/4	n/a	Min. edge distance (Reinforcing bars)	c_{min}	-	5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances							A_{Na} is a modification factor that accounts for the area of influence assumed to develop in concrete, with respect to bond failure, when a tension load is applied to a single adhesive anchor or a group of adhesive anchors. A_{Na} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Na} is defined by projected distances from the anchors that are in tension. The maximum projected distance from an anchor that is considered when calculating A_{Na} is limited to c_{Na}, where c_{Na} is defined by Equation (17.4.5.1d) in Section 17.4.5.1. Therefore, the maximum edge distance parameter used to calculate A_{Na} equals c_{Na}, and the maximum spacing parameter used to calculate A_{Na} equals a projected distance of c_{Na} on either side of the anchor; or $2.0c_{Na}$. The figure below illustrates how A_{Na} is calculated for a group of four anchors in tension with fixed edge distances in the -x and +y directions equal to c_{a1} and c_{a2}, respectively; and spacing parameters in the x and y directions equal to s_1 and s_2, respectively. Both c_{a1} and c_{a2} are assumed to be less than the value for c_{Na} calculated per Equation (17.4.5.1d). When modeling the parameter A_{Na}, if no fixed edge is present for a given direction, or the fixed edge distance is greater than the value calculated for c_{Na}, the maximum projected distance from an anchor(s) with respect to that direction is assumed to equal c_{Na}. For the application illustrated below, there are no fixed edges in the +x and -y directions; therefore, the maximum projected distance in those directions that is used to model A_{Na} equals c_{Na}. Since the maximum projected distance from an anchor that is considered when modeling A_{Na} equals c_{Na}, anchors spaced greater than $2.0c_{Na}$ from one another would not be considered to act as a group with respect to that spacing. For the illustration below, both s_1 and s_2 are assumed to be less than $2.0c_{Na}$.  $A_{Na} = (c_{a1} + s_1 + c_{Na})(c_{a2} + s_2 + c_{Na})$ where: $c_{min} < (c_{a1} \text{ and } c_{a2}) < c_{Na}$ $s_{min} < (s_1 \text{ and } s_2) < 2.0c_{Na}$ Adhesive anchor values for c_{min} and s_{min} are established via testing per the ICC-ES acceptance criteria AC308, and the ACI test standard ACI 355.4. These values are given in the ICC-ESR for the adhesive anchor system. Reference the Equations more information on A_{Na}. Reference the Calculations section for more information on c_{Na}.
DESIGN INFORMATION	Symbol				Units	Nominal Rod Diameter (in).																																											
		3/8 or #3	1/2 or #4	5/8 or #5		3/4 or #6	7/8 or #7	1 or #8	#9																																								
Min. anchor spacing	s_{min}	in.	1-7/8	2-1/2	3-1/8	3-3/4	4-3/8	5	5-5/8																																								
Min. edge distance (Threaded rods)	c_{min}	in.	1-3/4	1-3/4	2	2-1/8	2-1/4	2-3/4	n/a																																								
Min. edge distance (Reinforcing bars)	c_{min}	-	5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances																																														

Calculations A_{Na0}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																			
$A_{Na0} = (2c_{Na})^2$	17.4.5.1 A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{\tau_{k,uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,uncr}$) that could be used to calculate c_{Na} for a given anchor diameter (d_a) using Eq. (17.4.5.1d). ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 178°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	A_{Na0} is a modification factor that accounts for the area of influence assumed to develop in concrete, with respect to bond failure, when a tension load is applied to a single adhesive anchor without the influence of any fixed edges. A_{Na0} is calculated with the parameter "c_{Na}", which is defined in ACI 318-14 Chapter 2 as the "projected distance from the center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor". c_{Na} is a calculated value, and is calculated per ACI 318-14 Equation (17.4.5.1d). The geometry for A_{Na0} is defined by a projected distance of c_{Na} from the anchor, on either side of the anchor, in both the x and y directions. The calculated value for A_{Na0} is always equal to $(2c_{Na})^2$, and c_{Na} is always calculated per Equation (17.4.5.1c) when designing with the anchoring-to-concrete provisions of ACI 318-14. The figure below illustrates how A_{Na0} is calculated.  $A_{Na0} = (c_{Na} + c_{Na})(c_{Na} + c_{Na}) = (2c_{Na})^2$ Reference the Equations and Calculations section of the PROFIS Engineering report for more information on c_{Na}. Reference the Equations section of the PROFIS Engineering report for more information on A_{Na0}.
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in.)																																																																																																													
		3/8	1/2	5/8	3/4			7/8	1	1-1/4																																																																																																											
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	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																											
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Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0																																																																																																											

Calculations $\psi_{ec1,Na}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,Na}$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as: $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	When calculating nominal bond strength for a group of adhesive anchors in tension (N_{ag}), ACI 318 anchoring-to-concrete provisions designate the modification factor for tension eccentricity “$\psi_{ec,Na}$”. Per Section 17.4.5.3, tension eccentricity can be considered with respect to the x and y directions. PROFIS Engineering designates the modification factor for tension eccentricity in the x direction “$\psi_{ec1,Na}$”. The parameter $e_{c1,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the x direction using Eq. (17.4.5.3). PROFIS Engineering calculations for tension eccentricity with respect to the x direction are as follows: • Calculate a resultant tension load acting on the anchors • Calculate the distance in the x direction ($e_{c1,N}$) between this load and the centroid of the anchors loaded in tension • Calculate a modification factor for tension eccentricity ($\psi_{ec1,Na}$) with respect to the x direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,Na}$ modification factor for each direction ($\psi_{ec1,Na}$ for eccentricity with respect to the x direction and $\psi_{ec2,Na}$ for eccentricity with respect to the y direction). $\psi_{ec1,Na}$ and $\psi_{ec2,Na}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.5.3. Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the x direction when calculating bond strength in tension.  Section A-A $N_{u,ag}$ = resultant tension load $e_{c1,N} = 2.75"$ $c_{Na} = 10.65"$ $\psi_{ec1,Na} = \frac{1}{\left(1 + \frac{2.75"}{10.65"}\right)} = 0.795$

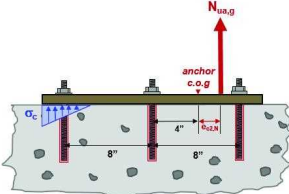
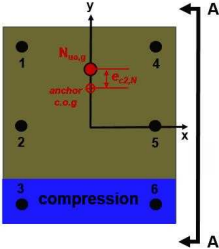
Calculations $\psi_{ec1,Na}$ (continued)

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,Na}$		Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec1,Na}$: Modification factor for tension eccentricity with respect to the x direction Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec2,Na}$: Modification factor for tension eccentricity with respect to the y direction

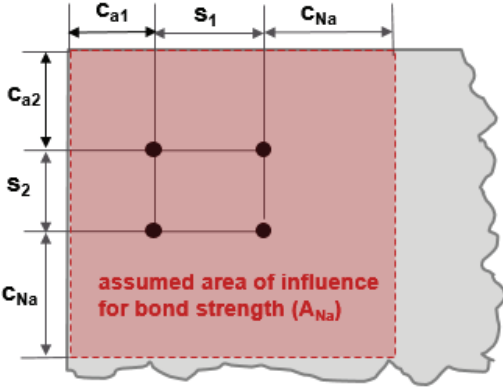
Calculations $\psi_{ec2,Na}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,Na}$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{C_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	When calculating nominal bond strength for a group of adhesive anchors in tension (N_{ag}), ACI 318 anchoring-to-concrete provisions designate the modification factor for tension eccentricity "$\psi_{ec,Na}$". Per Section 17.4.5.3, tension eccentricity can be considered with respect to the x and y directions. PROFIS Engineering designates the modification factor for tension eccentricity in the y direction "$\psi_{ec2,Na}$". The parameter $e_{c2,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the y direction using Eq. (17.4.5.3). PROFIS Engineering calculations for tension eccentricity with respect to the y direction are as follows: • Calculate a resultant tension load acting on the anchors • Calculate the distance in the y direction ($e_{c2,N}$) between this load and the centroid of the anchors loaded in tension • Calculate a modification factor for tension eccentricity ($\psi_{ec2,Na}$) with respect to the y direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,Na}$ for eccentricity with respect to the x direction and $\psi_{ec2,Na}$ for eccentricity with respect to the y direction). $\psi_{ec1,Na}$ and $\psi_{ec2,Na}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.5.3.

Calculations $\psi_{ec2,Na}$ (continued)

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,Na}$		Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the y direction when calculating bond strength in tension.  Section A-A $N_{u0,g}$ = resultant tension load $e_{c2,N} = 1.67"$ $c_{Na} = 10.65"$ $\psi_{ec2,Na} = \frac{1}{\left(1 + \frac{1.67"}{10.65"}\right)} = 0.864$ Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec2,Na}$: Modification factor for tension eccentricity with respect to the y direction Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec1,Na}$: Modification factor for tension eccentricity with respect to the x direction

Calculations $\psi_{ed,Na}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \leq 1.0$	17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) If $c_{a,min} < c_{Na}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b)	$\psi_{ed,Na}$ is a modification factor that is used to account for fixed edge distances less than c_{Na}, where c_{Na} corresponds to a projected distance from the center of the adhesive anchor element being modeled in PROFIS Engineering. The illustration below shows how the assumed area of influence (A_{Na}) would be defined for an adhesive anchoring application being modeled with two fixed edges (c_{a1} and c_{a2}) that are both less than c_{Na}, and with c_{a1} being less than c_{a2}. The smallest edge distance (c_{a1}) corresponds to the parameter $c_{a,min}$, and would be used to calculate the modification factor $\psi_{ed,Na}$.  $\psi_{ed,Na} = 0.7 + 0.3 (c_{a1} / c_{Na})$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameter: $c_{a,min}$: Parameter for the smallest fixed edge being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the following parameter: c_{Na}: Projected distance from an adhesive anchor

Calculations $\psi_{cp,Na}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{cp,Na} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}} \right) \leq 1.0$	17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}}$ (17.4.5.5b) but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0. $c_{Na} = 10d_a \sqrt{\frac{\tau_{k,uncr}}{1100}}$ (17.4.5.1d) 17.4.5.1 where and the constant 1100 carries the unit of lb/in². 17.4.5.2 For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: Adhesive anchors. $2h_{ef}$ ICC-ESR-3187 4.1.10.2 Threaded Rod, Steel Reinforcing Bars, and Hilti HIS-N and HIS-RN Inserts: The modification factor $\psi_{cp,Na}$ must be determined in accordance with ACI 318-14 17.4.5.5 or ACI 318-11 D.5.5 as applicable, except as noted below. For all cases where $c_{Na}/c_{ac} < 1.0$, $\psi_{cp,Na}$ determined from ACI 318-14 Eq. 17.4.5.5b or ACI 318-11 Eq. D-27, as applicable, need not be taken less than c_{Na}/c_{ac}. For all other cases $\psi_{cp,Na}$ shall be taken as 1.0. The critical edge distance c_{ac} must be calculated according to Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11, in lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6 as applicable. $c_{ac} = h_{ef} \left(\frac{\tau_{k,uncr}}{1160} \right)^{0.4} * \left[3.1 - 0.7 \frac{h}{h_{ef}} \right]$ (Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11) where $\left[\frac{h}{h_{ef}} \right]$ need not be taken as larger than 2.4; and $\tau_{k,uncr}$ is the characteristic bond strength in uncracked concrete, h is the member thickness, and h_{ef} is the embedment depth. $\tau_{k,uncr}$ need not be taken greater than: $\tau_{k,uncr} = \frac{k_{uncr} \sqrt{h_{ef} f'_c}}{\pi d}$ Eq. (4-1)	$\psi_{cp,Na}$ is a modification factor that considers splitting failure when calculating the nominal bond strength in tension (N_a or N_{ag}). Since ACI 318 anchoring-to-concrete provisions do not specifically consider concrete splitting as a failure mode, splitting is addressed through a modification factor. The parameter $\psi_{cp,Na}$ is only considered when designing adhesive anchors installed in uncracked concrete. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} used to calculate $\psi_{cp,Na}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” $\psi_{cp,Na}$ is not calculated if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}, or if cracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR ACI 318-14 Section 17.7.6 provides c_{ac} values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the provisions given in the adhesive anchor ICC-ESR to calculate a c_{ac} value. This value is used to calculate $\psi_{cp,Na}$ for the anchor element being modeled. The value for $\psi_{cp,Na}$ that PROFIS Engineering calculates will be limited to MAXIMUM $\{c_{a,min}/c_{ac} : c_{Na}/c_{ac}\}$ where $c_{a,min}$ is the smallest fixed edge distance being modeled in the application, and c_{Na} corresponds to an assumed projected distance from the center of the adhesive anchor element being modeled. When design per ACI 318-14 has been selected, PROFIS Engineering calculates c_{Na} per Equation (17.4.5.1d). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled c_{ac}: Value derived from testing per AC308/ACI 355.4 for the adhesive anchor system being modeled $\tau_{k,c,uncr}$: Characteristic bond stress for uncracked concrete conditions Reference the Calculations section of the PROFIS Engineering report for more information on the parameter c_{Na}. Reference the Variables section of the PROFIS Engineering report for Concrete Breakout in Tension for more information on the parameters k_{uncr}, h_{ef}, and f'_c. These parameters are used to calculate the limiting value for the characteristic bond stress in uncracked concrete, which is shown as “$\tau_{k,uncr}$” in the ICC-ESR-3187 Eq. (4-1) to the left.

Calculations N_{ba}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering															
$N_{ba} = \lambda_a \tau_{k,c} \alpha_{N,seis} \pi_{da} h_{ef}$	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi_{da} h_{ef} \quad (17.4.5.2)$ The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. Where analysis indicates cracking at service load levels, adhesive anchors shall be shown compliance for use in cracked concrete in accordance with ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{uncr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age of 21 days (e) Concrete temperature at time of installation shall be at least 50°F Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1] [2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4. Example: Example of a table in an ICC-ESR showing characteristic bond stress values (τ_{kcr} and $\tau_{k,uncr}$) and the seismic reduction value $\alpha_{N,seis}$	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. It is used to calculate the nominal bond strength in tension (N_a or N_{ag}). Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), and the anchor element geometry (π_{da} and h_{ef}), where d_a corresponds to the nominal diameter of the anchor element and h_{ef} corresponds to the effective embedment depth that has been input into PROFIS Engineering for the selected anchor element. If cracked concrete conditions are being modeled, PROFIS Engineering uses the characteristic bond stress for cracked concrete (τ_{cr}) to calculate N_{ba}. If uncracked concrete conditions are being modeled, PROFIS Engineering uses the characteristic bond stress for uncracked concrete (τ_{uncr}) to calculate N_{ba}. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR and are designated “$\tau_{k,cr}$”, corresponding to the characteristic bond stress in cracked concrete, and “$\tau_{k,uncr}$”, corresponding to the characteristic bond stress in uncracked concrete. The values given in ACI 318-14 Table 17.4.5.2 for “τ_{cr}” or “τ_{uncr}” are intended to be used as guide values in the absence of product-specific data. PROFIS Engineering calculates N_{ba} with the $\tau_{k,cr}$ and $\tau_{k,uncr}$ values given in the adhesive anchor ICC-ESR. Although noted in the ICC-ESR as a “strength”, $\tau_{k,cr}$ and $\tau_{k,uncr}$ are stress parameters having units of psi. The parameter “$\alpha_{N,seis}$” is a reduction factor derived from testing per AC308/ACI 354. It is used to calculate N_{ba} when seismic load conditions are assumed. PROFIS Engineering uses the $\alpha_{N,seis}$-values given in the adhesive anchor ICC-ESR to calculate N_{ba}. The parameter “λ_a” is a lightweight concrete modification factor. Provisions for determining λ_a are given in the adhesive anchor ICC-ESR. PROFIS Engineering uses the λ_a-provisions given in the adhesive anchor ICC-ESR to calculate N_{ba}.
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi													
Outdoor	Dry to fully saturated	175	200	650													
Indoor	Dry	110	300	1000													

Calculations N_{ba} (continued)

Calculations	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																		
$N_{ba} = \lambda_a \tau_{k,c} \alpha_{N,seis} \pi d_a h_{ef}$	Example: Example of a table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,cr}$ and $\tau_{k,uncl}$) and the seismic reduction value $\alpha_{N,seis}$. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncl}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncl}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncl}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.										DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxxx}$: characteristic bond stress for cracked or uncracked concrete. $\alpha_{N,seis}$: Seismic modification factor d_a: Anchor element diameter h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Equations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)																																																																																																																									
				3/8	1/2	5/8	3/4	7/8	1	1-1/4																																																																																																																			
Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127																																																																																																																			
Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)																																																																																																																			
Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)																																																																																																																			
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																																			
Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)																																																																																																																			
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																																			
Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)																																																																																																																			
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncl}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)																																																																																																																			
Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0																																																																																																																			

Results N_a

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$	17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$	ACI 318 anchoring-to-concrete provisions for the nominal bond strength of a single anchor (N_a) require calculation of various modification factors corresponding to area of influence (A_{Na}/A_{Na0}), edge distance ($\psi_{ed,Na}$), and splitting ($\psi_{cp,Na}$); and then multiplying these factors by what is termed the “basic bond strength in tension” (N_{ba}) to obtain a “nominal bond strength in tension” (N_a). Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic bond strength in tension Reference the Equations section of the PROFIS Engineering report for more information on N_a.

Results ϕN_a

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕN_a	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading Table 17.3.1.1 Failure Mode Bond Strength of Adhesive Anchor in Tension Single Anchor $\phi N_a \geq N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_a) against a factored tension load (N_{ua}). Reference the Equations section of the PROFIS Engineering report for more information on: ϕN_a: Design bond strength in tension Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{bond}: Strength reduction factor for bond failure $\phi_{seismic}$: Strength reduction factor for seismic tension N_a: Design bond strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Results N_{ag}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$	17.4.5.1 The nominal bond strength in tension, ... N_{ag} of a group of adhesive anchors, shall not exceed: (b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$	ACI 318 anchoring-to-concrete provisions for the nominal bond strength of a group of adhesive anchors (N_{ag}) require calculation of various modification factors corresponding to area of influence (A_{Na}/A_{Na0}), eccentricity ($\psi_{ec,Na}$), edge distance ($\psi_{ed,Na}$), and splitting ($\psi_{cp,Na}$); and then multiplying these factors by what is termed the “basic bond strength in tension” (N_{ba}) to obtain a “nominal bond strength in tension” (N_{ag}). Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ec,Na}$: Tension modification factor for eccentricity $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic bond strength in tension Reference the Equations section of the PROFIS Engineering report for more information on N_{ag}.

Results ϕN_{ag}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕN_{ag}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Bond Strength in Tension Anchors as a Group $\phi N_{ag} > N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{ag}) against a factored tension load (N_{ua}). Reference the Equations section of the PROFIS Engineering report for more information on: ϕN_{ag}: Design bond strength in tension Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{bond}: Strength reduction factor for bond failure $\phi_{seismic}$: Strength reduction factor for seismic tension N_{ag}: Design bond strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Results ϕ_{bond}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
ϕ_{bond}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table> 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ 17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2.	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for bond failure in tension require calculation of a nominal bond strength (N_a or N_{ag}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_a or ϕN_{ag}). ϕ-factors are relevant to static and seismic load conditions. PROFIS Engineering designates the ϕ-factor corresponding to bond failure for static load conditions “ϕ_{bond}”. Adhesive anchor systems can be shown compliance to under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. PROFIS Engineering uses the ϕ-factors derived from AC308/ACI 355.4 testing, as given in the ICC-ESR for the adhesive anchor system, to calculate design bond strength (ϕN_a or ϕN_{ag}). These ϕ-factors are relevant to the condition of the concrete in the drilled hole into which the adhesive and anchor element are inserted. Possible drilled hole installation conditions include dry, water saturated, water filled, and underwater (submerged). Reference the ICC-ESR for ϕ-factors that are specific to these conditions. PROFIS Engineering uses the ϕ-factor corresponding to the drilled hole condition that has been selected to calculate ϕN_a or ϕN_{ag}, and designates this parameter “ϕ_{bond}” in the Results section of the report. PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions “ϕ_{seismic}”. The provisions given in ACI 318-14 Section 17.3.1.2 are used to calculate a bond strength ($0.55\phi N_{ba}$) for a single anchor, which is checked against the highest factored sustained tension load ($N_{ua,s}$) determined to be acting on a single anchor within the anchorage. Equations, variables, calculations and results relevant to this sustained load check are given in the PROFIS Engineering report section titled Sustained Tension Load Bond Strength. PROFIS Engineering uses the ϕ-factor corresponding to the drilled hole condition that has been selected (dry, water saturated, water filled, submerged) to calculate $0.55\phi N_{ba}$ and designates this parameter “ϕ_{bond}” in the Results section of the Sustained Tension Load Bond Strength section of the report.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
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Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Results ϕ_{bond} (continued)

Results	ACI 318-14 Chapter 17 Provision											Comments for PROFIS Engineering																																																																																																																																						
Φ_{bond}	Example: Example of an ICC-ESR showing strength reduction factors (Φ-factors) for bond strength. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{\text{ef,min}}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{\text{ef,max}}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncl}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncl}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncl}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td rowspan="2">Permissible Installation Conditions</td><td rowspan="2">Dry and water saturated concrete</td><td>Anchor Category</td><td colspan="8">1</td></tr><tr><td>Φ_d, Φ_{ws}</td><td colspan="8">0.65</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.											DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{\text{ef,min}}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{\text{ef,max}}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$T_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$T_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$T_{k,uncl}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Permissible Installation Conditions	Dry and water saturated concrete	Anchor Category	1								Φ_d, Φ_{ws}	0.65								Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	Reference the Calculations section of the PROFIS Engineering Bond Strength section of the report for more information on: N_{ba}: Basic bond strength Reference the Results section of the PROFIS Engineering Bond Strength section of the report for more information on the following parameters: N_a or N_{ag}: Nominal bond strength ΦN_a or ΦN_{ag}: Design bond strength Φ_{seismic}: Strength reduction factor for seismic tension Reference the PROFIS Engineering report section titled Sustained Tension Load Bond Strength for more information about the sustained load check referenced in Section 17.3.1.2.
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)																																																																																																																																														
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	Characteristic bond strength in uncracked concrete	$T_{k,uncl}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																																																								
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Results ϕ_{seismic}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
ϕ_{seismic}	17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ (c) (d) (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table> PROFIS Engineering calculations for bond failure in tension when seismic load conditions are being modeled: single anchor: design bond strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_a$. anchor group: design bond strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{ag}$.	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for bond failure in tension require calculation of a nominal bond strength (N_a or N_{ag}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_a or ϕN_{ag}). ϕ-factors are relevant to static and seismic load conditions. ACI 318-14 Section 17.2.3.4.4 contains provisions to calculate tension design strengths for seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in this section as "ϕ_{seismic}". This reduction is applied to non-steel tension failure modes. When calculating tension design strengths for adhesive anchors, the relevant non-steel tension failure modes to which this reduction is applied include concrete breakout failure ($0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$) and bond failure ($0.75\phi N_a$ or $0.75\phi N_{ag}$), as referenced in the excerpt to the left. The ϕ-factors referenced in Table 17.3.1.1 correspond to tension design strengths calculated for static load conditions. The PROFIS Engineering report designates the ϕ-factor corresponding to bond failure for static load conditions "ϕ_{bond}". PROFIS Engineering uses the ϕ-factors derived from AC308/ACI 355.4 testing, as given in the ICC-ESR for the adhesive anchor system, for the parameter "ϕ_{bond}". When seismic load conditions are modeled in PROFIS Engineering for an adhesive anchor system, the software calculates a design bond strength corresponding to ($0.75 \phi_{\text{bond}} N_a$ or $0.75 \phi_{\text{bond}} N_{ag}$). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_a or N_{ag}: Nominal bond strength ϕN_a or ϕN_{ag}: Design bond strength ϕ_{bond}: Strength reduction factor for concrete failure
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
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Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Results $\phi_{\text{nonductile}}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.3.1.1 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table> ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ (c) (d) (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for bond failure in tension require calculation of a nominal bond strength (N_a or N_{ag}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_a or ϕN_{ag}). ϕ-factors are relevant to static and seismic load conditions. The ϕ-factors referenced in Table 17.3.1.1 correspond to tension design strengths calculated for static load conditions. The PROFIS Engineering report designates the ϕ-factor corresponding to bond failure for static load conditions "ϕ_{bond}". PROFIS Engineering uses the ϕ-factors derived from AC308/ACI 355.4 testing, as given in the ICC-ESR for the adhesive anchor system, for the parameter "ϕ_{bond}". ACI 318-14 Section 17.2.3.4.4 contains provisions to calculate tension design strengths for seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in this section as "ϕ_{seismic}". This reduction is applied to non-steel tension failure modes. When calculating tension design strengths for adhesive anchors, the relevant non-steel tension failure modes to which this reduction is applied include concrete breakout failure ($0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$) and bond failure ($0.75\phi N_a$ or $0.75\phi N_{ag}$), as referenced in the excerpt to the left. The parameter "$\phi_{\text{nonductile}}$" is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor "$\phi_{\text{nonductile}}$". "$\phi_{\text{nonductile}}$" is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$																									
Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Results N_{ua}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
N_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for bond failure in tension require calculation of a nominal bond strength (N_a or N_{ag}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_a or ϕN_{ag}). Design strength is checked against a factored tension load, defined by the parameter "N_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored tension load parameter "N_{ua}". N_{ua} = factored tensile force applied to anchor or individual anchor in a group of anchors (lb) $N_{ua,i}$ = factored tensile force applied to most highly stressed anchor in a group of anchors (lb) $N_{ua,g}$ = total factored tensile force applied to anchor group (lb) The design bond strength for a single anchor in tension (ϕN_a) calculated per Section 17.4.5 is checked against the factored tension load acting on the anchor, which is designated "N_{ua}" in Table 17.3.1.1. If $\phi N_a > N_{ua}$, the provisions for considering bond failure in tension have been satisfied per Table 17.3.1.1. The design bond strength for a group of anchors in tension (ϕN_{ag}) calculated per Section 17.4.5 is checked against the total factored tension load acting on the anchors that are in tension, which is designated "$N_{ua,g}$" in Table 17.3.1.1. If $\phi N_{ag} > N_{ua,g}$, the provisions for considering bond failure in tension have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation "N_{ua}" to define the factored tension load being checked against the calculated design bond strength ϕN_a or ϕN_{ag}. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting tension loads. The software only performs tension load checks per Table 17.3.1.1 if tension loads have been input via one of the load input functionalities. If a single anchor in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_a, and checks this value against either (a) the factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchor. If a group of anchors in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{ag}, and checks this value against either (a) the total factored tension load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored tension load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored tension load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the total factored tension load determined to be acting on the anchor group. Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameters ϕN_a and ϕN_{ag}.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$																									
Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Equation N_{cb}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b$	17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$	Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete

Equation ϕN_{cb}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi N_{cb} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Tension Single Anchor $\phi N_{cb} > N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{cb}) against a factored tension load (N_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{cb}: Nominal concrete breakout strength in tension $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic tension ϕN_{cb}: Design concrete breakout strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

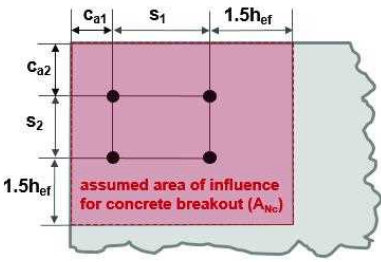
Equation N_{cbg}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N}$	17.4.2.1 The nominal concrete breakout strength in tension, ... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$	Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ec,N}$: Tension modification factor for eccentricity $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete

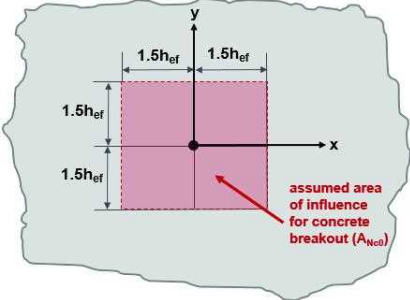
Equation ϕN_{cb}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi N_{cb} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Tension Anchors as a Group $\phi N_{cbg} > N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{cb}) against a factored tension load (N_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{cbg}: Nominal concrete breakout strength in tension $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic tension ϕN_{cbg}: Design concrete breakout strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Equation A_{Nc}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Nc}	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors.....	A_{Nc} is a modification factor that accounts for the area of influence assumed to develop in concrete when a tension load is applied to a single anchor or a group of anchors. A_{Nc} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Nc} is defined by projected distances from the anchors that are in tension. The maximum projected distance from an anchor that is considered when calculating A_{Nc} is limited to $1.5h_{ef}$, where h_{ef} is the effective embedment depth of the anchor. Therefore, the maximum edge distance parameter used to calculate A_{Nc} equals $1.5h_{ef}$ and the maximum spacing parameter used to calculate A_{Nc} equals $3.0h_{ef}$. The figure below illustrates how A_{Nc} is calculated for a group of four anchors in tension with fixed edge distances equal to c_{a1} and c_{a2}, and spacing parameters equal to s_1 and s_2. Note that the maximum edge distance parameter used to calculate A_{Nc} equals $1.5h_{ef}$. Anchors spaced greater than $3.0h_{ef}$ from one another would not be considered to act as a group with respect to that spacing.  $A_{Nc} = (c_{a1} + s_1 + 1.5h_{ef})(c_{a2} + s_2 + 1.5h_{ef})$ where: c_{a1} and c_{a2} are $\leq 1.5h_{ef}$ s_1 and s_2 are $\leq 3.0h_{ef}$ Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Nc}.

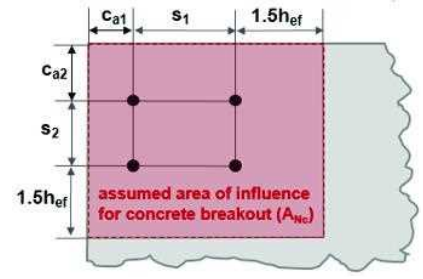
Equation A_{Nc0}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$A_{Nc0} = 9h_{ef}^2$	17.4.2.1 A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance equal to or greater than $1.5h_{ef}$. $A_{Nc0} = 9h_{ef}^2$ (17.4.2.1c)	A_{Nc0} is a modification factor that accounts for the area of influence assumed to develop in concrete when a tension load is applied to a single anchor without the influence of any fixed edges. A_{Nc0} is calculated with the effective embedment depth of the anchor (h_{ef}) input into the PROFIS Engineering model. The geometry for A_{Nc0} is defined by a projected distance of $1.5h_{ef}$ from the anchor in the x and y directions. The figure below illustrates how A_{Nc0} is calculated.  $A_{Nc0} = (1.5h_{ef} + 1.5h_{ef})(1.5h_{ef} + 1.5h_{ef})$$= (3.0h_{ef})^2$ Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Nc}.

Equation $\psi_{ec,N}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \leq 1.0$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	$\psi_{ec,N}$ is a modification factor that is used to account for a resultant tension load that is eccentric with respect to the centroid of anchors that are loaded in tension. $\psi_{ec,N}$ is only considered when calculating the nominal concrete breakout strength in tension for an anchor group (N_{cbg}). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction h_{ef}: Parameter for anchor effective embedment depth. Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: $\psi_{ec1,N}$: Modification factor for tension eccentricity with respect to the x direction $\psi_{ec2,N}$: Modification factor for tension eccentricity with respect to the y direction

Equation $\psi_{ed,N}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right) \leq 1.0$	17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,N} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right)$ (17.4.2.5b)	$\psi_{ed,N}$ is a modification factor that is used to account for fixed edge distances less than $1.5h_{ef}$, where h_{ef} corresponds to the effective embedment depth that has been selected for the anchor being modeled in PROFIS Engineering. The illustration below shows how the assumed area of influence (A_{Ne}) would be defined for an anchoring application being modeled with two fixed edges (c_{a1} and c_{a2}) that are both less than $1.5h_{ef}$, and with c_{a1} being less than c_{a2}. The smallest edge distance (c_{a1}) corresponds to the parameter $c_{a,min}$, and would be used to calculate the modification factor $\psi_{ed,N}$.  $\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a1}}{1.5h_{ef}} \right)$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: Parameter for the smallest fixed edge being modeled h_{ef}: Parameter for anchor effective embedment depth

Equation $\psi_{cp,N}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering								
$\psi_{cp,N} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5h_{ef}}{c_{ac}} \right) \leq 1.0$	17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq 1.5c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, including cast-in anchors, $\psi_{cp,N}$ shall be taken as 1.0. 17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors.....</td><td>.2h_{ef}</td></tr><tr><td>Undercut anchors.....</td><td>.2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors.....</td><td>.4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchors.....</td><td>.4h_{ef}</td></tr></table>	Adhesive anchors.....	.2h_{ef}	Undercut anchors.....	.2.5h_{ef}	Torque-controlled expansion anchors.....	.4h_{ef}	Displacement-controlled expansion anchors.....	.4h_{ef}	$\psi_{cp,N}$ is a modification factor that considers splitting failure when calculating the nominal concrete breakout strength in tension (N_{cb} or N_{cbg}) for a post-installed anchor. Since ACI 318 anchoring-to-concrete provisions do not specifically consider concrete splitting as a failure mode, splitting is addressed through the $\psi_{cp,N}$ modification factor. The parameter $\psi_{cp,N}$ is only considered when designing post-installed mechanical or adhesive anchors installed in uncracked concrete. Splitting failure will typically not occur for cast-in-place anchors; therefore, the parameter $\psi_{cp,N}$ is not considered in PROFIS Engineering when modeling cast-in-place anchors. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\psi_{cp,N}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” $\psi_{cp,N}$ does not need to be calculated if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}, or if cracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2 is used to derive c_{ac} values for mechanical anchors. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR. ACI 318-14 Section 17.7.6 provides c_{ac}-values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the c_{ac}-value that is given in the ICC-ES evaluation report for an anchor to calculate $\psi_{cp,N}$. The value for $\psi_{cp,N}$ that PROFIS Engineering calculates will be limited to MAXIMUM {$c_{a,min}/c_{ac}$: $1.5h_{ef}/c_{ac}$} where $c_{a,min}$ is the smallest fixed edge distance being modeled in the application and h_{ef} is the effective embedment depth that has been selected for the anchor being modeled. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled c_{ac}: Value derived from testing per AC193/ACI 355.2 or AC308/ACI 355.4 for the anchor being modeled h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter $\psi_{cp,N}$.
Adhesive anchors.....	.2h_{ef}									
Undercut anchors.....	.2.5h_{ef}									
Torque-controlled expansion anchors.....	.4h_{ef}									
Displacement-controlled expansion anchors.....	.4h_{ef}									

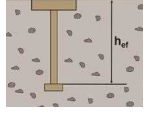
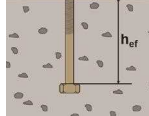
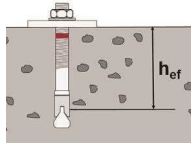
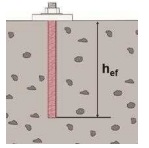
Equation $N_b = \lambda_a k_c$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_b = \lambda_a k_c \sqrt{f'_c h_{ef}}^{1.5}$	17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_b = \lambda_a k_c \sqrt{f'_c h_{ef}}^{1.5} \quad (17.4.2.2a)$ where $k_c = 24$ for cast-in anchors and 17 for post-installed anchors. The value of k_c for post-installed anchors shall be permitted to be increased above 17 based on ACI 355.2 or ACI 355.4 product-specific tests, but shall not exceed 24.	ACI 318 anchoring-to-concrete provisions for concrete breakout strength in tension require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{No}), eccentricity ($\psi_{ec,N}$), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete ($\psi_{c,N}$), and splitting ($\psi_{sp,N}$); and then multiplying these factors by what is termed the “basic concrete breakout strength in tension” (N_b) to obtain a “nominal concrete breakout strength in tension” (N_{cb} or N_{cbg}). The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The parameter “coefficient for the basic concrete breakout strength in tension” (k_c) defaults to a value of 24 for cast-in-place anchors, corresponding to cracked concrete conditions. PROFIS Engineering always uses a k_c-value of 24 for cast-in-place anchors installed at an effective embedment depth (h_{ef}) less than 11 in, for both cracked and uncracked concrete conditions. When designing cast-in-place anchors in uncracked concrete, the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). The default k_c-value noted for post-installed mechanical anchors and adhesive anchor systems in ACI 318-14 Section 17.4.2.2 equals 17. This section also notes that testing per the ACI test standards ACI 355.2 and ACI 355.4 can be used to derive k_c values for these anchors. k_c values for mechanical anchors can be derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. k_c values for adhesive anchor systems can be derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. These k_c values are specific to either cracked or uncracked concrete conditions; are relevant to the effective embedment depth range for the anchor; and are provided in an ICC-ESR. PROFIS Engineering uses the k_c-value that is given in the ICC-ES evaluation report for a post-installed anchor to calculate N_b. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c: Coefficient for basic concrete breakout strength in tension λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength h_{ef}: Effective embedment depth that has been selected for the anchor being modeled $\psi_{c,N}$: Modification factor for cracked or uncracked concrete conditions Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_b.

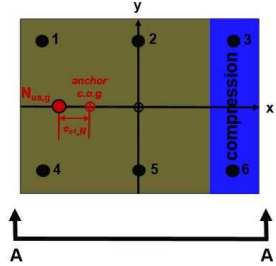
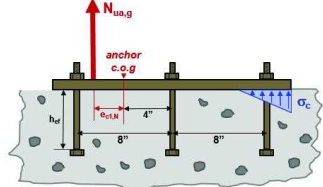
Equation $N_b = 16\lambda_a$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_b = 16\lambda_a \sqrt{f'_c h_{ef}}^{5/3}$	17.4.2.2 Alternatively, for cast-in headed studs and headed bolts with 11 in. $< h_{ef} < 25$ in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c h_{ef}}^{5/3} \quad (17.4.2.2b)$	ACI 318 anchoring-to-concrete provisions for concrete breakout strength in tension require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{Nco}), eccentricity ($\psi_{ec,N}$), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete ($\psi_{c,N}$), and splitting ($\psi_{sp,N}$); and then multiplying these factors by what is termed the “basic concrete breakout strength in tension” (N_b) to obtain a “nominal concrete breakout strength in tension” (N_{cb} or N_{cbg}). The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The general equation for calculating N_b is defined as Eq. (17.4.2.2a) in ACI 318-14. This equation is written as: ACI 318 anchoring-to-concrete provisions include a special case for calculating N_b when designing cast-in-place headed studs and headed bolts installed at an embedment depth within the range 11 in $< h_{ef} < 25$ in. This case is defined in ACI 318-14 by Eq. (17.4.2.2b). The “coefficient for the basic concrete breakout strength in tension” (k_c) equals 16 in Eq. (17.4.2.2b), and the effective embedment depth (h_{ef}) is raised to the 5/3 power instead of being raised to the 1.5 power per Eq. (17.4.2.2a). The provisions associated with use of Eq. (17.4.2.2b) are only relevant for cast-in-place headed studs and headed bolts installed at an embedment depth within the range 11 in $< h_{ef} < 25$ in. $k_c = 16$ corresponds to cracked concrete conditions. When designing cast-in-place anchors in uncracked concrete per Eq. (17.4.2.2b); the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). PROFIS Engineering calculates N_b per Eq. (17.4.2.2b) when cast-in-place headed studs and headed bolts with an embedment depth 11 in $< h_{ef} < 25$ in are being modeled. The commentary R17.4.2.2 notes that concrete breakout calculations for $h_{ef} > 25$ in per Equation (17.4.2.2b) could be unconservative. PROFIS Engineering calculations for concrete breakout strength in tension limit the embedment depth for both cast-in-place and post-installed anchors to a maximum value of 25 in. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c: Coefficient for basic concrete breakout strength in tension λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength h_{ef}: Effective embedment depth that has been selected for the anchor being modeled $\psi_{c,N}$: Modification factor for cracked or uncracked concrete conditions Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_b.

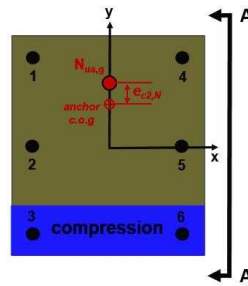
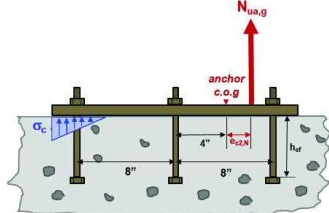
Variables h_{ef}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
h_{ef}	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors..... 17.4.2.1 A_{Nco} is the projected concrete failure area of a single anchor with an edge distance equal to or greater than $1.5h_{ef}$. $A_{Nco} = 9h_{ef}^2 \quad (17.4.2.1c)$ 17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \quad (17.4.2.4)$ 17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,N} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,N} = 1.0 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.2.5a) 17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_b = \lambda_a k_c \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $< h_{ef} < 25$ in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c} h_{ef}^{5/3} \quad (17.4.2.2b)$	h_{ef} is defined as the “effective embedment depth of an anchor”. This parameter corresponds to the embedded portion of the anchor that is “effective” in transferring tension load from the anchor into the concrete. Excerpted ACI 318-14 anchoring-to-concrete provisions and equations that include h_{ef} for calculating concrete breakout strength in tension are shown to the left. For cast-in-place anchors, PROFIS Engineering permits users to input h_{ef} values ranging between $4d_{anchor}$ and 25”. cast-in-place headed studs $4d_{anchor} < h_{ef} < 25"$  cast-in-place headed bolts $4d_{anchor} < h_{ef} < 25"$  For post-installed mechanical anchors, PROFIS Engineering permits users to input specific h_{ef} values that are relative to a specific diameter as given in the ICC-ES evaluation report for the anchor. post-installed expansion anchor (reference product approval for h_{ef})  For post-installed adhesive anchors, PROFIS Engineering permits users to input a range of h_{ef} values that are relative to a specific diameter as given in the ICC-ES evaluation report for the anchor. post-installed adhesive anchor $h_{ef,min} < h_{ef} < h_{ef,max}$ (reference product approval for $h_{ef,min}$ and $h_{ef,max}$) 

Variables $e_{c1,N}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c1,N}$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_{c1,N}}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity $e'_{c1,N}$ for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	$e_{c1,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the x direction. The value for $e_{c1,N}$ corresponds the distance in the x direction of a resultant tension load from the centroid of anchors that are loaded in tension. PROFIS Engineering uses $e_{c1,N}$ to calculate the ACI 318 modification factor for tension eccentricity ($\psi_{ec,N}$), and designates this modification factor $\psi_{ec1,N}$ to indicate eccentricity is being considered in the x direction. PROFIS Engineering calculations for tension eccentricity with respect to the x direction are as follows: - Calculate a resultant tension load acting on the anchors - Calculate the distance in the x direction ($e_{c1,N}$) between this load and the centroid of the anchors loaded in tension - Calculate a modification factor for tension eccentricity ($\psi_{ec1,N}$) with respect to the x direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.2.4 Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the x direction when calculating concrete breakout strength in tension.   Section A-A $N_{u,a,g}$ = resultant tension load $e_{c1,N} = 2.75"$ $h_{ef} = 7.0"$ $\psi_{ec1,N} = \frac{1}{\left(1 + \frac{(2)(2.75")}{(3)(7.0")}\right)} = 0.79$

Variables $e_{c2,N}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c2,N}$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_{c,N}}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity $e'_{c,N}$ for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	$e_{c2,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the y direction. The value for $e_{c2,N}$ corresponds the distance in the y direction of a resultant tension load from the centroid of anchors that are loaded in tension. PROFIS Engineering uses $e_{c2,N}$ to calculate the ACI 318 modification factor for tension eccentricity ($\psi_{ec,N}$), and designates this modification factor $\psi_{ec2,N}$ to indicate eccentricity is being considered in the y direction. PROFIS Engineering calculations for tension eccentricity with respect to the y direction are as follows: - Calculate a resultant tension load acting on the anchors - Calculate the distance in the y direction ($e_{c2,N}$) between this load and the centroid of the anchors loaded in tension - Calculate a modification factor for tension eccentricity ($\psi_{ec2,N}$) with respect to the y direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.2.4 Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the y direction when calculating concrete breakout strength in tension.   Section A-A $N_{u,a,g}$ = resultant tension load $e_{c2,N} = 1.67"$ $h_{ef} = 7.0"$ $\psi_{ec2,Na} = \frac{1}{\left(1 + \frac{(2)(1.67")}{(3)(7.0")}\right)} = 0.86$

Variables $c_{a,min}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{a,min}$	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors..... 17.4.2.1 A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance greater than $1.5h_{ef}$. $A_{Nc0} = 9h_{ef}^2 \quad (17.4.2.1c)$ 17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,N} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,N} = 1.0 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.2.5a) 17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6.	$c_{a,min}$ is defined as the “minimum distance from the center of an anchor shaft to the edge of concrete.” When one or more fixed edges are modeled in PROFIS Engineering, the report will show the smallest fixed edge as “$c_{a,min}$” in the Variables section. Excerpted ACI 318-14 anchoring-to-concrete provisions and equations that include $c_{a,min}$ for calculating concrete breakout strength in tension are shown to the left. Reference the parameters A_{Nc} and A_{Nc0} in the Equations section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Distance from the center of an anchor shaft to the edge of concrete in one direction (e.g. the x+ direction). For tension calculations, c_{a1} is the smallest fixed edge distance c_{a2}: Distance from the center of an anchor shaft to the edge of concrete in a direction perpendicular to c_{a1} (e.g. the y+ direction) Reference the parameters $\psi_{ed,N}$ and $\psi_{cp,N}$ in the Equations and Calculations sections of the PROFIS Engineering report for more information on how $c_{a,min}$ is used to calculate these parameters.

Variables $\psi_{c,N}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{c,N}$	17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted: (a) $\psi_{c,N} = 1.25$ for cast-in anchors (b) $\psi_{c,N} = 1.4$ for post-installed anchors, where the value of k_c used in Eq. (17.4.2.2a) is 17 $N_b = \lambda_a k_c \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ Where the value of k_c used in Eq. (17.4.2.2a) is taken from the ACI 355.2 or ACI 355.4 product evaluation report for post-installed anchors showed compliance for use in both cracked and uncracked concrete, the values of k_c and $\psi_{c,N}$, shall be based on the ACI 355.2 or ACI 355.4 product evaluation report. Where the value of k_c used in Eq. (17.4.2.2a) is taken from the ACI 355.2 or ACI 355.4 product evaluation report for post-installed anchors showed compliance for use in uncracked concrete, $\psi_{c,N}$, shall be taken as 1.0. When analysis indicates cracking at service load levels, $\psi_{c,N}$, shall be taken as 1.0 for both cast-in anchors and post-installed anchors. Post-installed anchors shall be shown compliance for use in cracked concrete in accordance with ACI 355.2 or ACI 355.4. The cracking in the concrete shall be controlled by flexural reinforcement distributed in accordance with 24.3.2, or equivalent crack control shall be provided by confining reinforcement.	$\psi_{c,N}$, is a modification factor for cracked or uncracked concrete conditions. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. Concrete is typically assumed to crack under service load conditions. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing cast-in-place and post-installed anchors, since cracks in the anchor vicinity can result in a reduced ultimate load capacity and increased displacement at ultimate load, compared to uncracked concrete conditions. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions. When a cast-in-place anchor is selected for cracked concrete conditions, PROFIS Engineering sets $\psi_{c,N}$ equal to 1.0 when calculating the nominal concrete breakout strength in tension (N_{cb} or N_{cbg}). If uncracked concrete conditions are selected, PROFIS Engineering sets $\psi_{c,N}$ equal to 1.25. When a post-installed anchor is selected, PROFIS Engineering uses the k_c-value for cracked or uncracked concrete (depending on the condition selected) derived from testing per ACI 355.2/AC193 (mechanical anchor) or ACI 355.4/AC308 (adhesive anchor system) to calculate the basic concrete breakout strength (N_b) per Eq. (17.4.2.2a). PROFIS Engineering always sets $\psi_{c,N}$ equal to 1.0 for a post-installed anchor. Reference the Variables section of the PROFIS Engineering report for more information on the coefficient for basic concrete breakout strength (k_c). Reference the Equations and Calculations sections for more information on the basic concrete breakout strength (N_b).

Variables c_{ac}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																							
c_{ac}	17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, including cast-in anchors, $\psi_{cp,N}$ shall be taken as 1.0. 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: Adhesive anchors. 2h_{ef} Undercut anchors. 2.5h_{ef} Torque-controlled expansion anchors 4h_{ef} Displacement-controlled expansion anchors. 4h_{ef} Example: Example of critical edge distance requirements given in a mechanical anchor approval. ICC-ES ECR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="12">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="3">1/2</th><th colspan="3">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td><td></td></tr><tr><td>Min. member thickness</td><td>h_{min}</td><td>in.</td><td>3-1/4</td><td>4</td><td>5</td><td>5</td><td>4</td><td>6</td><td>6</td><td>8</td><td>5</td><td>6</td><td>8</td><td>8</td></tr><tr><td>Critical edge distance</td><td>c_{ac}</td><td>in.</td><td>6</td><td>4-3/8</td><td>4</td><td>4-1/8</td><td>5-1/2</td><td>4-1/2</td><td>7-1/2</td><td>6</td><td>6-1/2</td><td>8-3/4</td><td>6-3/4</td><td>12</td></tr></table> Example: Example of critical edge distance requirements given in an adhesive anchor approval. Reference ICC-ESR-3187 Section 4.1.10.2. 4.1.10.2 Threaded Rod, Steel Reinforcing Bars, and Hilti HIS-N and HIS-RN Inserts: The modification factor $\psi_{cp,Na}$ must be determined in accordance with ACI 318-14 17.4.5.5 or ACI 318-11 D.5.5 as applicable, except as noted below. For all cases where $c_{Na}/c_{ac} < 1.0$, $\psi_{cp,Na}$ determined from ACI 318-14 Eq. 17.4.5.5b or ACI 318-11 Eq. D-27, as applicable, need not be taken less than c_{Na}/c_{ac}. For all other cases $\psi_{cp,Na}$ shall be taken as 1.0.	Design information	Symbol	Units	Nominal anchor diameter (in.)												3/8			1/2			5/8			3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4		Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	8	Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12	$\psi_{cp,N}$ is a modification factor that considers splitting failure when calculating the nominal concrete breakout strength in tension (N_{cb} or N_{cbg}) for a post-installed anchor. $\psi_{cp,N}$ is only considered when designing post-installed mechanical or adhesive anchors installed in uncracked concrete. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing anchors. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\psi_{cp,N}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” Testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2 is used to derive c_{ac} values for mechanical anchors. Values derived from this testing are provided in an ICC-ESR. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} for adhesive anchor systems is calculated using the effective embedment depth (h_{ef}), and characteristic bond stress in uncracked concrete ($\tau_{k,uncr}$). The c_{ac}-values for post-installed anchors noted in ACI 318-14 Section 17.7.6 are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering always uses the c_{ac}-value that is given (mechanical anchor) or calculated (adhesive anchor system) in the ICC-ES evaluation report for the anchor. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter $\psi_{cp,N}$. Reference the Variables section of the PROFIS Engineering report for more information on the parameter h_{ef}. Reference the Variables section for bond strength in the PROFIS Engineering report for more information on the parameter $\tau_{k,uncr}$.
Design information	Symbol				Units	Nominal anchor diameter (in.)																																																																			
		3/8				1/2			5/8			3/4																																																													
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																													
Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	8																																																											
Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12																																																											

Variables c_{ac} (continued)

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{ac}	The critical edge distance c_{ac} must be calculated according to Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11, in lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6 as applicable. $c_{ac} = h_{ef} \left(\frac{\tau_{k,uncr}}{1160} \right)^{0.4} * \left[3.1 - 0.7 \frac{h}{h_{ef}} \right]$ (Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11) where $\left[\frac{h}{h_{ef}} \right]$ need not be taken as larger than 2.4; and $\tau_{k,uncr}$ is the characteristic bond strength in uncracked concrete, h is the member thickness, and h_{ef} is the embedment depth. $\tau_{k,uncr}$ need not be taken greater than: $\tau_{k,uncr} = \frac{k_{uncr} \sqrt{h_{ef} f'_c}}{\pi_d} \quad \text{Eq. (4-1)}$	

Variables k_c

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																		
k_c	17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_b = \lambda_a k_c \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ where $k_c = 24$ for cast-in anchors and 17 for post-installed anchors. The value of k_c for post-installed anchors shall be permitted to be increased above 17 based on ACI 355.2 or ACI 355.4 product-specific tests, but shall not exceed 24. Alternatively, for cast-in headed studs and headed bolts with 11 in. $< h_{ef} < 25$ in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c} h_{ef}^{5/3} \quad (17.4.2.2b)$ Example: Example of k_c-values given in a mechanical anchor approval. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Effectiveness factor k_{uncr} for uncracked concrete</td><td></td><td></td><td colspan="10">24</td></tr><tr><td>Effectiveness factor k_c for cracked concrete</td><td></td><td></td><td colspan="10">17</td></tr></table> Example: Example of k_c-values given in an adhesive anchor system approval. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1-1/4 or #10</th></tr><tr><td>Effectiveness factor k_{uncr} for cracked concrete</td><td>$k_{c,cr}$</td><td>in-lb</td><td colspan="10">17</td></tr><tr><td>Effectiveness factor for uncracked concrete</td><td>$k_{c,uncr}$</td><td>in-lb</td><td colspan="10">24</td></tr><tr><td>Minimum embedment</td><td>$h_{ef,min}$</td><td>in.</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>4-1/2</td><td>5</td></tr><tr><td>Maximum embedment</td><td>$h_{ef,max}$</td><td>in.</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/2</td><td>20</td><td>22-1/2</td><td>25</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Effectiveness factor k_{uncr} for uncracked concrete			24										Effectiveness factor k_c for cracked concrete			17										DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1-1/4 or #10	Effectiveness factor k_{uncr} for cracked concrete	$k_{c,cr}$	in-lb	17										Effectiveness factor for uncracked concrete	$k_{c,uncr}$	in-lb	24										Minimum embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5	Maximum embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25	The “basic concrete breakout strength” (N_b) corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The parameter “coefficient for the basic concrete breakout strength in tension” (k_c) defaults to a value of 24 for cast-in-place anchors, corresponding to cracked concrete conditions. PROFIS Engineering always uses a k_c-value of 24 for cast-in-place anchors installed at an effective embedment depth (h_{ef}) less than 11 in, for both cracked and uncracked concrete conditions. When designing cast-in-place anchors in uncracked concrete, the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). The default k_c-value of 17 noted for post-installed mechanical anchors and adhesive anchor systems in ACI 318-14 Section 17.4.2.2 is only intended to be used as “guide value” in the absence of k_c values derived from product-specific testing. k_c values for mechanical anchors can be derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. k_c values for adhesive anchor systems can be derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. These k_c values are specific to either cracked or uncracked concrete conditions; are relevant to the effective embedment depth range for the anchor; and are provided in an ICC-ESR. PROFIS Engineering uses the k_c-value that is given in the ICC-ES evaluation report for a post-installed anchor to calculate N_b per Eq. (17.4.2.2a) For cast-in-place headed studs and headed bolts installed at an embedment depth range 11 in $< h_{ef} < 25$ in k_c equals 16 per Eq. (17.4.2.2b). $k_c = 16$ corresponds to cracked concrete conditions. When designing cast-in-place anchors in uncracked concrete per Eq. (17.4.2.2b); the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). PROFIS Engineering calculates N_b per Eq. (17.4.2.2b) when cast-in-place headed studs and headed bolts with an embedment depth 11 in $< h_{ef} < 25$ in are being modeled. The report will show the k_c-value as 16. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_b. Reference the Variables section of the PROFIS Engineering report for more information on the parameter $\psi_{c,n}$.
DESIGN INFORMATION	Symbol				Units	Nominal anchor diameter (in.)																																																																																																																														
		3/8		1/2		5/8		3/4																																																																																																																												
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																																																																								
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			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1-1/4 or #10																																																																																																																										
Effectiveness factor k_{uncr} for cracked concrete	$k_{c,cr}$	in-lb	17																																																																																																																																	
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Maximum embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25																																																																																																																										

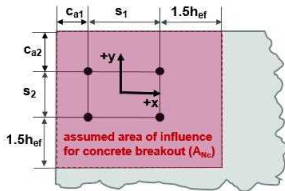
Variables λ_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure 1.0 λ Expansion and adhesive anchor concrete failure 0.8λ Adhesive anchor bond failure per Eq. (17.4.5.2). 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85 ⁽¹⁾</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33</td><td>0.85 to 1 ⁽²⁾</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> ¹ Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. ² Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}}{6.7 \sqrt{f_{cm}}}^{1.5} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_b = \lambda_a k_c \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. < h_{ef} < 25 in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c} h_{ef}^{5/3} \quad (17.4.2.2b)$	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33	0.85 to 1 ⁽²⁾	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	λ_a is a modification factor for lightweight concrete that is used to calculate the “basic concrete breakout strength in tension” (N_b) per Eq. (17.4.2.2a) or Eq. (17.4.2.2b). Generally speaking, ACI 318 applies a multiplier to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete”, and designates this parameter “λ”. The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to anchoring-to-concrete calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ, determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the type of anchor being used, to obtain the parameter λ_a. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. For post-installed anchor design, PROFIS Engineering uses a λ_a-value as referenced in the ICC-ESR provisions for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. Per ACI 318 provisions for determining λ_a, when designing cast-in-place anchors and post-installed undercut anchors, PROFIS Engineering uses the λ-value that has been input, for the λ_a-value to calculate N_b. When designing post-installed expansion and adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.8 (expansion and adhesive anchor concrete failure) or 0.6 (adhesive anchor bond failure), for the λ_a-value to calculate N_b. Therefore, the PROFIS Engineering λ_a-value for calculating N_b, when designing cast-in-place and undercut anchors, will equal the λ-value that has been input. Likewise, the PROFIS Engineering λ_a-value for calculating N_b, when designing expansion and adhesive anchors, will equal 0.8λ since the parameter N_b is relevant to concrete failure. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_b.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33	0.85 to 1 ⁽²⁾																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

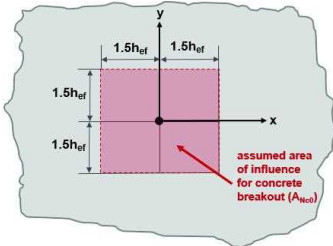
Variables f'_c

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
f'_c	17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors, and 8000 psi for post-installed anchors. Testing is required for post-installed anchors when used in concrete with f'_c greater than 8000 psi. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_b = \lambda_a k_c \sqrt{f'_c h_{ef}^{1.5}} \quad (17.4.2.2a)$ where $k_c = 24$ for cast-in anchors and 17 for post-installed anchors. The value of k_c for post-installed anchors shall be permitted to be increased above 17 based on ACI 355.2 or ACI 355.4 product-specific tests, but shall not exceed 24. Alternatively, for cast-in headed studs and headed bolts with 11 in. < h_{ef} < 25 in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c h_{ef}^{5/3}} \quad (17.4.2.2b)$	f'_c is a parameter used to define concrete compressive strength. This parameter is used to calculate the “basic concrete breakout strength in tension” (N_b) when calculating the nominal concrete breakout strength in tension (N_{cb} or N_{cbg}). Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. f'_c provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. PROFIS Engineering uses these f'_c provisions for post-installed anchor design. The post-installed anchor portfolio in PROFIS Engineering is limited to installation in concrete having a specified compressive strength between 2500 psi and 8500 psi, and design using an f'_c-value less than or equal to 8000 psi. Reference the ICC-ESR for f'_c information specific to a post-installed anchor. PROFIS Engineering users can input an f'_c-value within the range 2500 psi < f'_c < 8500 psi for post-installed anchor design. The maximum f'_c-value for calculations will be limited to 8000 psi. PROFIS Engineering users can input an f'_c-value within the range 2500 psi < f'_c < 10,000 psi for cast-in-place anchor design. The maximum f'_c-value for calculations will be limited to 10,000 psi. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_b.

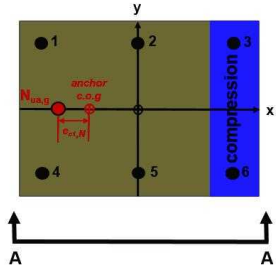
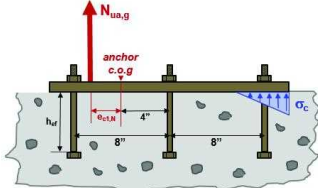
Calculations A_{Nc}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																								
A_{Nc}	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward 1.5h_{ef} from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors..... 17.7.1 Unless determined in accordance with 17.7.4, minimum center-to-center spacing of anchors shall be 4d_a for cast-in-anchors that will not be torqued, and 6d_a for torqued cast-in-anchors and post-installed anchors. 17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be 6d_a. 17.7.3 Unless determined in accordance with 17.7.4, minimum edge distances for post-installed anchors shall be based on the greater of specified cover requirements for reinforcement in 20.6.1, or minimum edge distance requirements for the products as determined by tests in accordance with ACI 355.2 or ACI 355.4, and shall not be less than twice the maximum aggregate size. In the absence of product-specific ACI 355.2 or ACI 355.4 test information, the minimum edge distance shall not be less than: Adhesive anchors 6d_a Undercut anchors. 6d_a Torque-controlled anchors 8d_a Displacement-controlled anchors 10d_a 17.7.4 For anchors where installation does not produce a splitting force that will not be torqued, if the edge distance or spacing is less than those specified in 17.7.1 to 17.7.3, calculations shall be performed by substituting for d_a a smaller value d_a´ that meets the requirements of 17.7.1 to 17.7.3. Calculated forces applied to the anchor shall be limited to the values corresponding to an anchor having a diameter of d_a´. Example: Example of minimum edge distance and spacing requirements given in a mechanical anchor approval. ICC-ESR-3187 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal Anchor Diameter (in).</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="2">3/4</th><th colspan="2"></th></tr><tr><td rowspan="2">Min. edge distance</td><td>c_{min}</td><td>in.</td><td>8</td><td>2-1/2</td><td>2-1/2</td><td>2-3/4</td><td>2-3/8</td><td>3-5/8</td><td>3-1/4</td><td>9-1/2</td><td>4-3/4</td><td>4-1/8</td></tr><tr><td>for s ≥</td><td>in.</td><td>8</td><td>5</td><td>5</td><td>5-3/4</td><td>5-3/4</td><td>6-1/8</td><td>5-7/8</td><td>5</td><td>10-1/2</td><td>8-7/8</td></tr><tr><td rowspan="2">Min. anchor spacing</td><td>s_{min}</td><td>in.</td><td>8</td><td>2-1/2</td><td>2.5</td><td>2-3/4</td><td>2-3/8</td><td>3-1/2</td><td>3</td><td>5</td><td>5</td><td>4</td></tr><tr><td>for c ≥</td><td>in.</td><td>8</td><td>3-5/8</td><td>3.625</td><td>4-1/8</td><td>3-1/2</td><td>4-3/4</td><td>4-1/4</td><td>9-1/2</td><td>9-1/2</td><td>7-3/4</td></tr></table> Example: Example of minimum edge distance and spacing requirements given in an adhesive anchor system approval. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal Rod Diameter (in).</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th></tr><tr><td>Min. anchor spacing</td><td>s_{min}</td><td>in.</td><td>1-7/8</td><td>2-1/2</td><td>3-1/8</td><td>3-3/4</td><td>4-3/8</td><td>5</td><td>5-5/8</td></tr><tr><td>Min. edge distance (Threaded rods)</td><td>c_{min}</td><td>in.</td><td>1-3/4</td><td>1-3/4</td><td>2</td><td>2-1/8</td><td>2-1/4</td><td>2-3/4</td><td>n/a</td></tr><tr><td>Min. edge distance (Reinforcing bars)</td><td>c_{min}</td><td>-</td><td colspan="7">5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal Anchor Diameter (in).										3/8		1/2		5/8		3/4				Min. edge distance	c _{min}	in.	8	2-1/2	2-1/2	2-3/4	2-3/8	3-5/8	3-1/4	9-1/2	4-3/4	4-1/8	for s ≥	in.	8	5	5	5-3/4	5-3/4	6-1/8	5-7/8	5	10-1/2	8-7/8	Min. anchor spacing	s _{min}	in.	8	2-1/2	2.5	2-3/4	2-3/8	3-1/2	3	5	5	4	for c ≥	in.	8	3-5/8	3.625	4-1/8	3-1/2	4-3/4	4-1/4	9-1/2	9-1/2	7-3/4	DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in).							3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	Min. anchor spacing	s _{min}	in.	1-7/8	2-1/2	3-1/8	3-3/4	4-3/8	5	5-5/8	Min. edge distance (Threaded rods)	c _{min}	in.	1-3/4	1-3/4	2	2-1/8	2-1/4	2-3/4	n/a	Min. edge distance (Reinforcing bars)	c _{min}	-	5d; or see Section 4.1.9.2 of this report for design with reduced minimum edge distances							A_{Nc} is a modification factor that accounts for the area of influence assumed to develop in concrete when a tension load is applied to a single anchor or a group of anchors. A_{Nc} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering file. The model used to define A_{Nc} limits the maximum edge distance for calculation purposes to a projected distance of 1.5h_{ef} from the anchor. PROFIS Engineering will use a projected distance of 1.5h_{ef} from an anchor to define an outer edge of the area defined by A_{Nc} when the fixed edge distance is greater than 1.5h_{ef}, or the edge is infinite. For cast-in-place anchor design, PROFIS Engineering limits the minimum spacing and edge distance to a value defined by the requirements given in ACI 318 anchoring-to-concrete provisions. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. For post-installed anchor design, PROFIS Engineering uses the minimum spacing and edge distance parameters derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. PROFIS Engineering will not perform A_{Nc} calculations using spacing or edge distance values that are less than the minimum values permitted for a particular anchor. The model used to define A_{Nc} limits the maximum spacing for cast-in-place and post-installed anchors to a projected distance of 1.5h_{ef} on either side of the anchor in both the x and y directions. Therefore, PROFIS Engineering considers anchors spaced greater than 3.0h_{ef} from one another in either the x or y direction to not act as a group with respect to that spacing, and calculations for A_{Nc} do not consider this spacing. Instead, PROFIS Engineering will use a projected distance of 1.5h_{ef} to define the outer edge of A_{Nc} for the anchor or anchor group being considered. The figure below illustrates how A_{Nc} is calculated for a group of four anchors in tension with fixed edge distances equal to c_{a1} and c_{a2}, spacing parameters equal to s₁ and s₂, and infinite edges in the +x and -y directions.  $A_{Nc} = (c_{a1} + s_1 + 1.5h_{ef})(c_{a2} + s_2 + 1.5h_{ef})$ where: c_{min} ≤ (c_{a1} and c_{a2}) ≤ 1.5h_{ef} s_{min} ≤ (s₁ and s₂) ≤ 3.0h_{ef} Post-installed anchor values for c_{min} and s_{min} are established via testing and can be referenced in the ICC-ESR for the anchor. Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Equations section of the PROFIS Engineering report for more information on A_{Nc}.
DESIGN INFORMATION	Symbol				Units	Nominal Anchor Diameter (in).																																																																																																																				
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Min. edge distance	c _{min}	in.	8	2-1/2	2-1/2	2-3/4	2-3/8	3-5/8	3-1/4	9-1/2	4-3/4	4-1/8																																																																																																														
	for s ≥	in.	8	5	5	5-3/4	5-3/4	6-1/8	5-7/8	5	10-1/2	8-7/8																																																																																																														
Min. anchor spacing	s _{min}	in.	8	2-1/2	2.5	2-3/4	2-3/8	3-1/2	3	5	5	4																																																																																																														
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Min. anchor spacing	s _{min}	in.	1-7/8	2-1/2	3-1/8	3-3/4	4-3/8	5	5-5/8																																																																																																																	
Min. edge distance (Threaded rods)	c _{min}	in.	1-3/4	1-3/4	2	2-1/8	2-1/4	2-3/4	n/a																																																																																																																	
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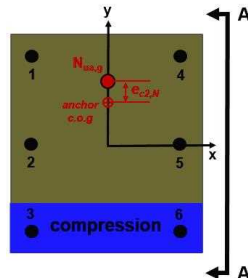
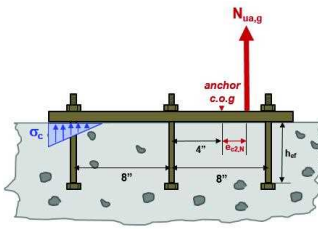
Calculations A_{Nc0}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																													
$A_{Nc0} = 9h_{ef}^2$	17.4.2.1 A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance equal to or greater than $1.5h_{ef}$. $A_{Nc0} = 9h_{ef}^2 \quad (17.4.2.1c)$ 17.7.5 Unless determined from tests in accordance with ACI 355.2, the value of h_{ef} for an expansion or undercut post-installed anchor shall not exceed the greater of 2/3 of the member thickness, h_a, and the member thickness minus 4 in. Example: Example of embedment depth and concrete thickness requirements given in a mechanical anchor approval. ICC-ESR-3187 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="12">Nominal Anchor Diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="3">1/2</th><th colspan="3">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective minimum embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Minimum member thickness</td><td>h_{min}</td><td>in.</td><td>3-1/4</td><td>4</td><td>5</td><td>5</td><td>4</td><td>6</td><td>6</td><td>8</td><td>5</td><td>6</td><td>8</td><td>8</td></tr></table> Example: Example of embedment depth and concrete thickness requirements given in an adhesive anchor system approval. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1/4 or #10</th></tr><tr><td>Minimum embedment</td><td>$h_{ef,min}$</td><td>in.</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>4-1/2</td><td>5</td></tr><tr><td>Maximum embedment</td><td>$h_{ef,max}$</td><td>in.</td><td>7-1/2</td><td>10</td><td>12.5</td><td>15</td><td>17-1/2</td><td>20</td><td>22.5</td><td>25</td></tr><tr><td>Maximum concrete thickness</td><td>h_{min}</td><td>-</td><td colspan="2">$h_{ef} + 1-1/4$</td><td colspan="6">$h_{ef} + 2d_0$</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal Anchor Diameter (in.)												3/8			1/2			5/8			3/4			Effective minimum embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Minimum member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	8	DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)										3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1/4 or #10	Minimum embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5	Maximum embedment	$h_{ef,max}$	in.	7-1/2	10	12.5	15	17-1/2	20	22.5	25	Maximum concrete thickness	h_{min}	-	$h_{ef} + 1-1/4$		$h_{ef} + 2d_0$						A_{Nc0} is a modification factor that accounts for the area of influence assumed to develop in concrete when a tension load is applied to a single anchor without the influence of any fixed edges. A_{Nc0} is calculated with the effective embedment depth of the anchor (h_{ef}) input into the PROFIS Engineering file. A_{Nc0} is always defined as a square that has sides equal to $3.0h_{ef}$. The length of the side in the x direction corresponds to a projected distance of $1.5h_{ef}$ from the anchor in the +x and -x directions. The length of side in the y direction corresponds to a projected distance of $1.5h_{ef}$ from the anchor in the +y and -y directions. For cast-in-place anchor design, PROFIS Engineering uses the following embedment depth and concrete thickness parameters: embedment depth (h_{ef}) $4d_a < h_{ef} < 25$ in d_a = nominal anchor diameter minimum concrete thickness (h_{min}) $h_{min} = h_{ef} + t_h + 0.375$ in t_h = anchor head thickness Values for t_h are taken from product data for ASTM F1554 hex, heavy hex, square and heavy square bolts; and from AWS D1.1 headed studs. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. For post-installed anchor design, PROFIS Engineering uses the embedment depth and concrete thickness parameters derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. PROFIS Engineering will not perform calculations for an anchor if the embedment depth or concrete thickness are outside the limits noted above. The figure below illustrates how A_{Nc0} is calculated.  $A_{Nc0} = (1.5h_{ef} + 1.5h_{ef})(1.5h_{ef} + 1.5h_{ef})$ $= (9.0h_{ef})^2$ Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Equations section of the PROFIS Engineering report for more information on A_{Nc0}.
DESIGN INFORMATION	Symbol				Units	Nominal Anchor Diameter (in.)																																																																																																									
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Effective minimum embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																																																			
Minimum member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	8																																																																																																	
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Minimum embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5																																																																																																					
Maximum embedment	$h_{ef,max}$	in.	7-1/2	10	12.5	15	17-1/2	20	22.5	25																																																																																																					
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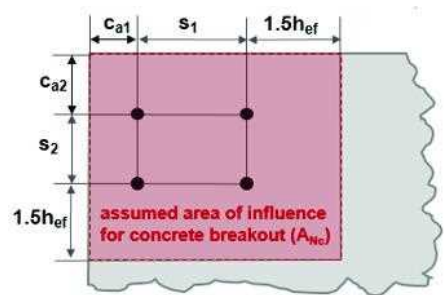
Calculations $\psi_{ec1,N}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,N}$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_{c,N}}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity $e'_{c,N}$ for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	When calculating nominal concrete breakout strength for a group of anchors in tension (N_{cbg}), ACI 318 anchoring-to-concrete provisions designate the modification factor for tension eccentricity “$\psi_{ec,N}$”. Per Section 17.4.2.4, tension eccentricity can be considered with respect to the x and y directions. PROFIS Engineering designates the modification factor for tension eccentricity in the x direction “$\psi_{ec1,N}$”. The parameter $e_{c1,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the x direction using Eq. (17.4.2.4). PROFIS Engineering calculations for tension eccentricity with respect to the x direction are as follows: • Calculate a resultant tension load acting on the anchors • Calculate the distance in the x direction ($e_{c1,N}$) between this load and the centroid of the anchors loaded in tension • Calculate a modification factor for tension eccentricity ($\psi_{ec1,N}$) with respect to the x direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.2.4. Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for tension eccentricity with respect to the y direction Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the x direction when calculating concrete breakout strength in tension.  Diagram illustrating the calculation of tension eccentricity with respect to the x direction. The anchors are arranged in a 2x3 grid. Anchors 1, 2, and 3 are in tension, while anchors 4, 5, and 6 are in compression. The resultant tension load $N_{u0,g}$ acts at an eccentricity $e_{c1,N}$ from the centroid of the tensioned anchors. The x and y axes are shown.  Section A-A $N_{u0,g}$ = resultant tension load $e_{c1,N} = 2.75"$ $h_{ef} = 7.0"$ $\psi_{ec1,Na} = \frac{1}{\left(1 + \frac{(2)(2.75")}{(3)(7.0")}\right)} = 0.79$

Calculations $\psi_{ec2,N}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,N}$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	When calculating nominal concrete breakout strength for a group of anchors in tension (N_{cbg}), ACI 318 anchoring-to-concrete provisions designate the modification factor for tension eccentricity "$\psi_{ec,N}$". Per Section 17.4.2.4, tension eccentricity can be considered with respect to the x and y directions. PROFIS Engineering designates the modification factor for tension eccentricity in the y direction "$\psi_{ec2,N}$". The parameter $e_{c2,N}$ is a PROFIS Engineering parameter to define tension eccentricity with respect to the y direction using Eq. (17.4.2.4). PROFIS Engineering calculations for tension eccentricity with respect to the y direction are as follows: • Calculate a resultant tension load acting on the anchors • Calculate the distance in the y direction ($e_{c2,N}$) between this load and the centroid of the anchors loaded in tension • Calculate a modification factor for tension eccentricity ($\psi_{ec2,N}$) with respect to the y direction If the resultant tension load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for eccentricity per ACI 318-14 Section 17.4.2.4 Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for tension eccentricity with respect to the x direction Below is an illustration showing how PROFIS Engineering accounts for eccentricity with respect to the y direction when calculating concrete breakout strength in tension.   Section A-A $N_{u,g}$ = resultant tension load $e_{c2,N} = 1.67"$ $h_{ef} = 7.0"$ $\psi_{ec2,N} = \frac{1}{\left(1 + \frac{(2)(1.67")}{(3)(7.0")}\right)} = 0.86$

Calculations $\psi_{ed,N}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right) \leq 1.0$	17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,N} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b)	$\psi_{ed,N}$ is a modification factor that is used to account for fixed edge distances less than $1.5h_{ef}$. The parameter h_{ef} corresponds to the effective embedment depth that has been selected for the anchor being modeled in PROFIS Engineering. When calculating the nominal concrete breakout strength in tension (N_{cb} or N_{cbs}), the model used to define the projected concrete failure area (A_{Nc}) limits the maximum edge distance for calculation purposes to a projected distance of $1.5h_{ef}$ from the anchors in tension. PROFIS Engineering will use a projected distance of $1.5h_{ef}$ from an anchor, or row of anchors, to define an outer edge of the area defined by A_{Nc} when the fixed edge distance from the anchor(s) is greater than $1.5h_{ef}$, or the edge is infinite. $\psi_{ed,N}$ is calculated whenever a fixed edge distance from an anchor(s) in tension is less than $1.5h_{ef}$. The parameter $c_{a,min}$ in the $\psi_{ed,N}$ equation corresponds to a fixed edge distance less than $1.5h_{ef}$. ACI 318 anchoring-to-concrete provisions define $c_{a,min}$ as the “minimum distance from the center of an anchor shaft to the edge of concrete”. When more than one fixed edge distance is less than $1.5h_{ef}$, the smallest value is input as $c_{a,min}$, and used to calculate $\psi_{ed,N}$. The illustration below shows how the projected concrete failure area (A_{Nc}) would be defined for an anchoring application being modeled with two fixed edges (c_{a1} and c_{a2}) that are both less than $1.5h_{ef}$, and with c_{a1} being less than c_{a2}. The smallest edge distance (c_{a1}) corresponds to the parameter $c_{a,min}$, that would be used to calculate the modification factor $\psi_{ed,N}$.  $\psi_{ed,N} = 0.7 + 0.3 (c_{a1} / 1.5h_{ef})$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: Parameter for the smallest fixed edge being modeled h_{ef}: Parameter for anchor effective embedment depth

Calculations $\psi_{cp,N}$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																	
$\Psi_{cp,N} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}} , \frac{1.5h_{ef}}{c_{ac}} \right) \leq 1.0$	17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\Psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq 1.5c_{ac}$, then $\Psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\Psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\Psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than 1.5h_{ef}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, including cast-in anchors, $\Psi_{cp,N}$ shall be taken as 1.0. 17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors.....</td><td>2h_{ef}</td></tr><tr><td>Undercut anchors.....</td><td>2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors.....</td><td>4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchors.....</td><td>4h_{ef}</td></tr></table> Example: Example of critical edge distance requirements given in a mechanical anchor approval. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="12">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="3">1/2</th><th colspan="3">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td><td></td></tr><tr><td>Min. member thickness</td><td>h_{min}</td><td>in.</td><td>3 1/4</td><td>4</td><td>5</td><td>5</td><td>4</td><td>6</td><td>6</td><td>8</td><td>5</td><td>6</td><td>8</td><td>5-1/2</td></tr><tr><td>Critical edge distance</td><td>c_{ac}</td><td>in.</td><td>6</td><td>4-3/8</td><td>4</td><td>4-1/8</td><td>5-1/2</td><td>4-1/2</td><td>7-1/2</td><td>6</td><td>6-1/2</td><td>8-3/4</td><td>6-3/4</td><td>12</td></tr></table> Example: Example of critical edge distance requirements given in an adhesive anchor approval. ICC-ESR-Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1 1/4 or #10</th></tr><tr><td>Critical edge distance — splitting (for uncracked concrete)</td><td>c_{ac}</td><td>-</td><td colspan="10">See Section 4.10.2 of this report.</td></tr></table>	Adhesive anchors.....	2h_{ef}	Undercut anchors.....	2.5h_{ef}	Torque-controlled expansion anchors.....	4h_{ef}	Displacement-controlled expansion anchors.....	4h_{ef}	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)												3/8			1/2			5/8			3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4		Min. member thickness	h_{min}	in.	3 1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12	DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)										3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1 1/4 or #10	Critical edge distance — splitting (for uncracked concrete)	c_{ac}	-	See Section 4.10.2 of this report.										$\Psi_{cp,N}$ is a modification factor that considers splitting failure when calculating the nominal concrete breakout strength in tension (N_{cb} or N_{cbg}) for a post-installed anchor. The parameter $\Psi_{cp,N}$ is only considered when designing post-installed mechanical or adhesive anchors installed in uncracked concrete. Splitting failure will typically not occur for cast-in-place anchors; therefore, $\Psi_{cp,N}$ is always shown equal to 1.0 in PROFIS Engineering when modeling cast-in-place anchors. Likewise, since splitting failure is only considered relevant to uncracked concrete conditions, $\Psi_{cp,N}$ is always shown equal to 1.0 in PROFIS Engineering when modeling cast-in-place or post-installed anchors for cracked concrete conditions. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\Psi_{cp,N}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” $\Psi_{cp,N}$ will be shown equal to 1.0 in PROFIS Engineering if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}. Testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2 is used to derive c_{ac} values for mechanical anchors. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR. ACI 318-14 Section 17.7.6 provides c_{ac}-values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the c_{ac}-value that is given in the ICC-ES evaluation report for an anchor to calculate $\Psi_{cp,N}$. The value for $\Psi_{cp,N}$ that PROFIS Engineering calculates will be limited to MAXIMUM {$c_{a,min}/c_{ac}$: 1.5h_{ef}/c_{ac}} where $c_{a,min}$ is the smallest fixed edge distance less than c_{ac} and h_{ef} is the effective embedment depth that has been selected for the anchor being modeled. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled. c_{ac}: Value derived from testing per AC193/ACI 355.2 or AC308/ACI 355.4 for the anchor being modeled. h_{ef}: Effective embedment depth that has been selected for the anchor being modeled. Reference the Equations section of the PROFIS Engineering report for more information on the parameter $\Psi_{cp,N}$.
Adhesive anchors.....	2h_{ef}																																																																																																																		
Undercut anchors.....	2.5h_{ef}																																																																																																																		
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Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																																																							
Min. member thickness	h_{min}	in.	3 1/4	4	5	5	4	6	6	8	5	6	8	5-1/2																																																																																																					
Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12																																																																																																					
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Critical edge distance — splitting (for uncracked concrete)	c_{ac}	-	See Section 4.10.2 of this report.																																																																																																																

Calculations $N_b = k_c \lambda_a$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_b = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5}$	17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_b = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5} \quad (17.4.2.2a)$ where $k_c = 24$ for cast-in anchors and 17 for post-installed anchors. The value of k_c for post-installed anchors shall be permitted to be increased above 17 based on ACI 355.2 or ACI 355.4 product-specific tests, but shall not exceed 24.	ACI 318 anchoring-to-concrete provisions for concrete breakout strength in tension require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{Nco}), eccentricity ($\psi_{ec,N}$), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete (ψ_{cn}), and splitting ($\psi_{sp,N}$); and then multiplying these factors by what is termed the “basic concrete breakout strength in tension” (N_b) to obtain a “nominal concrete breakout strength in tension” (N_{cb} or N_{cbg}). The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The parameter “coefficient for the basic concrete breakout strength in tension” (k_c) defaults to a value of 24 for cast-in-place anchors, corresponding to cracked concrete conditions. PROFIS Engineering always uses a k_c-value of 24 for cast-in-place anchors installed at an effective embedment depth (h_{ef}) less than 11 in, for both cracked and uncracked concrete conditions. When designing cast-in-place anchors in uncracked concrete, the modification factor ψ_{cn} can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). The default k_c-value noted for post-installed mechanical anchors and adhesive anchor systems in ACI 318-14 Section 17.4.2.2 equals 17. This section also notes that testing per the ACI test standards ACI 355.2 and ACI 355.4 can be used to derive k_c values for these anchors. k_c values for mechanical anchors can be derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. k_c values for adhesive anchor systems can be derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. These k_c values are specific to either cracked or uncracked concrete conditions; are relevant to the effective embedment depth range for the anchor; and are provided in an ICC-ESR. PROFIS Engineering uses the k_c-value that is given in the ICC-ES evaluation report for a post-installed anchor to calculate N_b. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c: Coefficient for basic concrete breakout strength in tension λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength h_{ef}: Effective embedment depth that has been selected for the anchor being modeled ψ_{cn}: Modification factor for cracked or uncracked concrete conditions Reference the Equations section of the PROFIS Engineering report for more information on the parameter N_b.

Calculations $N_b = 16\lambda_a$

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_b = 16\lambda_a \sqrt[5]{f'_c h_{ef}^{5/3}}$	17.4.2.2 Alternatively, for cast-in headed studs and headed bolts with 11 in. < h_{ef} < 25 in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt[5]{f'_c h_{ef}^{5/3}} \quad (17.4.2.2b)$	ACI 318 anchoring-to-concrete provisions for concrete breakout strength in tension require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{Nco}), eccentricity ($\psi_{ec,N}$), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete ($\psi_{c,N}$), and splitting ($\psi_{cp,N}$); and then multiplying these factors by what is termed the “basic concrete breakout strength in tension” (N_b) to obtain a “nominal concrete breakout strength in tension” (N_{cb} or N_{cbg}). The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The general equation for calculating N_b is defined as Eq. (17.4.2.2a) in ACI 318-14. This equation is written as: $N_b = k_c \lambda_a \sqrt[5]{f'_c h_{ef}^{1.5}} \quad (17.4.2.2a)$ ACI 318 anchoring-to-concrete provisions include a special case for calculating N_b when designing cast-in-place headed studs and headed bolts installed at an embedment depth within the range 11 in < h_{ef} < 25 in. This case is defined in ACI 318-14 by Eq. (17.4.2.2b). The “coefficient for the basic concrete breakout strength in tension” (k_c) equals 16 in Eq. (17.4.2.2b), and the effective embedment depth (h_{ef}) is raised to the 5/3 power instead of being raised to the 1.5 power per Eq. (17.4.2.2a). The provisions associated with use of Eq. (17.4.2.2b) are only relevant for cast-in-place headed studs and headed bolts installed at an embedment depth within the range 11 in < h_{ef} < 25 in. $k_c = 16$ corresponds to cracked concrete conditions. When designing cast-in-place anchors in uncracked concrete per Eq. (17.4.2.2b); the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). PROFIS Engineering calculates N_b per Eq. (17.4.2.2b) when cast-in-place headed studs and headed bolts with an embedment depth 11 in < h_{ef} < 25 in are being modeled. The commentary R17.4.2.2 notes that concrete breakout calculations for $h_{ef} > 25$ in per Equation (17.4.2.2b) could be unconservative. PROFIS Engineering calculations for concrete breakout strength in tension limit the embedment depth for both cast-in-place and post-installed anchors to a maximum value of 25 in. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c: Coefficient for basic concrete breakout strength in tension λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength h_{ef}: Effective embedment depth that has been selected for the anchor being modeled $\psi_{c,N}$: Modification factor for cracked or uncracked concrete conditions Reference the Equations section of the PROFIS Engineering report for more information on the parameter N_b.

PART 3 TENSION LOAD / Concrete Breakout Failure Mode

Results N_{cb}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
N_{cb}	17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$	ACI 318 anchoring-to-concrete provisions for the nominal concrete breakout strength of a single anchor in tension (N_{cb}) require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{Nc0}), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete ($\psi_{c,N}$), and splitting ($\psi_{cp,N}$); and then multiplying these factors by what is termed the “basic concrete breakout strength in tension” (N_b) to obtain a “nominal concrete breakout strength in tension” (N_{cb}). Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete

Results ϕN_{cb}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕN_{cb}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Tension Single Anchor $\phi N_{cb} > N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{cb}) against a factored tension load (N_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{cb}: Nominal concrete breakout strength in tension $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Results N_{cbg}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
N_{cbg}	17.4.2.1 The nominal concrete breakout strength in tension, ... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$	ACI 318 anchoring-to-concrete provisions for the nominal concrete breakout strength of an anchor group in tension (N_{cbg}) require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{Nc0}), eccentricity ($\psi_{ec,N}$), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete ($\psi_{cp,N}$), and splitting ($\psi_{cp,N}$); and then multiplying these factors by what is termed the “basic concrete breakout strength in tension” (N_b) to obtain a “nominal concrete breakout strength in tension” (N_{cbg}). Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ec,N}$: Tension modification factor for eccentricity $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete

Results ϕN_{cbg}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕN_{cbg}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Tension Anchors as a Group $\phi N_{cbg} > N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{cbg}) against a factored tension load (N_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{cbg}: Nominal concrete breakout strength in tension $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Results ϕ_{concrete}

Results	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering									
ϕ_{concrete}	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used:																			
	(c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength																			
											Condition A					Condition B				
	(ii) Tension loads Cast-in headed studs, headed bolts, or hooked bolts										0.75					0.70				
	Post-installed anchors with category as determined from ACI 355.2 or ACI 355.4																			
	Category 1 (Low sensitivity to Installation and high reliability)										0.75					0.65				
	Category 2 (Medium sensitivity to Installation and medium reliability)										0.65					0.55				
	Category 3 (High sensitivity to Installation and lower reliability)										0.55					0.45				
	Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths.																			
	Example: Example of a post-installed mechanical anchor strength reduction factor (ϕ -factor) corresponding to concrete breakout failure in tension.																			
ICC-ESR-1917 Table 3																				
DESIGN INFORMATION		Symbol	Units	Nominal anchor diameter (in.)																
Effective min. embedment		h_{ef}	in.	3/8		1/2		5/8		3/4										
				1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4							
Strength reduction 0 factor for tension, concrete failure modes, or pullout, Condition B				0.55	0.65															
Example: Example of a post-installed adhesive anchor system strength reduction factor (ϕ -factor) corresponding to concrete breakout failure in tension.																				
ICC-ESR-3187 Table 12																				
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)																
Strength reduction 0 factor for tension, concrete failure modes, or pullout, Condition B		ϕ	-	3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1/4 or #10									
				0.65																
ACI 318-14 strength design provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ -factors) to obtain a design strength (ϕN_{cb} or ϕN_{cbg}). ϕ -factors are relevant to static and seismic load conditions.																				
PROFIS Engineering designates the ϕ -factor corresponding to concrete breakout failure for static load conditions " ϕ_{concrete} ". When designing cast-in-place anchors, PROFIS Engineering uses the ϕ -actors given in ACI 318-14 Section 17.3.3. The ϕ -factors in Section 17.3.3 that are given for post-installed anchors are only intended to be used as guide values in the absence of product-specific data.																				
Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. When Condition B is selected as a post-installed anchor design parameter, PROFIS Engineering uses the ϕ -factors derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. The ϕ -factors in the ICC-ESR correspond to Condition B.																				
PROFIS Engineering defaults to Condition B when calculating concrete breakout strength in tension. If Condition A is selected as a design parameter for either cast-in-place or post-installed anchors, PROFIS Engineering uses the Condition A ϕ -factors given in ACI 318-14 Section 17.3.3 to calculate the design concrete breakout strength in tension.																				
PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions " ϕ_{seismic} ".																				
Reference the Results section of the PROFIS Engineering report for more information on the following parameters:																				
N_{cb} or N_{cbg} : Nominal concrete breakout strength in tension																				
ϕN_{cb} or ϕN_{cbg} : Design concrete breakout strength in tension																				
ϕ_{seismic} : Strength reduction factor for seismic tension																				

Results $\phi_{\text{nonductile}}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 – As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	ACI 318-14 strength design provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_{cb} or ϕN_{cbg}). ϕ-factors are relevant to static and seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions "ϕ_{seismic}". This reduction is applied to non-steel failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors using ACI 318-14 anchoring-to-concrete provisions. When using ACI 318-14 anchoring-to-concrete provisions to calculate the design concrete breakout strength in tension for cast-in-place and post-installed anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report corresponds to the parameter "ϕ" shown in ACI 318-14 Section 17.2.3.4.4. The parameter "$\phi_{\text{nonductile}}$" is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor "$\phi_{\text{nonductile}}$". "$\phi_{\text{nonductile}}$" is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

Results N_{ua}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
N_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_{cb} or ϕN_{cbg}). ϕ-factors are relevant to static and seismic load conditions. Design strength is checked against a factored tension load, defined by the parameter “N_{ua}”. Chapter 2 in ACI 318-14 gives the following definitions for the factored tension load parameter “N_{ua}”. • N_{ua} = factored tensile force applied to anchor or individual anchor in a group of anchors (lb) • $N_{ua,i}$ = factored tensile force applied to most highly stressed anchor in a group of anchors (lb) • $N_{ua,g}$ = total factored tensile force applied to anchor group (lb) The design concrete breakout strength for a single anchor in tension (ϕN_{cb}) calculated per Section 17.4.2 is checked against the factored tension load acting on the anchor, which is designated “N_{ua}” in Table 17.3.1.1. If $\phi N_{cb} > N_{ua}$, the provisions for considering concrete breakout failure in tension have been satisfied per Table 17.3.1.1. The design concrete breakout strength for a group of anchors in tension (ϕN_{cbg}) calculated per Section 17.4.2 is checked against the total factored tension load acting on the anchors that are in tension, which is designated “$N_{ua,g}$” in Table 17.3.1.1. If $\phi N_{cbg} > N_{ua,g}$, the provisions for considering concrete breakout failure in tension have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation “N_{ua}” to define the factored tension load being checked against the calculated design concrete breakout strength ϕN_{cb} or ϕN_{cbg}. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting tension loads. The software only performs tension load checks per Table 17.3.1.1 if tension loads have been input via one of the load input functionalities. If a single anchor in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{cb}, and checks this value against either (a) the factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchor. If a group of anchors in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{cbg}, and checks this value against either (a) the total factored tension load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored tension load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored tension load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the total factored tension load determined to be acting on the anchor group. Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameters ϕN_{cb} and ϕN_{cbg}.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$																									
Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Equations N_{pn}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
cast-in anchors N_{pn}	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ where $\psi_{c,p}$ is defined in 17.4.3.6. 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors.	Nominal pullout strength (N_{pn}) is a possible tension failure mode for cast-in-place anchors and post-installed mechanical anchors. Generally speaking, bond failure is considered for adhesive anchor systems in lieu of pullout failure; however, the Hilti adhesive anchor system "HIT-HY 200" includes a proprietary anchor element known as a HIT-Z threaded rod, for which a nominal pullout strength is calculated in lieu of a nominal bond strength. PROFIS Engineering calculates the nominal pullout strength (N_{pn}) for the cast-in-place anchors in its portfolio using Eq. (17.4.3.1). The PROFIS Engineering cast-in-place anchor portfolio includes the following anchors: • AWS D1.1 Type B headed studs (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 1 1/2" nominal diameter) Section 17.4.3.2 notes that testing per the ACI test standard ACI 355.2 must be used to derive the pullout strength of a single anchor (N_p) for a post-installed mechanical anchor (e.g. expansion or undercut anchor). N_p is one of the parameters used to calculate the nominal pullout strength (N_{pn}). Mechanical anchor N_p-values can be derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. N_p-values for HIT-Z threaded rods used with HIT-HY 200 adhesive can be derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. Post-installed anchor N_p-values are provided in an ICC-ESR. PROFIS Engineering uses the N_p-values that are given in the ICC-ESR to calculate N_{pn} for relevant post-installed anchors in its portfolio. The parameter $\psi_{c,p}$ is a modification factor for cracked or uncracked concrete conditions. PROFIS Engineering determines $\psi_{c,p}$ per Section 17.4.3.6 for the cast-in anchors in its portfolio. PROFIS Engineering always uses a $\psi_{c,p}$-value equal to 1.0 when calculating N_{pn} for the post-installed anchors in its portfolio. When modeling cast-in anchors in PROFIS Engineering, reference the Equations and Calculations section of the report for more information on the parameter N_p. Reference the Variables section of the report for more information on the parameter $\psi_{c,p}$. When modeling post-installed anchors in PROFIS Engineering, Reference the Equations section of the report for information on the following anchor-specific pullout parameters: • $N_{pn,f,c}$ if mechanical anchors are being modeled • N_{pn} if HIT-HY 200 with HIT-Z and HIT-Z-R threaded rods is being modeled

Equations N_p

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																			
cast-in anchors $N_p = 8A_{brg} f'_c$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.3 For single cast-in headed studs and headed bolts, it shall be permitted to evaluate the pullout strength in tension using 17.4.3.4. For single J- or L-bolts, it shall be permitted to evaluate the pullout strength in tension using 17.4.3.5. Alternatively, it shall be permitted to use values of N_p based on the 5 percent fractile of tests performed and evaluated in the same manner as the ACI 355.2 procedures but without the benefit of friction. 17.4.3.4 The pullout strength in tension of a single headed stud or headed bolt, N_p, for use in Eq. (17.4.3.1), shall not exceed $N_p = 8A_{brg} f'_c \quad (17.4.3.4)$ 17.4.3.5 The pullout strength in tension of a single hooked bolt, N_p, for use in Eq. (17.4.3.1), shall not exceed $N_p = 0.9 f'_c e_h d_a \quad (17.4.3.5)$ Profis Engineering cast-in anchor portfolios for bearing area (A_{brg}). <table><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d_a) (in)</th><th>Bearing area (A_{brg} in²) Welded headed stud</th><th>Bearing area (A_{brg} in²) Square head bolt</th><th>Bearing area (A_{brg} in²) Heavy square bolt</th><th>Bearing area (A_{brg} in²) Hex head bolt</th><th>Bearing area (A_{brg} in²) Heavy hex head bolt</th></tr><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td></td><td></td><td></td><td></td></tr><tr><td>0.625</td><td>0.920</td><td></td><td></td><td></td><td></td></tr><tr><td>0.750</td><td>0.785</td><td></td><td></td><td></td><td></td></tr><tr><td>0.875</td><td>0.884</td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="11">ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105</td><td>0.500</td><td></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td></td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td></td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td></td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td></td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td></td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td></td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td></td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td></td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td></td><td>5.316</td></tr></table>	MATERIAL SPECIFICATION	Diameter (d_a) (in)	Bearing area (A_{brg} in ²) Welded headed stud	Bearing area (A_{brg} in ²) Square head bolt	Bearing area (A_{brg} in ²) Heavy square bolt	Bearing area (A_{brg} in ²) Hex head bolt	Bearing area (A_{brg} in ²) Heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920					0.750	0.785					0.875	0.884					ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105	0.500		0.464	0.569	0.291	0.467	0.625		0.693	0.822	0.454	0.671	0.750		0.824	1.210	0.654	0.911	0.875		1.121	1.465	0.891	1.188	1.000		1.465	1.855	1.163	1.501	1.125		1.854	2.291	1.472	1.851	1.250		2.228	2.773	1.817	2.237	1.375		2.769	3.300	2.199	2.659	1.500		3.295	3.873	2.617	3.118	1.750					4.144	2.000					5.316	The parameter “N_p” in Eq. (17.4.3.1) is defined as the “pullout strength in tension” for a single anchor. PROFIS Engineering calculates N_p per Eq. (17.4.3.4) for the cast-in anchors in its portfolio. The PROFIS Engineering cast-in-place anchor portfolio is as follows: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) Bearing area values (A_{brg}) for these anchors are shown in the table to the left. Cast-in J-bolts and L-bolts are not included in the PROFIS Engineering cast-in anchor portfolio. PROFIS Engineering only calculates N_p per Eq. (17.4.3.4) for cast-in anchors. N_p for post-installed anchors is derived from testing. Reference the Calculations section of the report for more information on the parameter N_p. Reference the Variables section of the report for more information on the following parameters: • A_{brg} — bearing area for a cast-in anchor • f'_c — concrete compressive strength PROFIS Engineering does not calculate N_p per Eq. (17.4.3.4) for the post-installed anchors in its portfolio. N_p-values are derived from product-specific testing. Reference the post-installed anchor report sections relevant to pullout strength in tension for more information.
MATERIAL SPECIFICATION	Diameter (d_a) (in)	Bearing area (A_{brg} in ²) Welded headed stud	Bearing area (A_{brg} in ²) Square head bolt	Bearing area (A_{brg} in ²) Heavy square bolt	Bearing area (A_{brg} in ²) Hex head bolt	Bearing area (A_{brg} in ²) Heavy hex head bolt																																																																																															
AWS D1.1 Type B Headed Stud	0.500	0.589																																																																																																			
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Equations $N_{p,f'c}$

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																													
mechanical anchors $N_{pn,f'c} = N_{p,2500} \lambda_a (f'_c / 2500)^n$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-1917 for the Hilti Kwik Bolt-TZ (KB-TZ) expansion anchor referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). 4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, respectively, as applicable, in cracked and uncracked concrete, N_{p,cr} and N_{p,uncr}, respectively, is given in Tables 3 and 4. For all design cases, ψ_{c,p} = 1.0. In accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, the nominal pullout strength in cracked concrete may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-1)$ In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,uncr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-2)$ Where values for N_{p,cr} or N_{p,uncr} are not provided in Table 3 or Table 4, the pullout strength in tension need not be evaluated. Excerpt from ICC-ESR-1917 showing values for N_{p,cr} and N_{p,uncr} derived from testing in 2500 psi concrete per AC193/ACI 355.2. ICC-ES ECR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Pullout strength cracked concrete</td><td>n_{p,uncr}</td><td>lb</td><td>2160</td><td>2515</td><td>4110</td><td>NA</td><td>5515</td><td>NA</td><td>9145</td><td>NA</td><td>8280</td><td>10680</td></tr><tr><td>Pullout strength uncracked concrete</td><td>N_{p,cr}</td><td>lb</td><td>NA</td><td>2270</td><td>3160</td><td>NA</td><td>4915</td><td>NA</td><td></td><td colspan="3">NA</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Pullout strength cracked concrete	n_{p,uncr}	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680	Pullout strength uncracked concrete	N_{p,cr}	lb	NA	2270	3160	NA	4915	NA		NA			PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). For mechanical anchors, the Equations and Results section of the report designate N_{pn} as “N_{pn,f'c}”. Per ACI 318-14 Section 17.4.3.2, the parameter “N_p” for mechanical anchors must be derived from testing. PROFIS Engineering uses the N_p-value given in the mechanical anchor ICC-ESR to calculate N_{pn,f'c}. PROFIS Engineering always uses ψ_{c,p} = 1.0 for mechanical anchor calculations. N_p-values in the ICC-ESR are derived from testing in 2500 psi concrete; therefore, the Variables section of the PROFIS Engineering report designates the N_p-value from the ICC-ESR as “N_{p,2500}”. The ICC-ESR provisions shown to the left illustrate how the N_p-value given in the ICC-ESR design tables (derived from testing in 2500 psi concrete) can be increased for design purposes when the concrete compressive strength (f'_c) for the application is greater than 2500 psi. Generally speaking, the factor by which “N_{p,2500}” can be increased equals (f'_c/2500)^{0.5}; however, the parameter (f'_c/2500) may be raised to another power. Reference Section 4.1.4 of the mechanical anchor ICC-ESR for specific information about this factor. PROFIS Engineering multiplies “N_{p,2500}” by (f'_c/2500)ⁿ when calculating nominal pullout strength for a mechanical anchor. The calculated value for (f'_c/2500)ⁿ is shown in the Calculations section of the mechanical anchor report. If pullout is not a possible controlling failure mode for a particular anchor diameter and embedment depth, the ICC-ESR will show “NA”, and no N_p-value will be given. PROFIS Engineering does not perform pullout calculations for anchor diameters/ embedment's for which “NA” is given in the ICC-ESR PROFIS Engineering applies a lightweight concrete modification factor (λ_a) to the N_p-value if lightweight concrete is being modeled. Reference the Variables section of the report for more information on the following parameters: • N_{p,2500} — tested pullout value in 2500 psi concrete • λ_a — lightweight concrete modification factor • f'_c — concrete compressive strength Reference the Calculations section of the report for more information on the parameter (f'c/2500)ⁿ. Reference the Results section of the report for more information on the parameter N_{pn,f'c}. When modeling cast-in anchors, PROFIS Engineering calculates nominal the pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DESIGN INFORMATION	Symbol				Units	Nominal anchor diameter (in.)																																																									
		3/8		1/2		5/8		3/4																																																							
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																			
Pullout strength cracked concrete	n_{p,uncr}	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680																																																			
Pullout strength uncracked concrete	N_{p,cr}	lb	NA	2270	3160	NA	4915	NA		NA																																																					

Equations N_{pn}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																															
HIT-Z anchor with HIT-HY 200 $N_{pn} = N_p \lambda_a$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-3187 for Hilti HIT-HY 200 adhesive, referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1) with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. 4.1.4.1 Static Pullout Strength in Tension: Hilti HIT-Z and HIT-Z-R Anchor Rods: The nominal static pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Table 10. For all design cases, $\psi_{c,p} = 1.0$. Pullout strength values are a function of the concrete compressive strength, whether the concrete is cracked or uncracked, the drilling method (hammer drill, including Hilti hollow drill bit, diamond core drill) and installation conditions (dry or water-saturated). The resulting characteristic pullout strength must be multiplied by the associated strength reduction factor ϕ_{nn} as follows: Hilti HIT-Z and HIT-Z-R threaded rods <table><tr><th>DRILLING METHOD</th><th>Concrete type</th><th>Permissible installation conditions</th><th>Pullout strength</th><th>Associated strength reduction factor</th></tr><tr><td rowspan="4">Hammer-drill (or Hilti TE-CD or TE-YD Hollow Drill Bit) or Diamond Core Bit</td><td rowspan="2">Uncracked</td><td>Dry</td><td>$N_{p,uncr}$</td><td>ϕ_d</td></tr><tr><td>Water saturated</td><td>$N_{p,uncr}$</td><td>ϕ_{ws}</td></tr><tr><td rowspan="2">Cracked</td><td>Dry</td><td>$N_{p,cr}$</td><td>ϕ_d</td></tr><tr><td>Water saturated</td><td>$N_{p,cr}$</td><td>ϕ_{ws}</td></tr></table> Excerpt from ICC-ESR-3187 Table 10 showing values for $N_{p,cr}$ and $N_{p,uncr}$ derived from testing per AC308/ACI 355.4. ICC-ESR-3187 Table 10 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td rowspan="2">Temperature Range A</td><td>Pullout strength in cracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>7,952</td><td>10,936</td><td>21,392</td><td>27,930</td></tr><tr><td>Pullout strength in uncracked concrete</td><td>$N_{p,uncr}$</td><td>lb</td><td>7,952</td><td>11,719</td><td>21,931</td><td>28,460</td></tr></table>	DRILLING METHOD	Concrete type	Permissible installation conditions	Pullout strength	Associated strength reduction factor	Hammer-drill (or Hilti TE-CD or TE-YD Hollow Drill Bit) or Diamond Core Bit	Uncracked	Dry	$N_{p,uncr}$	ϕ_d	Water saturated	$N_{p,uncr}$	ϕ_{ws}	Cracked	Dry	$N_{p,cr}$	ϕ_d	Water saturated	$N_{p,cr}$	ϕ_{ws}	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)				3/8	1/2	5/8	3/4	Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,392	27,930	Pullout strength in uncracked concrete	$N_{p,uncr}$	lb	7,952	11,719	21,931	28,460	PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). Although not referenced in ACI 318-14 Section 17.4.3.2, pullout failure in lieu of bond failure must be considered for Hilti HIT-HY 200 used with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. A characteristic pullout strength in tension (N_p) derived from testing is used to calculate a nominal pullout strength (N_{pn}) for HY 200 when used with HIT-Z/Z-R threaded rods. The parameter $\psi_{c,p}$ in Eq. (17.4.3.1) is a modification factor for cracked or uncracked concrete. PROFIS Engineering always uses $\psi_{c,p} = 1.0$ for HY 200/HIT-Z N_{pn} calculations because cracked and uncracked concrete conditions are accounted for in the N_p-values derived from testing. PROFIS Engineering applies a lightweight concrete modification factor (λ_a), and a seismic modification factor ($\alpha_{N,seis}$), to the N_{pn}-value if lightweight concrete and/or seismic conditions are being modeled. λ_a-values and $\alpha_{N,seis}$-values are shown in the Variables section of the report. N_p-values for HIT-Z and HIT-Z-R threaded rods derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4 (a) are provided in ICC-ESR-3187 Table 10, (b) are specific to the concrete condition (cracked or uncracked), and (c) are specific to anchor diameter. N_p-values in the ICC-ESR are valid for concrete compressive strengths $2500 \text{ psi} < f'_c < 8000 \text{ psi.}$ N_p-values for HIT-Z and HIT-Z-R threaded rods shown in the Variables section of the PROFIS Engineering report are taken from ICC-ESR-3187 Table 10. Reference the Variables section of the report for more information on the following parameters: • N_p — tested pullout value from ICC-ESR-3187 • λ_a — lightweight concrete modification factor • $\alpha_{N,seis}$ — seismic modification factor Reference the Results section of the report for more information on the parameter N_{pn}. When modeling cast-in anchors, PROFIS Engineering calculates the nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information
DRILLING METHOD	Concrete type	Permissible installation conditions	Pullout strength	Associated strength reduction factor																																													
Hammer-drill (or Hilti TE-CD or TE-YD Hollow Drill Bit) or Diamond Core Bit	Uncracked	Dry	$N_{p,uncr}$	ϕ_d																																													
		Water saturated	$N_{p,uncr}$	ϕ_{ws}																																													
	Cracked	Dry	$N_{p,cr}$	ϕ_d																																													
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	Pullout strength in uncracked concrete	$N_{p,uncr}$	lb	7,952	11,719	21,931	28,460																																										

Equations ϕN_{pn}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering						
$\phi N_{pn} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode <table> <tr> <td></td><td>Single Anchor</td><td>Individual Anchor in a Group</td></tr> <tr> <td>Pullout Strength in Tension</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} > N_{ua,i}$</td></tr> </table> Below is a summary of PROFIS Engineering pullout strength calculations. For a single anchor in tension, PROFIS Engineering checks the calculated design strength against the factored tension load acting on that anchor (N_{ua}). For a group of anchors in tension, PROFIS Engineering checks the calculated design strength against the highest factored tension load determined to be acting on a single anchor (N_{ua}). cast-in anchors PROFIS Engineering parameters for calculating the nominal pullout strength of cast-in anchors: $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ PROFIS Engineering parameters for calculating the design pullout strength of cast-in anchors: static load conditions — design strength = $\phi_{concrete} N_{pn}$ seismic load conditions — design strength = $\phi_{seismic} \phi_{concrete} N_{pn}$ mechanical anchors PROFIS Engineering parameters for calculating the nominal pullout strength of mechanical anchors: $N_{pn,f'c} = N_{p,2500} \lambda_a (f'_c / 2500)^n$ PROFIS Engineering parameters for calculating the design pullout strength of mechanical anchors: static load conditions — design strength = $\phi_{concrete} N_{pn,f'c}$ seismic load conditions — design strength = $\phi_{seismic} \phi_{concrete} N_{pn,f'c}$ HIT-Z/R threaded rods used with HIT-HY 200 adhesive PROFIS Engineering parameters for calculating the nominal pullout strength of HIT-Z and HIT-Z-R threaded rods used with HIT-HY 200 adhesive: $N_{pn} = N_p \lambda_a$ PROFIS Engineering parameters for calculating the design pullout strength of HIT-Z and HIT-Z-R anchors used with HIT-HY 200 adhesive: static load conditions — design strength = $\phi_{concrete} N_{pn}$ seismic load conditions — design strength = $\phi_{seismic} \phi_{concrete} N_{pn}$		Single Anchor	Individual Anchor in a Group	Pullout Strength in Tension	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} > N_{ua,i}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{pn}) against a factored tension load (N_{ua}). The parameter “design strength” is defined as the product of a “nominal strength” (N_{pn}) and one or more strength reduction factors (ϕ-factors). If $\phi N_{pn} > N_{ua}$ for all relevant tension failure modes, the ACI 318-14 tension provisions are satisfied. Nominal pullout strength in tension (N_{pn}) is always calculated for a single anchor when designing with the provisions of ACI 318-14. If an application consists of a group of anchors in tension, N_{pn} is calculated for a single anchor, and the design strength is checked against the highest loaded anchor in tension. Since pullout failure can be considered a “concrete” failure mode, PROFIS Engineering designates the strength reduction factor for pullout failure “$\phi_{concrete}$”. ACI 318-14 anchoring-to-concrete provisions for seismic load conditions require an additional ϕ-factor to be applied to non-steel design strengths. PROFIS Engineering designates this parameter “$\phi_{seismic}$”. ACI 318-08 anchoring-to-concrete provisions include an additional seismic reduction factor that is applied to anchor design strengths corresponding to brittle failure modes. Pullout failure is considered a brittle failure mode; therefore, design pullout strengths calculated using ACI 318-08 seismic provisions would include an additional strength reduction factor, which PROFIS Engineering designates “$\phi_{nonductile}$”. Since $\phi_{nonductile}$ is only relevant to seismic calculations with ACI 318-08 provisions, PROFIS Engineering always shows the parameter “$\phi_{nonductile}$” equal to 1.0 in the Results section of reports for ACI 318-14 provisions. Reference the Equations and Results section of the PROFIS Engineering report for more information on: N_{pn} or $N_{pn,f'c}$: Nominal pullout strength in tension Reference the Results section of the PROFIS Engineering report for more information on the following parameters: $\phi_{concrete}$: Strength reduction factor for pullout failure $\phi_{seismic}$: Strength reduction factor for seismic tension ϕN_{pn} or $\phi N_{pn,f'c}$: Design steel strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.
	Single Anchor	Individual Anchor in a Group						
Pullout Strength in Tension	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} > N_{ua,i}$						

Variables $\psi_{c,p}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{c,p}$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ where $\psi_{c,p}$ is defined in 17.4.3.6. 17.4.3.6 For an anchor loaded in a region of a concrete member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted $\psi_{c,p} = 1.4$ Where analysis indicates cracking at service load levels, $\psi_{c,p}$ shall be taken as 1.0. cast-in anchors PROFIS Engineering parameters for calculating the nominal pullout strength of cast-in anchors: $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ mechanical anchors PROFIS Engineering parameters for calculating the nominal pullout strength of mechanical anchors: $N_{pn,f'c} = N_{p,2500} \lambda_a (f'_c / 2500)^n$ HIT-Z/R threaded rods used with HIT-HY 200 adhesive PROFIS Engineering parameters for calculating the nominal pullout strength of HIT-Z and HIT-Z-R threaded rods used with HIT-HY 200 adhesive: $N_{pn} = N_p \lambda_a$	ACI 318 anchoring-to-concrete provisions default to an assumption that concrete will crack under service load conditions. $\psi_{c,p}$ is a modification factor for cracked or uncracked concrete conditions when calculating nominal pullout strength in tension. $\psi_{c,p} = 1.0$ for cracked concrete conditions. If analysis indicates that concrete will remain uncracked under service load conditions, $\psi_{c,p}$ can be increased to a value of 1.4. When designing cast-in anchors with PROFIS Engineering, and cracked concrete conditions are assumed; PROFIS Engineering calculates the nominal pullout strength (N_{pn}) using $\psi_{c,p} = 1.0$. If uncracked concrete conditions are assumed, PROFIS Engineering calculates the nominal pullout strength (N_{pn}) using $\psi_{c,p} = 1.4$. PROFIS Engineering always calculates pullout strength for the post-installed anchors in its portfolio using $\psi_{c,p} = 1.0$, regardless of whether cracked or uncracked concrete conditions have been assumed. When designing mechanical anchors, the nominal pullout strength ($N_{pn,f'c}$) accounts for cracked or uncracked concrete conditions via the parameter ($N_{p,2500}$). When designing HIT-Z or HIT-Z-R threaded rods with HIT-HY 200 adhesive, the nominal pullout strength (N_{pn}) accounts for cracked or uncracked concrete conditions via the parameter (N_p). Reference the Equations and Results section of the cast-in anchor report for more information on the following parameters: • N_{pn} — nominal pullout strength for cast-in or adhesive anchors Reference the Equations and Results section of the post-installed anchor report for more information on the following parameters: • N_{pn} — nominal pullout strength for HIT-Z/R anchors with HIT-HY 200 • $N_{pn,f'c}$ — nominal pullout strength for mechanical anchors Reference the Variables section of the post-installed anchor report for more information on the following parameters: • $N_{p,2500}$ — tested pullout strength for mechanical anchors • N_p — tested pullout strength for HIT-Z/R anchors with HIT-HY 200

Variables A_{brg}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																							
A_{brg}	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.3 For single cast-in headed studs and headed bolts, it shall be permitted to evaluate the pullout strength in tension using 17.4.3.4. For single J- or L-bolts, it shall be permitted to evaluate the pullout strength in tension using 17.4.3.5. Alternatively, it shall be permitted to use values of N_p based on the 5 percent fractile of tests performed and evaluated in the same manner as the ACI 355.2 procedures but without the benefit of friction. 17.4.3.4 The pullout strength in tension of a single headed stud or headed bolt, N_p, for use in Eq. (17.4.3.1), shall not exceed $N_p = 8A_{brg} f'_c \quad (17.4.3.4)$ 17.4.3.5 The pullout strength in tension of a single hooked bolt, N_p, for use in Eq. (17.4.3.1), shall not exceed $N_p = 0.9 f'_c e_n d_a \quad (17.4.3.5)$ Profis Engineering cast-in anchor portfolios for bearing area (A_{brg}). <table><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d) (in)</th><th>Bearing area (A_{brg} in²) Welded headed stud</th><th>Bearing area (A_{brg} in²) Square head bolt</th><th>Bearing area (A_{brg} in²) Heavy square bolt</th><th>Bearing area (A_{brg} in²) Hex head bolt</th><th>Bearing area (A_{brg} in²) Heavy hex head bolt</th></tr><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td></tr><tr><td>0.625</td><td>0.920</td></tr><tr><td>0.750</td><td>0.785</td></tr><tr><td>0.875</td><td>0.884</td></tr><tr><td rowspan="11">ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105</td><td>0.500</td><td></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td></td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td></td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td></td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td></td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td></td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td></td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td></td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td></td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td></td><td>5.316</td></tr></table>	MATERIAL SPECIFICATION	Diameter (d) (in)	Bearing area (A_{brg} in ²) Welded headed stud	Bearing area (A_{brg} in ²) Square head bolt	Bearing area (A_{brg} in ²) Heavy square bolt	Bearing area (A_{brg} in ²) Hex head bolt	Bearing area (A_{brg} in ²) Heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920	0.750	0.785	0.875	0.884	ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105	0.500		0.464	0.569	0.291	0.467	0.625		0.693	0.822	0.454	0.671	0.750		0.824	1.210	0.654	0.911	0.875		1.121	1.465	0.891	1.188	1.000		1.465	1.855	1.163	1.501	1.125		1.854	2.291	1.472	1.851	1.250		2.228	2.773	1.817	2.237	1.375		2.769	3.300	2.199	2.659	1.500		3.295	3.873	2.617	3.118	1.750					4.144	2.000					5.316	The parameter “N_p” in Eq. (17.4.3.1) is defined as the “pullout strength in tension” for a single anchor. PROFIS Engineering calculates N_p per Eq. (17.4.3.4) for the cast-in anchors in its portfolio. These anchors are as follows: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) J-bolts and L-bolts are not included in the PROFIS Engineering cast-in anchor portfolio. PROFIS Engineering only utilizes the bearing area parameter (A_{brg}) to calculate the parameter N_p per Eq. (17.4.3.4) for the cast-in anchors in its portfolio. The A_{brg}-values that PROFIS Engineering uses for these anchors are shown in the table to the left. PROFIS Engineering does not calculate N_p per Eq. (17.4.3.4) for the post-installed anchors in its portfolio. These N_p-values are derived from product-specific testing. Reference the post-installed anchor report sections relevant to pullout strength in tension for more information. Reference the Calculations section of the cast-in anchor report for more information on the parameter N_p. Reference the Variables section of the cast-in anchor report for more information on the following parameters: • A_{brg} — bearing area for a cast-in anchor • f'_c — concrete compressive strength
MATERIAL SPECIFICATION	Diameter (d) (in)	Bearing area (A_{brg} in ²) Welded headed stud	Bearing area (A_{brg} in ²) Square head bolt	Bearing area (A_{brg} in ²) Heavy square bolt	Bearing area (A_{brg} in ²) Hex head bolt	Bearing area (A_{brg} in ²) Heavy hex head bolt																																																																																			
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Variables λ_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure 1.0 λ Expansion and adhesive anchor concrete failure 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85 ⁽¹⁾</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33</td><td>0.85 to 1 ⁽²⁾</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> ¹ Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. ² Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}^{1.5}}{6.7 / f_{cm}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work. When lightweight concrete conditions are being modeled, PROFIS Engineering applies the parameter λ_a as follows: cast-in anchors $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ $N_p = 8A_{brg} f'_c \quad (17.4.3.4) \quad \lambda_a = 1.0 \text{ for pullout calculations}$ mechanical anchors $N_{pn,f_c} = N_{p,2500} \lambda_a (f'_c / 2500)^n \quad \text{where } \lambda_a = 0.8 \lambda$ HIT-Z/R threaded rods used with HIT-HY 200 adhesive $N_{pn} = N_p \lambda_a \quad \text{where } \lambda_a = 0.6 \lambda$	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33	0.85 to 1 ⁽²⁾	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	λ_a is a modification factor for lightweight concrete. Generally speaking, ACI 318 applies a multiplier to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete”, and designates this parameter “λ”. The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to anchoring-to-concrete calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the type of anchor being used, to obtain the parameter λ_a. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a-provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. For post-installed anchor design, PROFIS Engineering uses a λ_a-value as referenced in the ICC-ESR provisions for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. PROFIS Engineering uses the λ-value that has been input, to calculate a λ_a-value for the anchor being modeled. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. No reduction for lightweight concrete is required when calculating nominal pullout strength in tension for cast-in anchors per Eq. (17.4.3.4), because no $\sqrt{f'_c}$ parameter is present in the equation. If cast-in anchors are being modeled for lightweight concrete conditions in PROFIS Engineering, ($\lambda_a = 1.0 \lambda$) will be used in the concrete breakout, side-face blowout and pryout calculations. The λ_a-value will be calculated per Section 17.2.6. No λ_a-value will be used in the pullout calculations. The Variables section for pullout in the report will show the parameter λ_a equal to 1.0. If post-installed expansion anchors or HIT-Z/HIT-Z-R threaded rods with HIT HY 200 adhesive are being modeled for lightweight concrete conditions in PROFIS Engineering, the software calculates a λ_a-value per Section 17.2.6. The λ-value that has been input is multiplied by a factor of 0.8 (expansion anchors) or by a factor of 0.6 (HIT-Z/HIT-Z-R with HIT HY 200) to obtain a λ_a-value for pullout calculations. This functionality is summarized to the left. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_{pn} or N_{pn,f_c} when lightweight concrete conditions are being modeled for post-installed anchors.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33	0.85 to 1 ⁽²⁾																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

Variables f'_c

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																													
f'_c	17.4.3.4 The pullout strength in tension of a single headed stud or headed bolt, N_p, for use in Eq. (17.4.3.1), shall not exceed $N_p = 8A_{brg} f'_c \quad (17.4.3.4)$ 17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors, and 8000 psi for post-installed anchors. Testing is required for post-installed anchors when used in concrete with f'_c greater than 8000 psi. Excerpt from ICC-ESR-1917 for the Hilti Kwik Bolt-TZ (KB-TZ) expansion anchor referencing provisions for pullout strength in tension. 4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, respectively, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,un-cr}$, respectively, is given in Tables 3 and 4. For all design cases, $\Psi_{e,p} = 1.0$. In accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, the nominal pullout strength in cracked concrete may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-1)$ In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,un-cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-2)$ Where values for $N_{p,cr}$ or $N_{p,un-cr}$ are not provided in Table 3 or Table 4, the pullout strength in tension need not be evaluated. Excerpt from ICC-ESR-1917 showing values for $N_{p,cr}$ and $N_{p,un-cr}$ derived from testing in 2500 psi concrete per AC193/ACI 355.2. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Pullout strength cracked concrete</td><td>$N_{p,un-cr}$</td><td>lb</td><td>2160</td><td>2515</td><td>4110</td><td>NA</td><td>5515</td><td>NA</td><td>9145</td><td>NA</td><td>8280</td><td>10680</td></tr><tr><td>Pullout strength uncracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>NA</td><td>2270</td><td>3160</td><td>NA</td><td>4915</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Pullout strength cracked concrete	$N_{p,un-cr}$	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680	Pullout strength uncracked concrete	$N_{p,cr}$	lb	NA	2270	3160	NA	4915	NA	NA	NA	NA	NA	f'_c is a parameter used to define concrete compressive strength. This parameter is used to calculate the “pullout strength in tension for a single anchor” (N_p) per Eq. (17.4.3.4) for cast-in anchors, and the nominal pullout strength ($N_{p,f'c}$) per ICC-ESR provisions for post-installed mechanical anchors. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. f'_c provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. PROFIS Engineering uses these f'_c provisions for post-installed anchor design. The post-installed anchor portfolio in PROFIS Engineering is limited to installation in concrete having a specified compressive strength between 2500 psi and 8500 psi, and design using an f'_c-value less than or equal to 8000 psi. Reference the ICC-ESR for f'_c information specific to a post-installed anchor. PROFIS Engineering users can input an f'_c-value within the range 2500 psi < f'_c < 8500 psi for post-installed anchor design. The maximum f'_c-value for calculations will be limited to 8000 psi. PROFIS Engineering users can input an f'_c-value within the range 2500 psi < f'_c < 10,000 psi for cast-in anchor design. The maximum f'_c-value for calculations will be limited to 10,000 psi. Reference the Equations and Calculations sections of the PROFIS Engineering cast-in anchor report for more information on the parameter N_p. Reference the Equations and Calculations sections of the PROFIS Engineering mechanical anchor report for more information on the parameter $N_{pn,f'c}$. The PROFIS Engineering report designates the ICC-ESR parameter “$N_{p,f'c}$” as “$N_{pn,f'c}$”. Reference the Variables section of the PROFIS Engineering mechanical anchor report for more information on the parameter $(f'_c/2500)^{0.5}$.
DESIGN INFORMATION	Symbol				Units	Nominal anchor diameter (in.)																																																									
		3/8		1/2		5/8		3/4																																																							
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																			
Pullout strength cracked concrete	$N_{p,un-cr}$	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680																																																			
Pullout strength uncracked concrete	$N_{p,cr}$	lb	NA	2270	3160	NA	4915	NA	NA	NA	NA	NA																																																			

Variables $N_{p,2500}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																														
$N_{p,2500}$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. PROFIS Engineering uses this equation to calculate a nominal pullout strength for mechanical anchors: $N_{pn,f'c} = N_{p,2500} \lambda_a (f'_c / 2500)^n$ Excerpt from ICC-ESR-1917 for the Hilti Kwik Bolt-TZ (KB-TZ) expansion anchor referencing provisions for calculating nominal pullout strength in tension. 4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, respectively, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Tables 3 and 4. For all design cases, $\psi_{c,p} = 1.0$. In accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, the nominal pullout strength in cracked concrete may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-1)$ In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,uncr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-2)$ Where values for $N_{p,cr}$ or $N_{p,uncr}$ are not provided in Table 3 or Table 4, the pullout strength in tension need not be evaluated. Excerpt from ICC-ESR-1917 showing values for $N_{p,cr}$ and $N_{p,uncr}$ derived from testing in 2500 psi concrete per AC193/ACI 355.2. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="2">3/4</th><th colspan="2"></th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Pullout strength cracked concrete</td><td>$n_{p,uncr}$</td><td>lb</td><td>2160</td><td>2515</td><td>4110</td><td>NA</td><td>5515</td><td>NA</td><td>9145</td><td>NA</td><td>8280</td><td>10680</td></tr><tr><td>Pullout strength uncracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>NA</td><td>2270</td><td>3160</td><td>NA</td><td>4915</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4				Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Pullout strength cracked concrete	$n_{p,uncr}$	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680	Pullout strength uncracked concrete	$N_{p,cr}$	lb	NA	2270	3160	NA	4915	NA	NA	NA	NA	NA	PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). For mechanical anchors, the Equations and Results section of the report designate N_{pn} as "$N_{pn,f'c}$". Nominal pullout strength is calculated with the parameter "N_p" which is defined in ACI 318-14 Chapter 2 as the pullout strength in tension of a single anchor in cracked concrete. Mechanical anchor N_p-values are derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. These N_p-values are specific to the concrete condition (cracked or uncracked), and to the anchor diameter (d_a) and effective embedment depth (h_{ef}). PROFIS Engineering uses the ICC-ESR N_p-values to calculate the nominal pullout strength for a mechanical anchor. N_p-values in the ICC-ESR are derived from testing in 2500 psi concrete; therefore, the Variables section of the PROFIS Engineering report designates the N_p-value from the ICC-ESR as "$N_{p,2500}$". If pullout is not a possible controlling failure mode for a particular anchor diameter and embedment depth, the ICC-ESR will show "NA", and no N_p-value will be given. PROFIS Engineering does not perform pullout calculations for anchor diameters/embedment's for which "NA" is given in the ICC-ESR Reference the Variables section of the report for more information on the following parameters: • λ_a — lightweight concrete modification factor • f'_c — concrete compressive strength Reference the Calculations section of the report for more information on the parameter $(f'_c/2500)^n$. Reference the Results section of the report for more information on the parameter $N_{pn,f'c}$. When modeling cast-in anchors, PROFIS Engineering calculates nominal the pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DESIGN INFORMATION	Symbol				Units	Nominal anchor diameter (in.)																																																										
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Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																				
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Pullout strength uncracked concrete	$N_{p,cr}$	lb	NA	2270	3160	NA	4915	NA	NA	NA	NA	NA																																																				

Variables N_p

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																															
HIT-Z/HIT-Z-R anchor with HIT-HY 200 N_p	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-3187 for Hilti HIT-HY 200 adhesive, referencing provisions for calculating nominal pullout strength in tension (Npn) per ACI 318-14 Eq. (17.4.3.1) with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. 4.1.4.1 Static Pullout Strength in Tension: Hilti HIT-Z and HIT-Z-R Anchor Rods: The nominal static pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Table 10. For all design cases, $\Psi_{c,p} = 1.0$. Pullout strength values are a function of the concrete compressive strength, whether the concrete is cracked or uncracked, the drilling method (hammer drill, including Hilti hollow drill bit, diamond core drill) and installation conditions (dry or water-saturated). The resulting characteristic pullout strength must be multiplied by the associated strength reduction factor Φ_{nn} as follows: Hilti HIT-Z and HIT-Z-R threaded rods <table><tr><th>DRILLING METHOD</th><th>Concrete type</th><th>Permissible installation conditions</th><th>Pullout strength</th><th>Associated strength reduction factor</th></tr><tr><td rowspan="4">Hammer-drill (or Hilti TE-CD or TE-YD Hollow Drill Bit) or Diamond Core Bit</td><td rowspan="2">Uncracked</td><td>Dry</td><td>$N_{p,uncr}$</td><td>Φ_d</td></tr><tr><td>Water saturated</td><td>$N_{p,uncr}$</td><td>Φ_{ws}</td></tr><tr><td rowspan="2">Cracked</td><td>Dry</td><td>$N_{p,cr}$</td><td>Φ_d</td></tr><tr><td>Water saturated</td><td>$N_{p,cr}$</td><td>Φ_{ws}</td></tr></table> Excerpt from ICC-ESR-3187 Table 10 showing values for $N_{p,cr}$ and $N_{p,uncr}$ derived from testing per AC308/ACI 355.4. ICC-ESR-3187 Table 10 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td rowspan="2">Temperature Range A</td><td>Pullout strength in cracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>7,952</td><td>10,936</td><td>21,392</td><td>27,930</td></tr><tr><td>Pullout strength in uncracked concrete</td><td>$N_{p,uncr}$</td><td>lb</td><td>7,952</td><td>11,719</td><td>21,931</td><td>28,460</td></tr></table>	DRILLING METHOD	Concrete type	Permissible installation conditions	Pullout strength	Associated strength reduction factor	Hammer-drill (or Hilti TE-CD or TE-YD Hollow Drill Bit) or Diamond Core Bit	Uncracked	Dry	$N_{p,uncr}$	Φ_d	Water saturated	$N_{p,uncr}$	Φ_{ws}	Cracked	Dry	$N_{p,cr}$	Φ_d	Water saturated	$N_{p,cr}$	Φ_{ws}	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)				3/8	1/2	5/8	3/4	Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,392	27,930	Pullout strength in uncracked concrete	$N_{p,uncr}$	lb	7,952	11,719	21,931	28,460	PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). Although not referenced in ACI 318-14 Section 17.4.3.2, pullout failure in lieu of bond failure must be considered for Hilti HIT-HY 200 used with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. A characteristic pullout strength in tension (N_p) derived from testing is used to calculate a nominal pullout strength (N_{pn}) for HIT-HY 200 when used with HIT-Z/Z-R threaded rods. N_p-values for HIT-Z and HIT-Z-R threaded rods derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4 (a) are provided in ICC-ESR-3187 Table 10, (b) are specific to the concrete condition (cracked or uncracked), and (c) are specific to anchor diameter. N_p-values in the ICC-ESR are valid for concrete compressive strengths $2500 \text{ psi} < f'_c < 8000 \text{ psi}$. N_p-values for HIT-Z and HIT-Z-R threaded rods shown in the Variables section of the PROFIS Engineering report are taken from ICC-ESR-3187 Table 10. Reference the Variables section of the report for more information on the following parameters: λ_a — lightweight concrete modification factor $\alpha_{N,seis}$ — seismic modification factor Reference the Results section of the report for more information on the parameter N_{pn}. When modeling cast-in anchors, PROFIS Engineering calculates the nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DRILLING METHOD	Concrete type	Permissible installation conditions	Pullout strength	Associated strength reduction factor																																													
Hammer-drill (or Hilti TE-CD or TE-YD Hollow Drill Bit) or Diamond Core Bit	Uncracked	Dry	$N_{p,uncr}$	Φ_d																																													
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Variables $\alpha_{N,seis}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																							
HIT-Z/HIT-Z-R anchor with HIT-HY 200 $\alpha_{N,seis}$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. PROFIS Engineering calculates N_{pn} for HIT-Z and HIT-Z-R threaded rods used with HIT-HY 200 adhesive as follows: N_p, λ_a and α_{Nseis} are shown in the Variables section of the report. $\psi_{c,p}$ is not shown in the report for any post-installed anchor because PROFIS Engineering always sets $\psi_{c,p} = 1.0$ for post-installed anchors. Excerpt from ICC-ESR-3187 for Hilti HIT-HY 200 adhesive, referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1) with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. 4.1.4.1 Static Pullout Strength in Tension: Hilti HIT-Z and HIT-Z-R Anchor Rods: The nominal static pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Table 10. For all design cases, $\psi_{c,p} = 1.0$. Excerpt from ICC-ESR-3187 Table 10 showing values for $N_{p,cr}$, $N_{p,uncr}$ and $\alpha_{N,seis}$ derived from testing per AC308/ACI 355.4. ICC-ESR-3187 Table 10 <table><tr><th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr><tr><th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td rowspan="2">Temperature Range A</td><td>Pullout strength in cracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>7,952</td><td>10,936</td><td>21,392</td><td>27,930</td></tr><tr><td>Pullout strength in uncracked concrete</td><td>$N_{p,uncr}$</td><td>lb</td><td>7,952</td><td>11,719</td><td>21,931</td><td>28,460</td></tr><tr><td colspan="2">Reduction for seismic tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.94</td><td colspan="3">1.0</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)								3/8	1/2	5/8	3/4	Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,392	27,930	Pullout strength in uncracked concrete	$N_{p,uncr}$	lb	7,952	11,719	21,931	28,460	Reduction for seismic tension		$\alpha_{N,seis}$	-	0.94	1.0			PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). Although not referenced in ACI 318-14 Section 17.4.3.2, pullout failure in lieu of bond failure must be considered for Hilti HIT-HY 200 used with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. A characteristic pullout strength in tension (N_p) derived from testing is used to calculate a nominal pullout strength (N_{pn}) for HY 200 when used with HIT-Z/Z-R threaded rods. PROFIS Engineering calculates the nominal pullout strength (N_{pn}) for HIT-HY 200 used with HIT-Z or HIT-Z-R threaded rods as follows: • Determine the relevant N_p-value from ICC-ESR-3187 Table 10 • The parameter $\psi_{c,p}$ is set = 1.0 • Calculate a λ_a-value if lightweight concrete conditions are being modeled • Determine the relevant $\alpha_{N,seis}$-value from ICC-ESR-3187 Table 10 if seismic load conditions are being modeled N_p-values for HIT-Z and HIT-Z-R threaded rods derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4 are provided in ICC-ESR-3187 Table 10. PROFIS Engineering uses the N_p-values from ICC-ESR-3187 Table 10 to calculate the nominal pullout strength (N_{pn}) for HIT-Z and HIT-Z-R threaded rods used with HIT-HY 200 adhesive. The parameter $\psi_{c,p}$ in Eq. (17.4.3.1) is a modification factor for cracked or uncracked concrete. PROFIS Engineering uses $\psi_{c,p} = 1.0$ for HIT-HY 200/HIT-Z/Z-R pullout strength calculations because cracked and uncracked concrete conditions are accounted for in the N_p-values derived from testing . PROFIS Engineering applies a lightweight concrete modification factor (λ_a) if lightweight concrete conditions are being modeled. The parameter $\alpha_{N,seis}$ is an adhesive anchor modification factor for seismic load conditions. Values for $\alpha_{N,seis}$ are derived from testing per the ICC-ES acceptance criteria AC308. $\alpha_{N,seis}$-values are specific to the adhesive product, the anchor element being used with that product, and the anchor element diameter. Values for $\alpha_{N,seis}$ that are specific to HIT-Z and HIT-Z-R threaded rods used with HIT-HY 200 are given in ICC-ESR-3187 Table 10. Reference the Variables section of the report for more information on the following parameters: • N_p — tested pullout value from ICC-ESR-3187 • λ_a — lightweight concrete modification factor Reference the Results section of the report for more information on the parameter N_{pn}.
DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)																																					
				3/8	1/2	5/8	3/4																																		
Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,392	27,930																																		
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Calculations ($f'_c/2500$)ⁿ

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
($f'_c/2500$) ⁿ	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. PROFIS Engineering uses this equation to calculate a nominal pullout strength for mechanical anchors: $N_{pn,f'c} = N_{p,2500} \lambda_a (f'_c/2500)^n$ Excerpt from ICC-ESR-1917 for the Hilti Kwik Bolt-TZ (KB-TZ) expansion anchor referencing provisions for calculating nominal pullout strength in tension. 4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, respectively, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,unscr}$, respectively, is given in Tables 3 and 4. For all design cases, $\psi_{c,p} = 1.0$. In accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, the nominal pullout strength in cracked concrete may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-1)$ In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,unscr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-2)$ Where values for $N_{p,cr}$ or $N_{p,unscr}$ are not provided in Table 3 or Table 4, the pullout strength in tension need not be evaluated.	PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). For mechanical anchors, the Equations and Results section of the report designate N_{pn} as "$N_{pn,f'c}$". Nominal pullout strength is calculated with the parameter "N_p" which is defined in ACI 318-14 Chapter 2 as the pullout strength in tension of a single anchor in cracked concrete. Mechanical anchor N_p-values derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2 (a) are provided in an ICC-ESR, (b) are specific to the concrete condition (cracked or uncracked), and (c) are specific to anchor diameter (d_a) and effective embedment depth (h_{ef}). PROFIS Engineering uses these N_p-values to calculate the nominal pullout strength for a mechanical anchor. N_p-values in the ICC-ESR are derived from testing in 2500 psi concrete; therefore, the Variables section of the PROFIS Engineering report designates the N_p-value from the ICC-ESR as "$N_{p,2500}$". The ICC-ESR provisions shown to the left illustrate how the N_p-value given in the ICC-ESR design tables (derived from testing in 2500 psi concrete) can be increased for design purposes when the concrete compressive strength (f'_c) for the application is greater than 2500 psi. Generally speaking, the factor by which "$N_{p,2500}$" can be increased equals $(f'_c/2500)^{0.5}$; however, the parameter $(f'_c/2500)$ may be raised to another power. Reference Section 4.1.4 of the mechanical anchor ICC-ESR for specific information about this factor. PROFIS Engineering multiplies "$N_{p,2500}$" by $(f'_c/2500)^n$ when calculating nominal pullout strength for a mechanical anchor. The calculated value for $(f'_c/2500)^n$ is shown in the Calculations section of the mechanical anchor report. If pullout is not a possible controlling failure mode for a particular anchor diameter and embedment depth, the ICC-ESR will show "NA", and no N_p-value will be given. PROFIS Engineering does not perform pullout calculations for anchor diameters/ embedment's for which "NA" is given in the ICC-ESR Reference the Variables section of the report for more information on the following parameters: • $N_{p,2500}$ — tested pullout value in 2500 psi concrete • λ_a — lightweight concrete modification factor • f'_c — concrete compressive strength Reference the Results section of the report for more information on the parameter $N_{pn,f'c}$. When modeling cast-in anchors, PROFIS Engineering calculates nominal the pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.

Calculations N_p

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																													
cast-in anchors N_p	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.3 For single cast-in headed studs and headed bolts, it shall be permitted to evaluate the pullout strength in tension using 17.4.3.4. 17.4.3.4 The pullout strength in tension of a single headed stud or headed bolt, N_p, for use in Eq. (17.4.3.1), shall not exceed $N_p = 8A_{brg} f'_c \quad (17.4.3.4)$ Profis Engineering cast-in anchor portfolios for bearing area (A_{brg}). <table><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d_a) (in)</th><th>Bearing area (A_{brg} in²) Welded headed stud</th><th>Bearing area (A_{brg} in²) Square head bolt</th><th>Bearing area (A_{brg} in²) Heavy square bolt</th><th>Bearing area (A_{brg} in²) Hex head bolt</th><th>Bearing area (A_{brg} in²) Heavy hex head bolt</th></tr><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td></tr><tr><td>0.625</td><td>0.920</td></tr><tr><td>0.750</td><td>0.785</td></tr><tr><td>0.875</td><td>0.884</td></tr><tr><td rowspan="11">ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105</td><td>0.500</td><td rowspan="11"></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td>5.316</td></tr></table>	MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A_{brg} in ²) Welded headed stud	Bearing area (A_{brg} in ²) Square head bolt	Bearing area (A_{brg} in ²) Heavy square bolt	Bearing area (A_{brg} in ²) Hex head bolt	Bearing area (A_{brg} in ²) Heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920	0.750	0.785	0.875	0.884	ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105	0.500		0.464	0.569	0.291	0.467	0.625	0.693	0.822	0.454	0.671	0.750	0.824	1.210	0.654	0.911	0.875	1.121	1.465	0.891	1.188	1.000	1.465	1.855	1.163	1.501	1.125	1.854	2.291	1.472	1.851	1.250	2.228	2.773	1.817	2.237	1.375	2.769	3.300	2.199	2.659	1.500	3.295	3.873	2.617	3.118	1.750				4.144	2.000				5.316	The parameter “N_p” in Eq. (17.4.3.1) is defined as the “pullout strength in tension” for a single anchor. PROFIS Engineering calculates N_p per Eq. (17.4.3.4) for the cast-in anchors in its portfolio. The PROFIS Engineering cast-in-place anchor portfolio is as follows: - AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) - ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) - ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) - ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) - ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) Bearing area values (A_{brg}) for these anchors are shown in the table to the left. Cast-in J-bolts and L-bolts are not included in the PROFIS Engineering cast-in anchor portfolio. PROFIS Engineering only calculates N_p per Eq. (17.4.3.4) for cast-in anchors. N_p for post-installed anchors is derived from testing. Reference the Equations section of the report for more information on the parameter N_p. Reference the Variables section of the report for more information on the following parameters: A_{brg} — bearing area for a cast-in anchor f'_c — concrete compressive strength PROFIS Engineering does not calculate N_p per Eq. (17.4.3.4) for the post-installed anchors in its portfolio. N_p-values are derived from product-specific testing. Reference the post-installed anchor report sections relevant to pullout strength in tension for more information.
MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A_{brg} in ²) Welded headed stud	Bearing area (A_{brg} in ²) Square head bolt	Bearing area (A_{brg} in ²) Heavy square bolt	Bearing area (A_{brg} in ²) Hex head bolt	Bearing area (A_{brg} in ²) Heavy hex head bolt																																																																									
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Results N_{pn}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
cast-in anchors $N_{pn} = \psi_{c,p} N_p$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ where $\psi_{c,p}$ is defined in 17.4.3.6. 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors.	Nominal pullout strength (N_{pn}) is a possible tension failure mode for cast-in-place anchors and post-installed mechanical anchors. Generally speaking, bond failure is considered for adhesive anchor systems in lieu of pullout failure; however, the Hilti adhesive anchor system “HIT-HY 200” includes a proprietary anchor element known as a HIT-Z threaded rod, for which a nominal pullout strength is calculated in lieu of a nominal bond strength. The PROFIS Engineering cast-in-place anchor portfolio includes the following anchors: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) PROFIS Engineering calculates the nominal pullout strength (N_{pn}) for the cast-in anchors in its portfolio using Eq. (17.4.3.1). Section 17.4.3.2 notes that testing per the ACI test standard ACI 355.2 must be used to derive the pullout strength of a single anchor (N_p) for a post-installed mechanical anchor, which is used to calculate the nominal pullout strength (N_{pn}) for the mechanical anchor. N_p-values for HIT-Z (carbon steel) and HIT-Z-R (stainless steel) threaded rods used with HIT-HY 200 adhesive are derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. These values are used to calculate the nominal pullout strength (N_{pn}) for the HIT-Z/Z-R threaded rods used with HIT-HY 200. The parameter $\psi_{c,p}$ is a modification factor for cracked or uncracked concrete conditions. PROFIS Engineering determines $\psi_{c,p}$ per Section 17.4.3.6 for the cast-in anchors in its portfolio. PROFIS Engineering always uses a $\psi_{c,p}$-value equal to 1.0 when calculating N_{pn} for the post-installed anchors in its portfolio. When modeling cast-in anchors in PROFIS Engineering, Reference the Equations and Calculations section of the report for more information on the parameter N_p. Reference the Variables section of the report for more information on the parameter $\psi_{c,p}$. When modeling post-installed anchors in PROFIS Engineering, Reference the Equations section of the report for information on the following anchor-specific pullout parameters: • $N_{pn,fo}$ if mechanical anchors are being modeled • N_{pn} if HIT-HY 200 with HIT-Z and HIT-Z-R threaded rods is being modeled

Results $N_{pn, f'c}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																													
mechanical anchors $N_{pn, f'c} = N_{p,2500} \lambda_a (f'_c / 2500)^n$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-1917 for the Hilti Kwik Bolt-TZ (KB-TZ) expansion anchor referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). 4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, respectively, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Tables 3 and 4. For all design cases, $\psi_{c,p} = 1.0$. In accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, the nominal pullout strength in cracked concrete may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-1)$ In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,uncr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-2)$ Where values for $N_{p,cr}$ or $N_{p,uncr}$ are not provided in Table 3 or Table 4, the pullout strength in tension need not be evaluated. Excerpt from ICC-ESR-1917 showing values for $N_{p,cr}$ and $N_{p,uncr}$ derived from testing in 2500 psi concrete per AC193/ACI 355.2. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Pullout strength cracked concrete</td><td>$n_{p,uncr}$</td><td>lb</td><td>2160</td><td>2515</td><td>4110</td><td>NA</td><td>5515</td><td>NA</td><td>9145</td><td>NA</td><td>8280</td><td>10680</td></tr><tr><td>Pullout strength uncracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>NA</td><td>2270</td><td>3160</td><td>NA</td><td>4915</td><td>NA</td><td></td><td colspan="3">NA</td></tr></table>	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Pullout strength cracked concrete	$n_{p,uncr}$	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680	Pullout strength uncracked concrete	$N_{p,cr}$	lb	NA	2270	3160	NA	4915	NA		NA			PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). For mechanical anchors, the Equations and Results section of the report designate N_{pn} as "$N_{pn,f'c}$". Per ACI 318-14 Section 17.4.3.2, the parameter "N_p" for mechanical anchors must be derived from testing. PROFIS Engineering uses the N_p-value given in the mechanical anchor ICC-ESR to calculate $N_{pn,f'c}$. PROFIS Engineering always uses $\psi_{c,p} = 1.0$ for mechanical anchor calculations. N_p-values in the ICC-ESR are derived from testing in 2500 psi concrete; therefore, the PROFIS Engineering equation for $N_{pn,f'c}$ designates the N_p-value from the ICC-ESR as "$N_{p,2500}$". The mechanical anchor ICC-ESR provisions permit the N_p-value given in the ICC-ESR design tables to be increased by a factor $(f'_c/2500)^n$ for design purposes when the concrete compressive strength (f'_c) for the application is greater than 2500 psi. Reference Section 4.1.4 of the mechanical anchor ICC-ESR for specific information about this factor. PROFIS Engineering multiplies "$N_{p,2500}$" by $(f'_c/2500)^n$ when calculating nominal pullout strength for a mechanical anchor. PROFIS Engineering applies a lightweight concrete modification factor (λ_a) to the Np-value if lightweight concrete is being modeled. If pullout is not a possible controlling failure mode for a particular anchor diameter and embedment depth, the ICC-ESR will show "NA", and no N_p-value will be given. PROFIS Engineering does not perform pullout calculations for anchor diameters/ embedment's for which "NA" is given in the ICC-ESR Reference the Variables section of the report for more information on the following parameters: • $N_{p,2500}$ — tested pullout value in 2500 psi concrete • λ_a —lightweight concrete modification factor • f'_c — concrete compressive strength Reference the Calculations section of the report for more information on the parameter $(f'_c/2500)^n$. Reference the Equations section of the report for more information on the parameter $N_{pn,f'c}$. When modeling cast-in anchors, PROFIS Engineering calculates nominal the pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DESIGN INFORMATION	Symbol				Units	Nominal anchor diameter (in.)																																																									
		3/8		1/2		5/8		3/4																																																							
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																			
Pullout strength cracked concrete	$n_{p,uncr}$	lb	2160	2515	4110	NA	5515	NA	9145	NA	8280	10680																																																			
Pullout strength uncracked concrete	$N_{p,cr}$	lb	NA	2270	3160	NA	4915	NA		NA																																																					

Results N_{pn}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																															
HIT-Z anchor with HIT-HY 200 $N_{pn} = N_p \lambda_a$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-3187 for Hilti HIT-HY 200 adhesive, referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1) with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. 4.1.4.1 Static Pullout Strength in Tension: Hilti HIT-Z and HIT-Z-R Anchor Rods: The nominal static pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,uncr}$, respectively, is given in Table 10. For all design cases, $\psi_{c,p} = 1.0$. Excerpt from ICC-ESR-3187 Table 10 showing values for $N_{p,cr}$ and $N_{p,uncr}$ derived from testing per AC308/ACI 355.4. ICC-ESR-3187 Table 10 <table><tr><th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr><tr><th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td rowspan="2">Temperature Range A</td><td>Pullout strength in cracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>7,952</td><td>10,936</td><td>21,392</td><td>27,930</td></tr><tr><td>Pullout strength in uncracked concrete</td><td>$N_{p,uncr}$</td><td>lb</td><td>7,952</td><td>11,719</td><td>21,931</td><td>28,460</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)								3/8	1/2	5/8	3/4	Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,392	27,930	Pullout strength in uncracked concrete	$N_{p,uncr}$	lb	7,952	11,719	21,931	28,460	PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). Although not referenced in ACI 318-14 Section 17.4.3.2, pullout failure in lieu of bond failure must be considered for Hilti HIT-HY 200 used with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. A characteristic pullout strength in tension (N_p) derived from testing is used to calculate a nominal pullout strength (N_{pn}) for HIT-HY 200 when used with HIT-Z/Z-R threaded rods. The parameter $\psi_{c,p}$ in Eq. (17.4.3.1) is a modification factor for cracked or uncracked concrete. PROFIS Engineering always uses $\psi_{c,p} = 1.0$ for HY 200/HIT-Z N_{pn} calculations because cracked and uncracked concrete conditions are accounted for in the N_p-values derived from testing . PROFIS Engineering applies a lightweight concrete modification factor (λ_a), and a seismic modification factor ($\alpha_{N,seis}$), to the N_{pn}-value if lightweight concrete and/or seismic conditions are being modeled. λ_a-values and $\alpha_{N,seis}$-values are shown in the Variables section of the report. PROFIS Engineering uses the N_p-values given in ICC-ESR-3187 Table 10 to calculate a nominal pullout strength for HIT-Z and HIT-Z-R threaded rods used with HIT-HY 200 adhesive. These values are derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. They are specific to either cracked or uncracked concrete for a given anchor diameter, and are valid for concrete compressive strengths $2500 \text{ psi} < f'_c < 8000 \text{ psi.}$ Reference the Variables section of the report for more information on the following parameters: • N_p — tested pullout value from ICC-ESR-3187 • λ_a — lightweight concrete modification factor • $\alpha_{N,seis}$ — seismic modification factor Reference the Equations section of the report for more information on the parameter N_{pn}. When modeling cast-in anchors, PROFIS Engineering calculates the nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)																													
				3/8	1/2	5/8	3/4																										
Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,392	27,930																										
	Pullout strength in uncracked concrete	$N_{p,uncr}$	lb	7,952	11,719	21,931	28,460																										

Results ϕ_{concrete}

Results	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																		
ϕ_{concrete}	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used:																																																												
	(c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength																																																												
Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths.																																																													
Example: Example of a post-installed mechanical anchor strength reduction factor (ϕ -factor) corresponding to concrete breakout and pullout failure in tension.																																																													
ICC-ES ECR-1917 Table 3																																																													
<table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="2">3/4</th><th colspan="2"></th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td colspan="3">Strength reduction ϕ factor for tension, concrete failure modes, or pullout, Condition B</td><td colspan="2">0.55</td><td colspan="8">0.65</td></tr></table>													DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4				Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Strength reduction ϕ factor for tension, concrete failure modes, or pullout, Condition B			0.55		0.65							
DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)																																																										
			3/8		1/2		5/8		3/4																																																				
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																	
Strength reduction ϕ factor for tension, concrete failure modes, or pullout, Condition B			0.55		0.65																																																								
Excerpt from ICC-ESR-3187 Table 10 showing the strength reduction factor (ϕ -factor) corresponding to pullout failure in tension for HIT-Z/HIT-Z-R threaded rods used with HIT-HY 200 adhesive.																																																													
ICC-ESR-3187 Table 10																																																													
<table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td rowspan="2">Permissible installation conditions</td><td>Dry concrete, water saturated concrete</td><td>Anchor Category</td><td>-</td><td colspan="4">1</td></tr><tr><td></td><td>$\phi_d \phi_{ws}$</td><td>-</td><td colspan="4">0.65</td></tr></table>													DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)				3/8	1/2	5/8	3/4	Permissible installation conditions	Dry concrete, water saturated concrete	Anchor Category	-	1					$\phi_d \phi_{ws}$	-	0.65																									
DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)																																																									
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		$\phi_d \phi_{ws}$	-	0.65																																																									
ACI 318-14 strength design provisions treat pullout failure in tension as a “concrete” failure mode. The nominal pullout strength (N_{pn}) is multiplied by one or more strength reduction factors (ϕ -factors) to obtain a design pullout strength (ϕN_{pn}). The ϕ -factors given in ACI 318-14 Section 17.3.3 are used to calculate the design strength for pullout failure, concrete breakout failure and side-face blowout failure in tension. These ϕ -factors are relevant to static load conditions. An additional strength reduction factor (= 0.75) is used to calculate the design strength for these failure modes if the anchorage design is based on seismic load conditions.																																																													
PROFIS Engineering designates the ϕ -factor corresponding to “concrete” failure modes for static load conditions “ ϕ_{concrete} ”, and applies this ϕ -factor to the nominal pullout strength, concrete breakout strength and side-face blowout strengths in tension to obtain a design strength. If seismic load conditions are being modeled, PROFIS Engineering also applies the 0.75 seismic reduction factor to the design strength.																																																													
When designing cast-in-place anchors, PROFIS Engineering uses the ϕ -factors given in ACI 318-14 Section 17.3.3(c)(ii) to calculate the design pullout strength. The ϕ -factors given in Section 17.3.3(c)(ii) for post-installed anchors are only intended to be used as guide values in the absence of product-specific data.																																																													
Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. PROFIS Engineering uses the ϕ -factors derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ES evaluation report (ICC-ESR) for the anchor, to calculate the design pullout strength for the post-installed anchors in its portfolio. The ϕ -factors in the anchor ICC-ESR correspond to Condition B.																																																													
As noted in ACI 318-14 Section 17.3.3, only Condition B ϕ -factors are used to calculate a design pullout strength. PROFIS Engineering defaults to the Condition B ϕ -factor relevant to the anchor that has been selected when calculating design pullout strength. If Condition A is selected as a design parameter, PROFIS Engineering only uses the Condition A ϕ -factors given in ACI 318-14 Section 17.3.3 to calculate the design concrete breakout strength in tension.																																																													
PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions “ ϕ_{seismic} ”.																																																													
Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: ϕN_{pn} or $\phi N_{pn,f'c}$: Design pullout strength in tension																																																													
Reference the Results section of the PROFIS Engineering report for more information on the following parameter: ϕ_{seismic} : Strength reduction factor for seismic tension																																																													

Results ϕ_{seismic}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕ_{seismic}	17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{sa}]$ corresponds to steel failure (tension) in Table 17.3.1.1] (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided $[\phi N_{cb}]$ or $[\phi N_{cbg}]$ correspond to concrete breakout failure (tension) in Table 17.3.1.1] (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{pn}]$ corresponds to pullout failure (tension) in Table 17.3.1.1] (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ $[\phi N_{sb}]$ or $[\phi N_{sbg}]$ correspond to side-face blowout failure (tension) in Table 17.3.1.1] (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ $[\phi N_a]$ or $[\phi N_{ag}]$ correspond to bond failure (tension) in Table 17.3.1.1] where ϕ is in accordance with 17.3.3. PROFIS Engineering calculations for pullout failure in tension when seismic load conditions are being modeled: single anchor: design pullout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} (N_{pn} \text{ or } \phi N_{pn,fc})$.	ACI 318-14 strength design provisions for pullout failure in tension require calculation of a nominal pullout strength (N_{pn}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design pullout strength (ϕN_{pn}). ϕ-factors are relevant to static and seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions "ϕ_{seismic}". This reduction is applied to non-steel failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors. When calculating the design pullout strength in tension for cast-in-place anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report is taken from Section 17.3.3, and corresponds to the parameter "ϕ" shown in Section 17.2.3.4.4. When calculating the design pullout strength in tension for post-installed anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report corresponds to the parameter "ϕ" shown in Section 17.2.3.4.4. Values for ϕ_{concrete} in the pullout section of the PROFIS Engineering report are relevant to "Condition B", and are taken from the ICC-ESR for the anchor. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕN_{pn} or $\phi N_{pn,fc}$: Design pullout strength in tension ϕ_{concrete}: Strength reduction factor for concrete failure

Results $\phi_{\text{nonductile}}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	ACI 318-14 strength design provisions for pullout failure in tension require calculation of a nominal pullout strength (N_{pn}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design pullout strength (ϕN_{pn}). ϕ-factors are relevant to static and seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions "ϕ_{seismic}". This reduction is applied to non-steel failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors using ACI 318-14 anchoring-to-concrete provisions. When using ACI 318-14 anchoring-to-concrete provisions to calculate the design pullout strength in tension for cast-in-place and post-installed anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report corresponds to the parameter "ϕ" shown in ACI 318-14 Section 17.2.3.4.4. The parameter "$\phi_{\text{nonductile}}$" is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor "$\phi_{\text{nonductile}}$". "$\phi_{\text{nonductile}}$" is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

PART 3 TENSION LOAD / Pullout Failure Mode

Results ϕN_{pn}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering						
cast-in anchors ϕN_{pn}	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn} , shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$	ACI 318-14 strength design provisions for tension define the parameter “design strength” as the product of a “nominal strength” (N_n) and one or more strength reduction factors (ϕ -factors). Nominal pullout strength in tension (N_{pn}) is always calculated for a single anchor when designing with the provisions of ACI 318-14. PROFIS Engineering calculates the nominal pullout strength (N_{pn}) for the cast-in-place anchors in its portfolio using Eq. (17.4.3.1).						
	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength	The PROFIS Engineering cast-in-place anchor portfolio includes the following anchors: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter)						
	<table><thead><tr><th></th><th>Condition A</th><th>Condition B</th></tr></thead><tbody><tr><td>(ii) Tension loads Cast-in headed studs, headed bolts, or hooked bolts</td><td>0.75</td><td>0.70</td></tr></tbody></table>		Condition A	Condition B	(ii) Tension loads Cast-in headed studs, headed bolts, or hooked bolts	0.75	0.70	
		Condition A	Condition B					
	(ii) Tension loads Cast-in headed studs, headed bolts, or hooked bolts	0.75	0.70					
Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths.								
Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths.								
17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors where ϕ is in accordance with 17.3.3.		When modeling static load conditions for a cast-in anchor, PROFIS Engineering uses the strength reduction factor (ϕ-factor) for “Condition B” given in ACI 318-14 Section 17.3.3 to calculate the design pullout strength. This ϕ-factor is designated “$\phi_{concrete}$” in the PROFIS Engineering report, and the report parameter “ϕN_{pn}” corresponding to “design pullout strength” is calculated as “$\phi_{concrete} N_{pn}$”. If seismic load conditions are being modeled; PROFIS Engineering applies the additional 0.75 reduction factor to “$\phi_{concrete} N_{pn}$” per Section 17.2.3.4.4, and designates this factor “$\phi_{seismic}$”. The report parameter “ϕN_{pn}” corresponds to “$\phi_{seismic} \phi_{concrete} N_{pn}$”. Reference the Equations and Calculations section of the report for more information on the parameter N_p. Reference the Results section of the report for more information on the parameters $\phi_{concrete}$ and $\phi_{seismic}$. When modeling post-installed anchors in PROFIS Engineering, Reference the Equations section of the report for information on the following anchor-specific pullout parameters: • $\phi N_{pn,fc}$ if mechanical anchors are being modeled • ϕN_{pn} if HIT-HY 200 with HIT-Z and HIT-Z-R threaded rods is being modeled						

Results $\phi N_{pn,f'c}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																														
mechanical anchors $\phi N_{pn,f'c}$	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-1917 for the Hilti Kwik Bolt-TZ (KB-TZ) expansion anchor referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). 4.1.4 Requirements for Static Pullout Strength in Tension: The nominal pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, respectively, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,un-cr}$, respectively, is given in Tables 3 and 4. For all design cases, $\psi_{c,p} = 1.0$. In accordance with ACI 318-14 17.4.3 or ACI 318-11 D.5.3, as applicable, the nominal pullout strength in cracked concrete may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-1)$ In regions where analysis indicates no cracking in accordance with ACI 318-14 17.4.3.6 or ACI 318-11 D.5.3.6, as applicable, the nominal pullout strength in tension may be calculated in accordance with the following equation: $N_{p,f'c} = N_{p,un-cr} \sqrt{\frac{f'_c}{2500}} \quad (Eq-2)$ Excerpt from ICC-ESR-1917 showing values for $N_{p,cr}$, $N_{p,un-cr}$ and ϕ-factors. ICC-ESR-1917 Table 3 <table><tr><th>DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th></th><th></th><th></th><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="2">3/4</th><th colspan="2">4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in. (mm)</td><td>1-1/2 38</td><td>2 51</td><td>2-3/4 70</td><td>2 51</td><td>3-1/4 83</td><td>3-1/8 79</td><td>4 102</td><td>3-1/4 83</td><td>3-3/4 95</td><td>4-3/4 121</td></tr><tr><td>Pullout strength cracked concrete</td><td>$N_{p,un-cr}$</td><td>lb (kn)</td><td>2160 (9.6)</td><td>2515 (11.2)</td><td>4110 (18.3)</td><td>NA</td><td>5515 (24.5)</td><td>NA</td><td>9145 (40.7)</td><td>NA</td><td>8280 (36.8)</td><td>10680 (47.5)</td></tr><tr><td>Pullout strength uncracked concrete</td><td>$N_{p,cr}$</td><td>lb (kn)</td><td>NA</td><td>2270 (10.4)</td><td>3160 (14.1)</td><td>NA</td><td>4915 (21.9)</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr><tr><td colspan="3">Strength reduction factor for tension, concrete failure modes, or pullout, Condition B</td><td colspan="3">0.55</td><td colspan="7">0.65</td></tr></table> 17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths. 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)													3/8		1/2		5/8		3/4		4		Effective min. embedment	h_{ef}	in. (mm)	1-1/2 38	2 51	2-3/4 70	2 51	3-1/4 83	3-1/8 79	4 102	3-1/4 83	3-3/4 95	4-3/4 121	Pullout strength cracked concrete	$N_{p,un-cr}$	lb (kn)	2160 (9.6)	2515 (11.2)	4110 (18.3)	NA	5515 (24.5)	NA	9145 (40.7)	NA	8280 (36.8)	10680 (47.5)	Pullout strength uncracked concrete	$N_{p,cr}$	lb (kn)	NA	2270 (10.4)	3160 (14.1)	NA	4915 (21.9)	NA	NA	NA	NA	NA	Strength reduction factor for tension, concrete failure modes, or pullout, Condition B			0.55			0.65							ACI 318-14 strength design provisions for tension define the parameter “design strength” as the product of a “nominal strength” (N_n) and one or more strength reduction factors (ϕ-factors). Nominal pullout strength in tension (N_{pn}) is always calculated for a single anchor when designing with the provisions of ACI 318-14. PROFIS Engineering calculates the nominal pullout strength (N_{pn}) for the mechanical anchors in its portfolio using pullout values derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI test standard ACI 355.2. These pullout values are given in the ICC-ES evaluation report for the mechanical anchor. The PROFIS Engineering report designates the ESR pullout values “$N_{p,2500}$”, and the calculated nominal pullout strength “$N_{pn,f'c}$”. The ICC-ESR for the mechanical anchors in the PROFIS Engineering portfolio also include ϕ-factors that are derived from testing per AC193/ACI 355.2. When modeling static load conditions for a mechanical anchor, PROFIS Engineering uses the ϕ-factors given in the ICC-ESR to calculate the design pullout strength. These ϕ-factors correspond to “Condition B” as defined in ACI 318-14 Section 17.3.3, and are designated “$\phi_{concrete}$” in the PROFIS Engineering report. Design pullout strength for static load conditions is designated “$\phi N_{pn,f'c}$” in the PROFIS Engineering report, and is calculated as “$\phi_{concrete} N_{pn,f'c}$” using the values from the mechanical anchor ICC-ESR. If seismic load conditions are being modeled; PROFIS Engineering applies the additional 0.75 reduction factor to “$\phi_{concrete} N_{pn,f'c}$” per Section 17.2.3.4.4, and designates this factor “$\phi_{seismic}$”. The report parameter “$\phi N_{pn,f'c}$” corresponds to “$\phi_{seismic} \phi_{concrete} N_{pn,f'c}$”. Reference the Equations and Results section of the report for more information on the parameter $N_{pn,f'c}$. Reference the Results section of the report for more information on the parameters $\phi_{concrete}$ and $\phi_{seismic}$. When modeling HIT-Z and HIT-Z-R threaded rods with HIT-HY 200 adhesive in PROFIS Engineering, Reference the Equations and Results section of the report for information on the pullout parameter ϕN_{pn}. When modeling cast-in anchors, PROFIS Engineering calculates nominal the pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)																																																																													
			3/8		1/2		5/8		3/4		4																																																																					
Effective min. embedment	h_{ef}	in. (mm)	1-1/2 38	2 51	2-3/4 70	2 51	3-1/4 83	3-1/8 79	4 102	3-1/4 83	3-3/4 95	4-3/4 121																																																																				
Pullout strength cracked concrete	$N_{p,un-cr}$	lb (kn)	2160 (9.6)	2515 (11.2)	4110 (18.3)	NA	5515 (24.5)	NA	9145 (40.7)	NA	8280 (36.8)	10680 (47.5)																																																																				
Pullout strength uncracked concrete	$N_{p,cr}$	lb (kn)	NA	2270 (10.4)	3160 (14.1)	NA	4915 (21.9)	NA	NA	NA	NA	NA																																																																				
Strength reduction factor for tension, concrete failure modes, or pullout, Condition B			0.55			0.65																																																																										

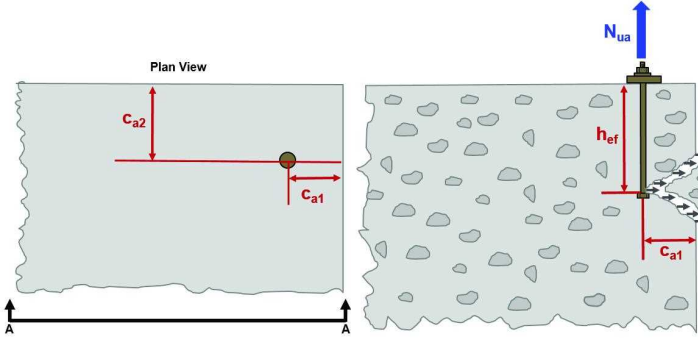
Results ϕN_{pn}

Results	ACI 318-14 Chapter 17 Provision						Comments for PROFIS Engineering																																														
HIT-Z anchor with HIT-HY 200 ϕN_{pn}	17.4.3.1 The nominal pullout strength of a single cast-in, post-installed expansion, and post-installed undercut anchor in tension, N_{pn}, shall not exceed $N_{pn} = \psi_{c,p} N_p \quad (17.4.3.1)$ 17.4.3.2 For post-installed expansion and undercut anchors, the values of N_p shall be based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. It is not permissible to calculate the pullout strength in tension for such anchors. Excerpt from ICC-ESR-3187 for Hilti HIT-HY 200 adhesive, referencing provisions for calculating nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1) with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. 4.1.4.1 Static Pullout Strength in Tension: Hilti HIT-Z and HIT-Z-R Anchor Rods: The nominal static pullout strength of a single anchor in accordance with ACI 318-14 17.4.3.1 and 17.4.3.2 or ACI 318-11 D.5.3.1 and D.5.3.2, as applicable, in cracked and uncracked concrete, $N_{p,cr}$ and $N_{p,un-cr}$, respectively, is given in Table 10. For all design cases, $\psi_{c,p} = 1.0$. Excerpt from ICC-ESR-3187 Table 10 showing values for $N_{p,cr}$, $N_{p,un-cr}$ and ϕ-factors derived from testing per AC308/ACI 355.4. ICC-ESR-3187 Table 10 <table> <tr> <th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr> <tr> <th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr> <tr> <td rowspan="2">Temperature Range A</td><td>Pullout strength in cracked concrete</td><td>$N_{p,cr}$</td><td>lb</td><td>7,952</td><td>10,936</td><td>21,931</td><td>27,930</td></tr> <tr> <td>Pullout strength in uncracked concrete</td><td>$N_{p,un-cr}$</td><td>lb</td><td>7,952</td><td>11,719</td><td>21,931</td><td>28,460</td></tr> <tr> <td rowspan="2">Permissible Installation Conditions</td><td>Dry concrete, water saturated concrete</td><td>Anchor Category</td><td>-</td><td colspan="4">1</td></tr> <tr> <td></td><td>ϕ_d, ϕ_{ws}</td><td>-</td><td colspan="4">0.65</td></tr> </table> 17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths. 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors						DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)								3/8	1/2	5/8	3/4	Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,931	27,930	Pullout strength in uncracked concrete	$N_{p,un-cr}$	lb	7,952	11,719	21,931	28,460	Permissible Installation Conditions	Dry concrete, water saturated concrete	Anchor Category	-	1					ϕ_d, ϕ_{ws}	-	0.65				PROFIS Engineering calculates nominal pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1). Although not referenced in ACI 318-14 Section 17.4.3.2, pullout failure in lieu of bond failure must be considered for Hilti HIT-HY 200 used with HIT-Z (carbon steel) or HIT-Z-R (stainless steel) threaded rods. Characteristic pullout strength values derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI test standard ACI 355.4 are used to calculate a nominal pullout strength (N_{pn}) for HIT-HY 200 when used with HIT-Z/Z-R threaded rods. These characteristic values are shown as "$N_{p,cr}$" and "$N_{p,un-cr}$" in Table 10 of ICC-ESR-3187. Table 10 also includes ϕ-factors derived from testing per AC308/ACI 355.4, which are shown as "ϕ_d" and "ϕ_{ws}". When modeling static load conditions for HIT-Z/Z-R threaded rods used with HY 200, PROFIS Engineering uses the $N_{p,xxxx}$-values and ϕ-factors given in Table 10 of ICC-ESR-3187 to calculate the design pullout strength. The ICC-ESR ϕ-factors correspond to "Condition B" as defined in ACI 318-14 Section 17.3.3, and are designated "$\phi_{concrete}$" in the PROFIS Engineering report. Design pullout strength for static load conditions is designated "ϕN_{pn}" in the PROFIS Engineering report, and is calculated as "$\phi_{concrete} N_{pn}$" using the relevant $N_{p,xxxx}$-values and ϕ-factors from ICC-ESR-3187 Table 10. If seismic load conditions are being modeled; PROFIS Engineering applies the additional 0.75 reduction factor to "$\phi_{concrete} N_{pn}$" per ACI 318-14 Section 17.2.3.4.4, and designates this factor "$\phi_{seismic}$". The PROFIS Engineering report parameter "ϕN_{pn}" corresponds to "$\phi_{seismic} \phi_{concrete} N_{pn}$". Reference the Equations and Results section of the report for more information on the parameter N_{pn}. Reference the Results section of the report for more information on the parameters $\phi_{concrete}$ and $\phi_{seismic}$. When modeling mechanical anchors in PROFIS Engineering, Reference the Equations and Results section of the report for information on the pullout parameter $\phi N_{pn,fc}$. When modeling cast-in anchors, PROFIS Engineering calculates nominal the pullout strength in tension (N_{pn}) per ACI 318-14 Eq. (17.4.3.1), and the parameter N_p per ACI 318-14 Eq. (17.4.3.4). Reference the cast-in anchor report sections relevant to pullout strength in tension for more information.
DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)																																																	
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Temperature Range A	Pullout strength in cracked concrete	$N_{p,cr}$	lb	7,952	10,936	21,931	27,930																																														
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Permissible Installation Conditions	Dry concrete, water saturated concrete	Anchor Category	-	1																																																	
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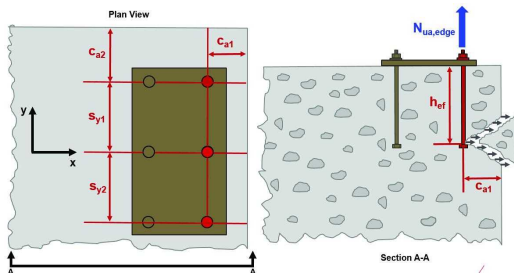
Results N_{ua}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
N_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for pullout failure in tension require calculation of a nominal pullout strength (N_{pn}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕN_{pn}). Design strength is checked against a factored tension load, defined by the parameter “N_{ua}”. Chapter 2 in ACI 318-14 gives the following definitions for the factored tension load parameter “N_{ua}”. • N_{ua} = factored tensile force applied to anchor or individual anchor in a group of anchors (lb) • $N_{ua,i}$ = factored tensile force applied to most highly stressed anchor in a group of anchors (lb) • $N_{ua,g}$ = total factored tensile force applied to anchor group (lb) The design pullout strength for a single anchor in tension (ϕN_{pn}) calculated per Section 17.4.3 is checked against the factored tension load acting on the anchor, which is designated “N_{ua}” in Table 17.3.1.1. If $\phi N_{pn} > N_{ua}$, the provisions for considering pullout failure in tension have been satisfied per Table 17.3.1.1. If an application consists of a group of anchors in tension, N_{pn} is calculated for a single anchor, and the design strength (ϕN_{pn}) is checked against the highest individually loaded anchor in tension, which is designated “$N_{ua,i}$” in Table 17.3.1.1. If $\phi N_{pn} > N_{ua,i}$, the provisions for considering pullout failure in tension have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation “N_{ua}” to reference either the only tension load acting on anchor, or the highest tension load acting on an individual anchor within an anchor group. The PROFIS Engineering Load Engine permits users to input service loads that are factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting tension loads. The software only performs tension load checks per Table 17.3.1.1 if tension loads have been input via one of the load input functionalities. If a single anchor in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{pn}, and checks this value against either (a) the factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchor. If a group of anchors in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{pn}, and checks this value against either (a) the total factored tension load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored tension load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored tension load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the total factored tension load determined to be acting on the anchor group. Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameter ϕN_{pn}.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$																									
Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Equation $N_{sb} = 160 \alpha_{corner} c_{a1}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																			
$N_{sb} = 160 \alpha_{corner} c_{a1} \sqrt{A_{brg}} \lambda_a / \sqrt{f'_c}$	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / \sqrt{f'_c} \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 < c_{a2}/c_{a1} < 3.0$. PROFIS Engineering permits h_{ef}-values ranging between $4d_{anchor}$ and 25" to be input for the cast-in anchors in its portfolio. PROFIS Engineering bearing area values (A_{brg}) for the cast-in anchors in its portfolio.  Profis Engineering cast-in anchor portfolios for bearing area (A_{brg}). <table><thead><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d_f) (in)</th><th>Bearing area (A_{brg} in²) welded headed stud</th><th>Bearing area (A_{brg} in²) square head bolt</th><th>Bearing area (A_{brg} in²) heavy square bolt</th><th>Bearing area (A_{brg} in²) hex head bolt</th><th>Bearing area (A_{brg} in²) heavy hex head bolt</th></tr></thead><tbody><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td></td><td></td><td></td><td></td></tr><tr><td>0.625</td><td>0.920</td><td></td><td></td><td></td><td></td></tr><tr><td>0.750</td><td>0.785</td><td></td><td></td><td></td><td></td></tr><tr><td>0.875</td><td>0.884</td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="11">"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"</td><td>0.500</td><td></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td></td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td></td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td></td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td></td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td></td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td></td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td></td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td></td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td></td><td>5.316</td></tr></tbody></table> 17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure.....1.0 λ where λ is determined in accordance with 19.2.4. 17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors.....	MATERIAL SPECIFICATION	Diameter (d_f) (in)	Bearing area (A_{brg} in ²) welded headed stud	Bearing area (A_{brg} in ²) square head bolt	Bearing area (A_{brg} in ²) heavy square bolt	Bearing area (A_{brg} in ²) hex head bolt	Bearing area (A_{brg} in ²) heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920					0.750	0.785					0.875	0.884					"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"	0.500		0.464	0.569	0.291	0.467	0.625		0.693	0.822	0.454	0.671	0.750		0.824	1.210	0.654	0.911	0.875		1.121	1.465	0.891	1.188	1.000		1.465	1.855	1.163	1.501	1.125		1.854	2.291	1.472	1.851	1.250		2.228	2.773	1.817	2.237	1.375		2.769	3.300	2.199	2.659	1.500		3.295	3.873	2.617	3.118	1.750					4.144	2.000					5.316	Side-face blowout is a tension failure mode that can occur when anchors are installed at a "deep" embedment ($h_{ef} > 2.5c_{a1}$), near a fixed edge (c_{a1}). In lieu of concrete breakout or pullout occurring, the applied tension load creates lateral bursting stresses at the head of the anchor which cause the concrete to "blow out" at the face of the fixed edge. PROFIS Engineering assumes the parameter h_{ef} corresponds to the embedded portion of the anchor that is "effective" in transferring tension load from the anchor into the concrete. The parameter c_{a1} corresponds to the nearest fixed edge, i.e. the edge where side-face blowout is assumed to occur. Side-face blowout is a possible failure mode for cast-in anchors. Splitting failure, rather than side-face blowout, is a more common failure mode for post-installed anchors; however, side-face blowout could possibly occur with undercut anchors. PROFIS Engineering does not consider side-face blowout for the HDA-P and HDA-T undercut anchors in its portfolio because it will not be a controlling tension failure mode for these anchors. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. When modeling a single anchor in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor $(1 + c_{a2}/c_{a1})/4$ if a corner formed by the fixed edge distances c_{a1} and c_{a2} exists. PROFIS Engineering designates this factor "α_{corner}". The parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1}. The PROFIS Engineering cast-in anchor portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) λ_a is a modification factor for lightweight concrete. PROFIS Engineering uses the provisions of Sections 17.2.6 and 19.2.4 to calculate λ_a. f'_c corresponds to the concrete compressive strength being modeled. PROFIS Engineering uses the provisions of Section 17.2.7 to calculate f'_c. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, and f'_c. Reference the Calculations section of the report for more information on the parameters α_{corner} and N_{sb}.
MATERIAL SPECIFICATION	Diameter (d_f) (in)	Bearing area (A_{brg} in ²) welded headed stud	Bearing area (A_{brg} in ²) square head bolt	Bearing area (A_{brg} in ²) heavy square bolt	Bearing area (A_{brg} in ²) hex head bolt	Bearing area (A_{brg} in ²) heavy hex head bolt																																																																																															
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	0.750		0.824	1.210	0.654	0.911																																																																																															
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	1.000		1.465	1.855	1.163	1.501																																																																																															
	1.125		1.854	2.291	1.472	1.851																																																																																															
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	1.375		2.769	3.300	2.199	2.659																																																																																															
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	1.750					4.144																																																																																															
	2.000					5.316																																																																																															

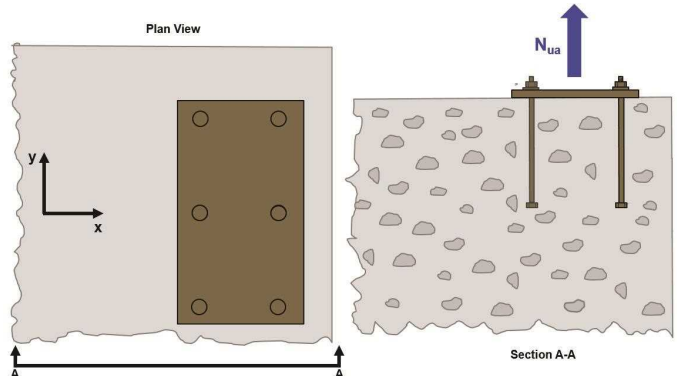
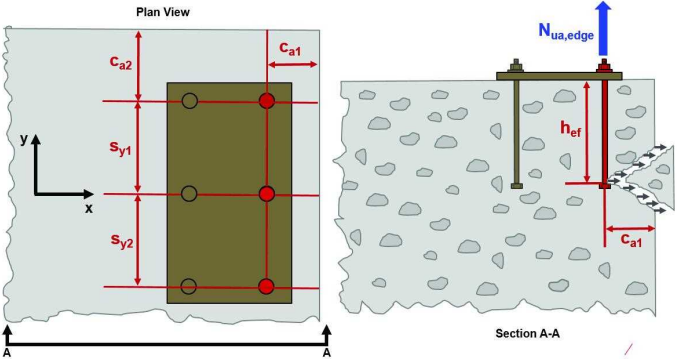
Equation $N_{sb} = 160 c_{a1}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																			
anchor group in tension $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c}$	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c} \quad (17.4.4.1)$ 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. PROFIS Engineering permits h_{ef} -values ranging between $4d_{anchor}$ and 25" to be input for the cast-in anchors in its portfolio. For the illustration below: $N_{sbg} = [1+ (s_{y1} + s_{y2})/6c_{a1}] N_{sb}$ PROFIS Engineering bearing area values (A_{brg}) for the cast-in anchors in its portfolio.  Profis Engineering cast-in anchor portfolios for bearing area (A_{brg}). <table><thead><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d_a) (in)</th><th>Bearing area (A_{brg} in²) welded headed stud</th><th>Bearing area (A_{brg} in²) square head bolt</th><th>Bearing area (A_{brg} in²) heavy square bolt</th><th>Bearing area (A_{brg} in²) hex head bolt</th><th>Bearing area (A_{brg} in²) heavy hex head bolt</th></tr></thead><tbody><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td></td><td></td><td></td><td></td></tr><tr><td>0.625</td><td>0.920</td><td></td><td></td><td></td><td></td></tr><tr><td>0.750</td><td>0.785</td><td></td><td></td><td></td><td></td></tr><tr><td>0.875</td><td>0.884</td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="11">"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"</td><td>0.500</td><td></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td></td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td></td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td></td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td></td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td></td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td></td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td></td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td></td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td></td><td>5.316</td></tr></tbody></table>	MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A_{brg} in ²) welded headed stud	Bearing area (A_{brg} in ²) square head bolt	Bearing area (A_{brg} in ²) heavy square bolt	Bearing area (A_{brg} in ²) hex head bolt	Bearing area (A_{brg} in ²) heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920					0.750	0.785					0.875	0.884					"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"	0.500		0.464	0.569	0.291	0.467	0.625		0.693	0.822	0.454	0.671	0.750		0.824	1.210	0.654	0.911	0.875		1.121	1.465	0.891	1.188	1.000		1.465	1.855	1.163	1.501	1.125		1.854	2.291	1.472	1.851	1.250		2.228	2.773	1.817	2.237	1.375		2.769	3.300	2.199	2.659	1.500		3.295	3.873	2.617	3.118	1.750					4.144	2.000					5.316	Side-face blowout is a tension failure mode that can occur when anchors are installed at a "deep" embedment ($h_{ef} > 2.5c_{a1}$), near a fixed edge (c_{a1}). In lieu of concrete breakout or pullout occurring, the applied tension load creates lateral bursting stresses at the head of the anchors which cause the concrete to "blow out" at the face of the fixed edge. The parameter h_{ef} corresponds to the embedded portion of the anchor that is "effective" in transferring tension load from the anchor into the concrete. The parameter c_{a1} corresponds to the nearest fixed edge, where side-face blowout is assumed to occur. Side-face blowout is a possible failure mode for cast-in anchors. Splitting failure, rather than side-face blowout, is a more common failure mode for post-installed anchors; however, side-face blowout could possibly occur with undercut anchors. PROFIS Engineering does not consider side-face blowout for the HDA-P and HDA-T undercut anchors in its portfolio because it will not be a controlling tension failure mode for these anchors. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor $(1 + s/6c_{a1})$. PROFIS Engineering designates this factor "α_{group}". The parameter "s" corresponds to the distance between the outer anchors (e.g. $s_{y1} + s_{y2}$ in the illustration to the left) along the fixed edge being considered for side-face blowout. PROFIS Engineering limits the value of "s" to "$6c_{a1}$"; which means that PROFIS Engineering permits "α_{group}" values in the range: $1.0 < \alpha_{group} < 2.0$ The modification factor "α_{corner}" is not used to calculate N_{sbg}. The PROFIS Engineering cast-in anchor portfolio is as follows: - AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter) - ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) - ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter) - ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) - ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) λ_a is a modification factor for lightweight concrete. f'_c corresponds to the concrete compressive strength. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Calculations section of the report for more information on the parameters α_{group} and N_{sb}. Reference the PROFIS Engineering report section for N_{sb} (single anchor) for information on the parameter α_{corner}.
MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A_{brg} in ²) welded headed stud	Bearing area (A_{brg} in ²) square head bolt	Bearing area (A_{brg} in ²) heavy square bolt	Bearing area (A_{brg} in ²) hex head bolt	Bearing area (A_{brg} in ²) heavy hex head bolt																																																																																															
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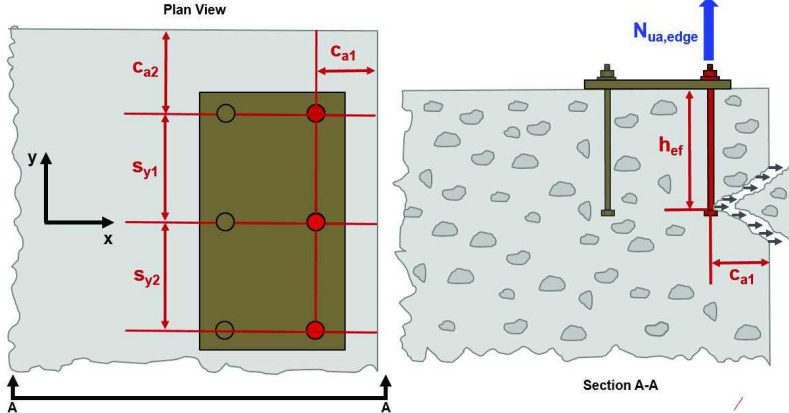
Equation ϕN_{sb}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering				
$\phi N_{sb} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 <table><tr><th>Failure Mode</th><th>Single Anchor</th></tr><tr><td>Side-Face Blowout Strength in Tension</td><td>$\phi N_{sb} \geq N_{ua}$</td></tr></table>	Failure Mode	Single Anchor	Side-Face Blowout Strength in Tension	$\phi N_{sb} \geq N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_u) against a factored tension load (N_{ua}). The parameter ϕN_{sb} corresponds to the design side-face blowout strength for a single anchor in tension. The parameter N_{ua} corresponds to the factored tension load acting on the anchor. If $\phi N_{sb} \geq N_{ua}$ for the application being modeled, the provisions of Section 17.3.1.1 are satisfied for side-face blowout failure. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: Nsb: nominal side-face blowout strength in tension $\phi_{concrete}$: Strength reduction factor for side-face blowout failure $\phi_{seismic}$: Strength reduction factor for seismic tension ϕN_{sb}: Design side-face blowout strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.
Failure Mode	Single Anchor					
Side-Face Blowout Strength in Tension	$\phi N_{sb} \geq N_{ua}$					

Equation ϕN_{sbg}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering				
$\phi N_{sbg} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 <table><tr><th>Failure Mode</th><th>Anchor Group</th></tr><tr><td>Side-Face Blowout Strength in Tension</td><td>$\phi N_{sbg} \geq N_{ua}$</td></tr></table> PROFIS Engineering uses the designation "$N_{ua,edge}$" to denote the factored load acting on anchors in tension nearest the fixed edge being considered for side-face blowout. In Illustration #1 below, the total factored tension load acting on all six anchors is equals "N_{ua}". In Illustration #2, the portion of N_{ua} acting on the anchors in red, i.e. the anchors in tension nearest the fixed edge being considered for side-face blowout, equals "$N_{ua,edge}$". Illustration #1  Illustration #2 	Failure Mode	Anchor Group	Side-Face Blowout Strength in Tension	$\phi N_{sbg} \geq N_{ua}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_{sbg}) against a factored tension load (N_{ua}). The parameter ϕN_{sbg} corresponds to the design side-face blowout strength for a group of anchors in tension. When performing side-face blowout calculations, the parameter N_{ua} corresponds to the factored tension load acting on the anchors nearest the fixed edge being considered for side-face blowout. PROFIS Engineering designates this parameter "$N_{ua,edge}$". If $\phi N_{sbg} \geq N_{ua,edge}$ for the application being modeled, the provisions of Section 17.3.1.1 are satisfied for side-face blowout failure. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{sbg}: Nominal side-face blowout strength in tension $\phi_{concrete}$: Strength reduction factor for side-face blowout failure $\phi_{seismic}$: Strength reduction factor for seismic tension $N_{ua,edge}$: Factored load acting on anchors in tension nearest the fixed edge being considered for side-face blowout A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.
Failure Mode	Anchor Group					
Side-Face Blowout Strength in Tension	$\phi N_{sbg} \geq N_{ua}$					

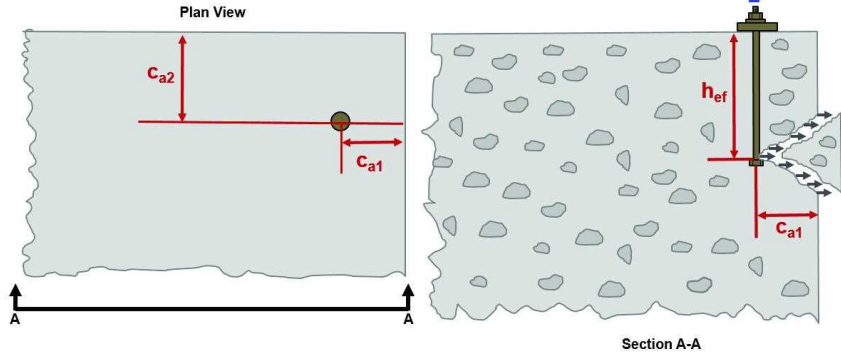
Equation N_{sbg}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{sbg} = \alpha_{group} N_{sb}$	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$. 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. For the illustration below: $N_{sbg} = [1 + (s_{y1} + s_{y2})/6c_{a1}] N_{sb} = \alpha_{group} N_{sb}$ 	When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor $(1 + s/6c_{a1})$. PROFIS Engineering designates this group modification factor "α_{group}". The parameter "s" corresponds to the distance between the outer anchors (e.g. $s_{y1} + s_{y2}$ in the illustration to the left) along the fixed edge being considered for side-face blowout. PROFIS Engineering limits the value of "s" to "$6c_{a1}$", which means that PROFIS Engineering permits "α_{group}" values in the range: $1.0 < \alpha_{group} < 2.0$ Per Section 17.4.4.2: "N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance". The modification factor "for a perpendicular edge distance" is defined in 17.4.4.1 as $(1 + c_{a2}/c_{a1})/4$, and is designated "α_{corner}" in PROFIS Engineering. The PROFIS Engineering report will not include α_{corner} when calculating side-face blowout for a group of anchors in tension. α_{corner} is only considered when calculating side-face blowout for a single anchor in tension. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Calculations section of the report for more information on the parameters α_{group} and N_{sb}. Reference the PROFIS Engineering report section for N_{sb} (single anchor) for information on the parameter α_{corner}.

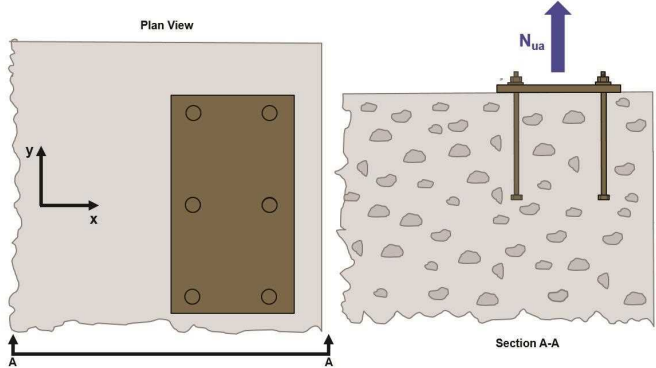
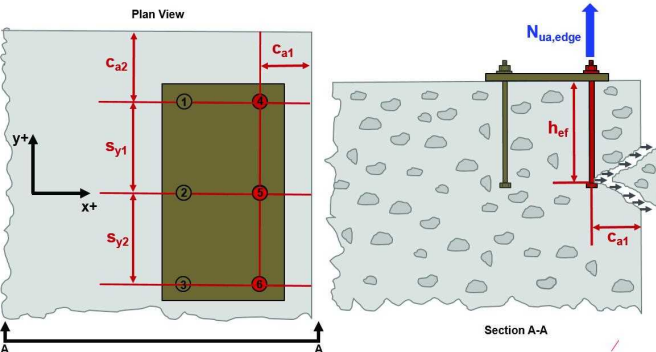
Equation α_{corner}

$$\alpha_{\text{corner}} = \frac{\left(1 + \frac{c_{a2}}{c_{a1}}\right)}{4}$$

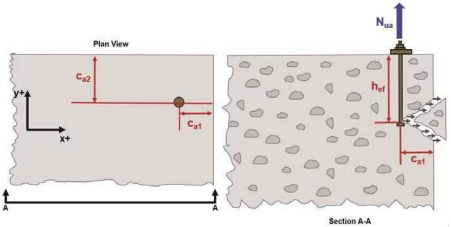
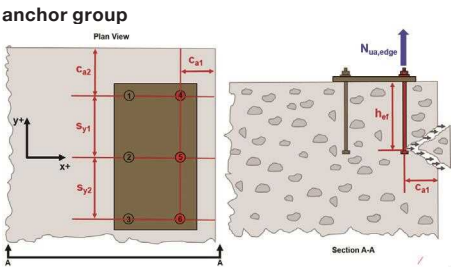
Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$. PROFIS Engineering permits h_{ef}-values ranging between $4d_{\text{anchor}}$ and 25" to be input for the cast-in anchors in its portfolio	PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. When modeling a single anchor in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated per Eq. (17.4.4.1), and modified by the factor $(1 + c_{a2}/c_{a1})/4$ if a corner formed by the fixed edge distances c_{a1} and c_{a2} exists. PROFIS Engineering designates this factor "α_{corner}". The parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1}. The PROFIS Engineering cast-in anchor portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) Reference the Variables section of the report for more information on the parameters c_{a1} and c_{a2}. Reference the Equations, Calculations and Results section of the report for more information on the parameter N_{sb}.



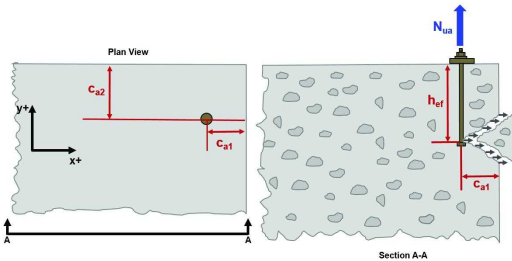
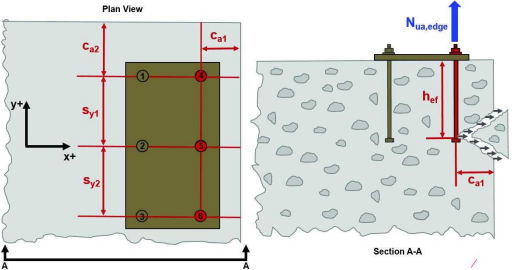
Equation α_{group}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\alpha_{\text{group}} = \left(1 + \frac{s}{6c_{a1}} \right)$	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sb} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. Illustration 1 	When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor $(1 + s/6c_{a1})$, per Eq. (17.4.4.2). PROFIS Engineering designates $(1 + s/6c_{a1})$ as "α_{group}". N_{sb} calculations for a group of anchors in tension only consider the anchors nearest to the edge where side-face blowout is being considered. Illustration 1 to the left shows six anchors, all of which are in tension. The total factored tension load acting on these anchors is designated "N_{ua}". These anchors have been numbered 1 through 6 in Illustration 2. Side-face blowout is being considered for the anchors highlighted in red, that are next to the x^+ edge, and numbered 4, 5 and 6. PROFIS Engineering designates the portion of the factored tension load N_{ua} acting on anchors 4, 5 and 6 as "$N_{ua,edge}$". The "α_{group}" parameter "s" from Illustration 2 corresponds to the distance between anchors 4 and 5 ($= s_{y1}$) plus the distance between anchors 5 and 6 ($= s_{y2}$); therefore, α_{group} for this application = $(s_{y1} + s_{y2})/6c_{a1}$. Section 17.4.4.2 notes that "α_{group}" is calculated when "anchor spacing is less than $6c_{a1}$", "where s is the distance between the outer anchors along the edge". For the example shown in Illustration 2, α_{group} is calculated if $(s_{y1} + s_{y2}) < 6c_{a1}$. PROFIS Engineering limits the value of "s" to "$6c_{a1}$"; which means that PROFIS Engineering permits "α_{group}" values in the range: $1.0 \leq \alpha_{\text{group}} \leq 2.0$ Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Calculations section of the report for more information on the parameters α_{group} and N_{sb}.
Illustration 2 $N_{sbg} = [1 + (s_{y1} + s_{y2})/6c_{a1}] N_{sb} = \alpha_{\text{group}} N_{sb}$		

Variables c_{a1}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{a1}	2.2 – Notation c_{a1} = distance from the center of an anchor shaft to the edge of concrete in one direction, in. If shear is applied to anchor, c_{a1} is taken in the direction of the applied shear. If tension is applied to the anchor, c_{a1} is the minimum edge distance. Where anchors subject to shear are located in narrow sections of limited thickness, see 17.5.2.4. 17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c} \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq ca2/ca1 \leq 3.0$. 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. 17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be $6d_a$. Illustration showing the parameters c_{a1} and c_{a2} that are used in side-face blowout calculations. single anchor  anchor group 	When calculating nominal side-face blowout strength (N_{sb} or N_{sbg}), the parameter “c_{a1}” corresponds to the distance from the center of the anchor(s) to the nearest fixed edge where side-face blowout is assumed to occur. When two or more fixed edges are present, the parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1} such that $c_{a1} < c_{a2}$. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The software uses the minimum edge distance requirements given in Section 17.7.2 for these anchors. The illustration to the left shows how the parameters c_{a1} and c_{a2} are utilized for side-face blowout calculations. Reference the Variables section of the report for more information on the parameters c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Calculations section of the report for more information on the parameter N_{sb}.

Variables c_{a2}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{a2}	2.2 – Notation c_{a2} = distance from center of an anchor shaft to the edge of concrete in the direction perpendicular to c_{a1}, in. 17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$. 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. 17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be $6d_a$. Illustration showing the parameters c_{a1} and c_{a2} that are used in side-face blowout calculations. single anchor  anchor group 	When calculating nominal side-face blowout strength (N_{sb} or N_{sbg}), the parameter “c_{a1}” corresponds to the distance from the center of the anchor(s) to the nearest fixed edge where side-face blowout is assumed to occur. When two or more fixed edges are present, the parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1} such that $c_{a1} < c_{a2}$. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The software uses the minimum edge distance requirements given in Section 17.7.2 for these anchors. The illustration to the left shows how the parameters c_{a1} and c_{a2} are utilized for side-face blowout calculations. Reference the Variables section of the report for more information on the parameters c_{a1}, A_{brg}, λ_a, f'_c and s. Reference the Calculations section of the report for more information on the parameter N_{sb}.

Variables A_{brg}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																			
A_{brg}	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$ Profis Engineering cast-in anchor portfolios for bearing area (A_{brg}). <table><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d_a) (in)</th><th>Bearing area (A_{brg}) (in²) welded headed stud</th><th>Bearing area (A_{brg}) (in²) square head bolt</th><th>Bearing area (A_{brg}) (in²) heavy square bolt</th><th>Bearing area (A_{brg}) (in²) hex head bolt</th><th>Bearing area (A_{brg}) (in²) heavy hex head bolt</th></tr><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td></td><td></td><td></td><td></td></tr><tr><td>0.625</td><td>0.920</td><td></td><td></td><td></td><td></td></tr><tr><td>0.750</td><td>0.785</td><td></td><td></td><td></td><td></td></tr><tr><td>0.875</td><td>0.884</td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="11">"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"</td><td>0.500</td><td></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td></td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td></td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td></td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td></td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td></td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td></td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td></td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td></td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td></td><td>5.316</td></tr></table>	MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A _{brg}) (in²) welded headed stud	Bearing area (A _{brg}) (in²) square head bolt	Bearing area (A _{brg}) (in²) heavy square bolt	Bearing area (A _{brg}) (in²) hex head bolt	Bearing area (A _{brg}) (in²) heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920					0.750	0.785					0.875	0.884					"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"	0.500		0.464	0.569	0.291	0.467	0.625		0.693	0.822	0.454	0.671	0.750		0.824	1.210	0.654	0.911	0.875		1.121	1.465	0.891	1.188	1.000		1.465	1.855	1.163	1.501	1.125		1.854	2.291	1.472	1.851	1.250		2.228	2.773	1.817	2.237	1.375		2.769	3.300	2.199	2.659	1.500		3.295	3.873	2.617	3.118	1.750					4.144	2.000					5.316	The parameter "N_{sb}" in Eq. (17.4.4.1) is defined as the "side-face blowout strength of a single anchor". It forms the basis for all side-face blowout calculations. N_{sb} is multiplied by additional factors if designing a single anchor in a corner, or designing a group of anchors subject to possible blowout failure. PROFIS Engineering only considers side-face blowout failure when modeling cast-in anchors. The PROFIS Engineering cast-in anchor portfolio is as follows: • AWS D1.1 Type B headed studs (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2" – 1 1/2" nominal diameter) J-bolts and L-bolts are not included in the PROFIS Engineering cast-in anchor portfolio. PROFIS Engineering utilizes the bearing area parameters (A_{brg}) shown in the table to the left to calculate the parameter N_{sb} per Eq. (17.4.4.1) for the cast-in anchors in its portfolio. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, λ_a, f'_c and s. Reference the Calculations section of the report for more information on the parameter N_{sb}.
MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A _{brg}) (in²) welded headed stud	Bearing area (A _{brg}) (in²) square head bolt	Bearing area (A _{brg}) (in²) heavy square bolt	Bearing area (A _{brg}) (in²) hex head bolt	Bearing area (A _{brg}) (in²) heavy hex head bolt																																																																																															
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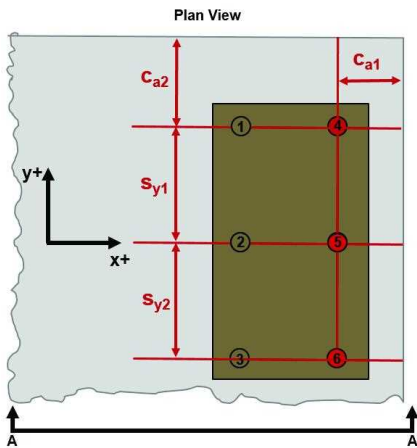
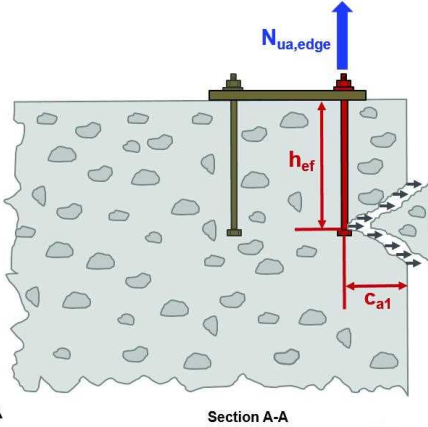
Variables λ_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{at}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{at} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c} \quad (17.4.4.1)$ 17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure. 1.0 λ Expansion and adhesive anchor concrete failure 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85 ⁽¹⁾</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33</td><td>0.85 to 1 ⁽²⁾</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> 1 Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. 2 Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}}{6.7 / f_{cm}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work.	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33	0.85 to 1 ⁽²⁾	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	λ_a is a modification factor for lightweight concrete. Generally speaking, ACI 318 applies a multiplier to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete”, and designates this parameter “λ”. The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to anchoring-to-concrete calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ, determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the type of anchor being used, to obtain the parameter λ_a. PROFIS Engineering uses the λ-value that has been input, to calculate a λ_a-value for the anchor being modeled. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The parameter λ_a is included in Eq. (17.4.4.1) to calculate the nominal side-face blowout strength for a single anchor (N_{sb}). Per Section 17.2.6, if lightweight concrete conditions are being modeled, PROFIS Engineering will use ($\lambda_a = 1.0 \lambda$) to calculate N_{sb} with Eq. (17.4.4.1). Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, f'_c and s. Reference the Calculations section of the report for more information on the parameters N_{sb}.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and 33	0.85 to 1 ⁽²⁾																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

Variables f'_c

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
f'_c	17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors, and 8000 psi for post-installed anchors. Testing is required for post-installed anchors when used in concrete with f'_c greater than 8000 psi. 17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c} \quad (17.4.4.1)$	f'_c is a parameter used to define concrete compressive strength. This parameter is used to calculate the nominal side-face blowout strength for a single anchor (N_{sb}) per Eq. (17.4.4.1). PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. Users can input an f'_c-value within the range 2500 psi $\leq f'_c \leq$ 10,000 psi for calculating N_{sb}. The maximum f'_c-value for calculations will be limited to 10,000 psi. The PROFIS Engineering cast-in anchor portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a and s. Reference the Calculations section of the report for more information on the parameters N_{sb}.

Variables s

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
s	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. 17.7.1 Unless determined in accordance with 17.7.4, minimum center-to-center spacing of anchors shall be $4d_a$ for cast-in anchors that will not be torqued, and $6d_a$ for torqued cast-in anchors and post-installed anchors. The PROFIS Engineering parameter "α_{group}" corresponds to the parameter $(1 + s/6c_{a1})$ given in Eq. (17.4.4.2). For the application being illustrated below: $N_{sbg} = \alpha_{group} N_{sb} = [1 + (s_{y1} + s_{y2})/6c_{a1}] N_{sb}$ Plan View  Section A-A 	When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated per Eq. (17.4.4.1) and modified by the factor $(1 + s/6c_{a1})$, per Eq. (17.4.4.2). PROFIS Engineering designates $(1 + s/6c_{a1})$ as "α_{group}". PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The software uses the minimum spacing requirements given in Section 17.7.1 for these anchors. N_{sbg} calculations for a group of anchors in tension only consider the anchors nearest to the edge where side-face blowout is being considered. The illustration to the left shows six anchors, numbered 1 through 6. Side-face blowout is being considered for the anchors highlighted in red, that are next to the $x+$ edge, and numbered 4, 5 and 6. Assuming "α_{group}" corresponds to the Eq. (17.4.4.2) parameter $(1 + s/6c_{a1})$, the value for "s" that is used to calculate α_{group} corresponds to the distance between anchors 4 and 5 ($= s_{y1}$) plus the distance between anchors 5 and 6 ($= s_{y2}$). Therefore, "α_{group}" for this application is defined using "s" $= (s_{y1} + s_{y2})$ such that $\alpha_{group} = (s_{y1} + s_{y2})/6c_{a1}$. Section 17.4.4.2 notes that "α_{group}" is calculated when "anchor spacing is less than $6c_{a1}$", "where s is the distance between the outer anchors along the edge". For the example shown in the illustration, α_{group} is calculated if $(s_{y1} + s_{y2}) < 6c_{a1}$. PROFIS Engineering limits the value of "s" to "$6c_{a1}$"; which means that PROFIS Engineering permits "α_{group}" values in the range: $1.0 \leq \alpha_{group} \leq 2.0$ Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, and f'_c. Reference the Calculations section of the report for more information on the parameters α_{group} and N_{sb}.

When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated per Eq. (17.4.4.1) and modified by the factor $(1 + s/6c_{a1})$, per Eq. (17.4.4.2). PROFIS Engineering designates $(1 + s/6c_{a1})$ as " α_{group} ".

PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The software uses the minimum spacing requirements given in Section 17.7.1 for these anchors.

 N_{sbg} calculations for a group of anchors in tension only consider the anchors nearest to the edge where side-face blowout is being considered. The illustration to the left shows six anchors, numbered 1 through 6. Side-face blowout is being considered for the anchors highlighted in red, that are next to the $x+$ edge, and numbered 4, 5 and 6. Assuming " α_{group} " corresponds to the Eq. (17.4.4.2) parameter $(1 + s/6c_{a1})$, the value for " s " that is used to calculate α_{group} corresponds to the distance between anchors 4 and 5 ($= s_{y1}$) plus the distance between anchors 5 and 6 ($= s_{y2}$). Therefore, " α_{group} " for this application is defined using " s " = $(s_{y1} + s_{y2})$ such that $\alpha_{group} = (s_{y1} + s_{y2})/6c_{a1}$.Section 17.4.4.2 notes that " α_{group} " is calculated when "anchor spacing is less than $6c_{a1}$ ", "where s is the distance between the outer anchors along the edge". For the example shown in the illustration, α_{group} is calculated if $(s_{y1} + s_{y2}) < 6c_{a1}$. PROFIS Engineering limits the value of " s " to " $6c_{a1}$ "; which means that PROFIS Engineering permits " α_{group} " values in the range:
$$1.0 \leq \alpha_{group} \leq 2.0$$
Reference the **Variables** section of the report for more information on the parameters c_{a1} , c_{a2} , A_{brg} , λ_a , and f'_c .Reference the **Calculations** section of the report for more information on the parameters α_{group} and N_{sb} .

Calculations α_{corner}

$$\alpha_{\text{corner}} = \frac{\left(1 + \frac{c_{a2}}{c_{a1}}\right)}{4}$$

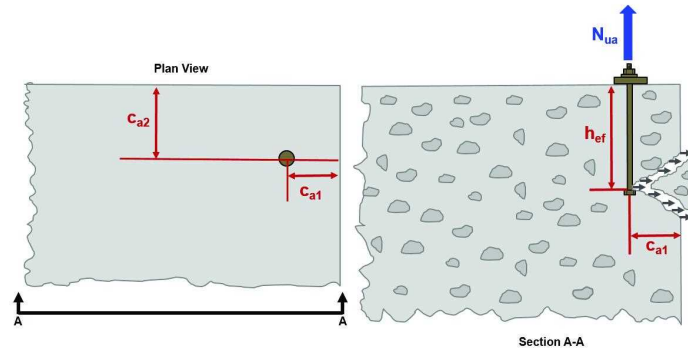
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17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb} , shall not exceed

$$N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$$

If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$.

17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be $6d_a$.



Comments for PROFIS Engineering

When modeling a single anchor in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated per Eq. (17.4.4.1), and modified by the factor $(1 + c_{a2}/c_{a1})/4$ if a corner exists. PROFIS Engineering designates the factor $(1 + c_{a2}/c_{a1})/4$ as " α_{corner} ". The parameter " c_{a1} " corresponds to the distance from the center of the anchor to the nearest fixed edge where side-face blowout is assumed to occur. When two or more fixed edges create a corner, the parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1} , such that $c_{a1} < c_{a2}$. Per the provisions given in 17.4.4.1, PROFIS Engineering does not calculate " α_{corner} " if $c_{a2} \geq 3c_{a1}$. The report will show $\alpha_{\text{corner}} = 1.0$ if $c_{a2} \geq 3c_{a1}$.

PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The software uses the minimum edge distance requirements given in Section 17.7.2 for these anchors.

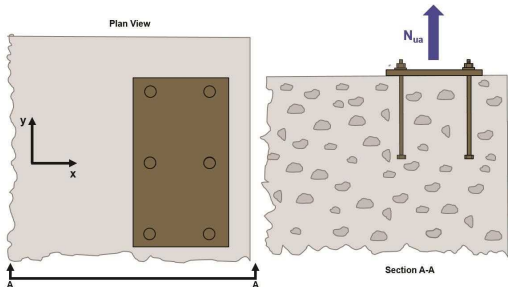
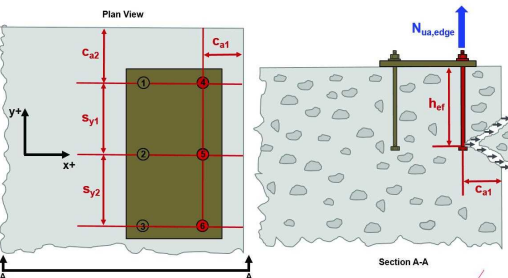
The PROFIS Engineering cast-in anchor portfolio is as follows:

- AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter)
- ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter)
- ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter)
- ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter)
- ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter)

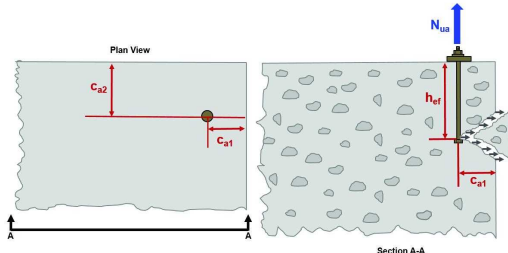
Reference the **Variables** section of the report for more information on the parameters c_{a1} and c_{a2} .

Reference the **Equations, Calculations** and **Results** section of the report for more information on the parameter N_{sb} .

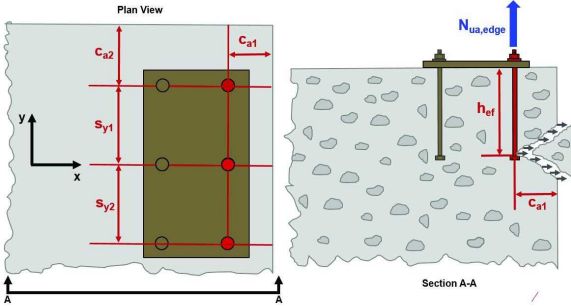
Calculations α_{group}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\alpha_{\text{group}} = \left(1 + \frac{s}{6c_{a1}} \right)$	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. 17.7.1 Unless determined in accordance with 17.7.4, minimum center-to-center spacing of anchors shall be $4d_a$ for cast-in anchors that will not be torqued, and $6d_a$ for torqued cast-in anchors and post-installed anchors. 17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be $6d_a$.	When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor $(1 + s/6c_{a1})$, per Eq. (17.4.4.2). PROFIS Engineering designates the factor $(1 + s/6c_{a1})$ as “α_{group}”. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. The software uses the minimum spacing requirements given in Section 17.7.1 and the minimum edge distance requirements given in Section 17.7.2 for these anchors. N_{sbg} calculations for a group of anchors in tension only consider the anchors nearest to the edge where side-face blowout is being considered. Illustration 1 to the left shows six anchors, all of which are in tension. These anchors have been numbered 1 through 6 in Illustration 2. Side-face blowout is being considered for the anchors highlighted in red, that are next to the $x+$ edge, and numbered 4, 5 and 6. The “α_{group}” parameter “s” from Illustration 2 corresponds to the distance between anchors 4 and 5 ($= s_{y1}$) plus the distance between anchors 5 and 6 ($= s_{y2}$); therefore, α_{group} for this application equals $(s_{y1} + s_{y2})/6c_{a1}$. Section 17.4.4.2 notes that “α_{group}” is calculated when “anchor spacing is less than $6c_{a1}$”, “where s is the distance between the outer anchors along the edge”. When calculating α_{group}, PROFIS Engineering limits the value of the total spacing along the outer edge to $6c_{a1}$, which means that PROFIS Engineering uses “α_{group}” values in the range: $\alpha_{1.0} \leq \alpha_{\text{group}} \leq 2.0$ For the example shown in Illustration 2, PROFIS Engineering would calculate $\alpha_{\text{group}} = (s_{y1} + s_{y2})/6c_{a1}$ if $(s_{y1} + s_{y2}) < 6c_{a1}$. PROFIS Engineering would calculate $\alpha_{\text{group}} = 2.0$ if $(s_{y1} + s_{y2}) > 6c_{a1}$. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, and s. Reference the Equations section of the report for more information on the parameter α_{group}. Reference the Equations and Calculations section of the report for more information on the parameter N_{sb}.
	Illustration 1 	
	Illustration 2 $N_{sbg} = [1 + (s_{y1} + s_{y2})/6c_{a1}] N_{sb} = \alpha_{\text{group}} N_{sb}$ 	

Calculations N_{sb}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
single anchor in tension N_{sb}	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor (1 + c_{a2}/c_{a1})/4, where 1.0 < c_{a2}/c_{a1} < 3.0. PROFIS Engineering calculation for N_{sb}: $N_{sb} = 160 \alpha_{corner} c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c$ 	PROFIS Engineering calculates side-face blowout when the anchor effective embedment depth (h_{ef}) is greater than 2.5 times the nearest fixed edge (c_{a1}). The applied tension load creates lateral bursting stresses at the head of the anchor which cause the concrete to “blow out” at the face of the fixed edge. Side-face blowout is a possible failure mode for cast-in anchors and post-installed undercut anchors; however, PROFIS Engineering does not consider side-face blowout for the HDA-P and HDA-T undercut anchors in its portfolio because it will not be a controlling tension failure mode for these anchors. When modeling a single anchor in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor (1 + c_{a2}/c_{a1})/4 if a corner formed by the fixed edge distances c_{a1} and c_{a2} exists. PROFIS Engineering designates this factor “α_{corner}”. The parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1}. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. This portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) The software uses the minimum spacing requirements given in Section 17.7.1 and the minimum edge distance requirements given in Section 17.7.2 for cast-in anchors. λ_a is a modification factor for lightweight concrete. PROFIS Engineering uses the provisions of Sections 17.2.6 and 19.2.4 to calculate λ_a. f'_c corresponds to the concrete compressive strength being modeled. PROFIS Engineering uses the provisions of Section 17.2.7 to calculate f'_c. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Equations section of the report for more information on the parameter N_{sb}. Reference the Equations and Calculations section of the report for more information on the parameter α_{corner}.
	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure. 1.0 λ where λ is determined in accordance with 19.2.4. 17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors..... 17.7.1 Unless determined in accordance with 17.7.4, minimum center-to-center spacing of anchors shall be 4d_a for cast-in anchors that will not be torqued, and 6d_a for torqued cast-in anchors..... 17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be 6d_a.	

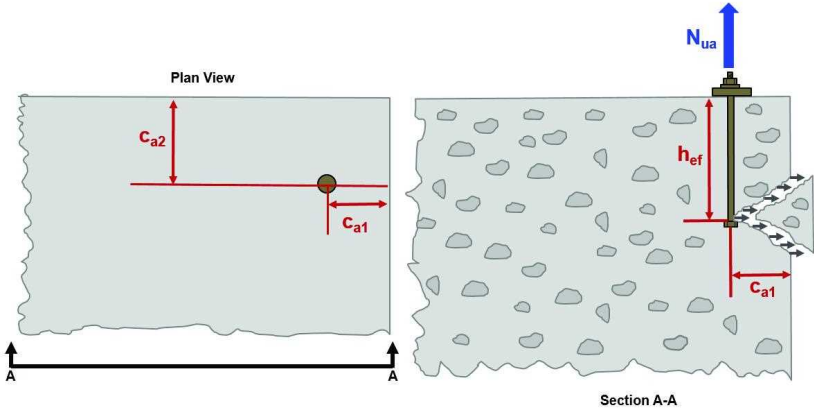
Calculations N_{sb}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
anchor group in tension N_{sb}	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sbg} shall not exceed $N_{sbg} = \left(1 + \frac{s}{6c_{a1}} \right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. PROFIS Engineering permits h_{ef}-values ranging between $4d_{anchor}$ and 25" to be input for the cast-in anchors in its portfolio. 	PROFIS Engineering calculates side-face blowout when the anchor effective embedment depth (h_{ef}) is greater than 2.5 times the nearest fixed edge (c_{a1}). The applied tension load creates lateral bursting stresses at the head of the anchor which cause the concrete to “blow out” at the face of the fixed edge. Side-face blowout is a possible failure mode for cast-in anchors and post-installed undercut anchors; however, PROFIS Engineering does not consider side-face blowout for the HDA-P and HDA-T undercut anchors in its portfolio because it will not be a controlling tension failure mode for these anchors. When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated, and modified by the factor $(1 + s/6c_{a1})$. PROFIS Engineering designates this factor “α_{group}”. The parameter “s” corresponds to the distance between the outer anchors (e.g. $s_{y1} + s_{y2}$ in the illustration to the left) along the fixed edge being considered for side-face blowout. The PROFIS Engineering cast-in anchor portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) λ_a is a modification factor for lightweight concrete. f'_c corresponds to the concrete compressive strength. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Equations section of the report for more information on the parameter N_{sb}. Reference the Equations and Calculations section of the report for more information on the parameter α_{group}. Reference the PROFIS Engineering report section for N_{sb} (single anchor) for information on the parameter α_{corner}.

Calculations N_{sb} (continued)

Calculations	ACI 318-14 Chapter 17 Provision						Comments for PROFIS Engineering
anchor group in tension N _{sb}	PROFIS Engineering bearing area values (A_{brg}) for the cast-in anchors in its portfolio.						
	MATERIAL SPECIFICATION	Diameter (d _s) (in)	Bearing area (A _{brg} in ²) welded headed stud	Bearing area (A _{brg} in ²) square head bolt	Bearing area (A _{brg} in ²) heavy square bolt	Bearing area (A _{brg} in ²) hex head bolt	Bearing area (A _{brg} in ²) heavy hex head bolt
	AWS D1.1 Type B Headed Stud	0.500	0.589				
		0.625	0.920				
		0.750	0.785				
		0.875	0.884				
	"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"	0.500		0.464	0.569	0.291	0.467
		0.625		0.693	0.822	0.454	0.671
		0.750		0.824	1.210	0.654	0.911
		0.875		1.121	1.465	0.891	1.188
		1.000		1.465	1.855	1.163	1.501
		1.125		1.854	2.291	1.472	1.851
		1.250		2.228	2.773	1.817	2.237
		1.375		2.769	3.300	2.199	2.659
		1.500		3.295	3.873	2.617	3.118
		1.750					4.144
		2.000					5.316
	17.2.6 Modification factor λ _a for lightweight concrete shall be taken as:						
	Cast-in and undercut anchor concrete failure. 1.0 λ where λ is determined in accordance with 19.2.4 .						
	17.2.7 The values of f' _c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors.....						
	17.7.1 Unless determined in accordance with 17.7.4, minimum center-to-center spacing of anchors shall be 4d_a for cast-in anchors that will not be torqued, and 6d_a for torqued cast-in anchors.....						
	17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be 6d_a .						

Results N_{sb}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
N_{sb}	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c} \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$. PROFIS Engineering permits h_{ef}-values ranging between 4danchor and 25" to be input for the cast-in anchors in its portfolio. PROFIS Engineering designates the factor $(1 + c_{a2}/c_{a1})/4$ as "α_{corner}". PROFIS Engineering calculation for N_{sb}: $N_{sb} = 160 \alpha_{corner} c_{a1} \sqrt{A_{brg}} \lambda_a \sqrt{f'_c}$ 	PROFIS Engineering calculates side-face blowout when the anchor effective embedment depth (h_{ef}) is greater than 2.5 times the nearest fixed edge (c_{a1}). When modeling a single anchor in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated per Eq. (17.4.4.1), and modified by the factor $(1 + c_{a2}/c_{a1})/4$ if a corner formed by the fixed edge distances c_{a1} and c_{a2} exists. PROFIS Engineering designates this factor "α_{corner}". The parameter c_{a2} corresponds to the fixed edge perpendicular to c_{a1}. PROFIS Engineering only performs side-face blowout calculations for the cast-in anchors in its portfolio. This portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) Values for bearing area (A_{brg}) used by PROFIS Engineering to calculate N_{sb} are shown to the left. The software uses the minimum spacing requirements given in Section 17.7.1 and the minimum edge distance requirements given in Section 17.7.2 for cast-in anchors. λ_a is a modification factor for lightweight concrete. PROFIS Engineering uses the provisions of Sections 17.2.6 and 19.2.4 to calculate λ_a. f'_c corresponds to the concrete compressive strength being modeled. PROFIS Engineering uses the provisions of Section 17.2.7 to calculate f'_c. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Equations and Calculations section of the report for more information on the parameter N_{sb}. Reference the Equations and Calculations section of the report for more information on the parameter α_{corner}.

Results N_{sb} (continued)

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																			
N_{sb}	PROFIS Engineering bearing area values (A_{brg}) for the cast-in anchors in its portfolio. <table><tr><th>MATERIAL SPECIFICATION</th><th>Diameter (d_a) (in)</th><th>Bearing area (A_{brg} in²) welded headed stud</th><th>Bearing area (A_{brg} in²) square head bolt</th><th>Bearing area (A_{brg} in²) heavy square bolt</th><th>Bearing area (A_{brg} in²) hex head bolt</th><th>Bearing area (A_{brg} in²) heavy hex head bolt</th></tr><tr><td rowspan="4">AWS D1.1 Type B Headed Stud</td><td>0.500</td><td>0.589</td><td></td><td></td><td></td><td></td></tr><tr><td>0.625</td><td>0.920</td><td></td><td></td><td></td><td></td></tr><tr><td>0.750</td><td>0.785</td><td></td><td></td><td></td><td></td></tr><tr><td>0.875</td><td>0.884</td><td></td><td></td><td></td><td></td></tr><tr><td rowspan="11">"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"</td><td>0.500</td><td></td><td>0.464</td><td>0.569</td><td>0.291</td><td>0.467</td></tr><tr><td>0.625</td><td></td><td>0.693</td><td>0.822</td><td>0.454</td><td>0.671</td></tr><tr><td>0.750</td><td></td><td>0.824</td><td>1.210</td><td>0.654</td><td>0.911</td></tr><tr><td>0.875</td><td></td><td>1.121</td><td>1.465</td><td>0.891</td><td>1.188</td></tr><tr><td>1.000</td><td></td><td>1.465</td><td>1.855</td><td>1.163</td><td>1.501</td></tr><tr><td>1.125</td><td></td><td>1.854</td><td>2.291</td><td>1.472</td><td>1.851</td></tr><tr><td>1.250</td><td></td><td>2.228</td><td>2.773</td><td>1.817</td><td>2.237</td></tr><tr><td>1.375</td><td></td><td>2.769</td><td>3.300</td><td>2.199</td><td>2.659</td></tr><tr><td>1.500</td><td></td><td>3.295</td><td>3.873</td><td>2.617</td><td>3.118</td></tr><tr><td>1.750</td><td></td><td></td><td></td><td></td><td>4.144</td></tr><tr><td>2.000</td><td></td><td></td><td></td><td></td><td>5.316</td></tr></table> 17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure 1.0 λ where λ is determined in accordance with 19.2.4. 17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors..... 17.7.1 Unless determined in accordance with 17.7.4, minimum center-to-center spacing of anchors shall be 4d_a for cast-in anchors that will not be torqued, and 6d_a for torqued cast-in anchors..... 17.7.2 Unless determined in accordance with 17.7.4, minimum edge distances for cast-in anchors that will not be torqued shall be based on specified cover requirements for reinforcement in 20.6.1. For cast-in anchors that will be torqued, the minimum edge distances shall be 6d_a.	MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A _{brg} in ²) welded headed stud	Bearing area (A _{brg} in ²) square head bolt	Bearing area (A _{brg} in ²) heavy square bolt	Bearing area (A _{brg} in ²) hex head bolt	Bearing area (A _{brg} in ²) heavy hex head bolt	AWS D1.1 Type B Headed Stud	0.500	0.589					0.625	0.920					0.750	0.785					0.875	0.884					"ASTM F1554 Headed Bolt Gr. 36, Gr.55, Gr. 105"	0.500		0.464	0.569	0.291	0.467	0.625		0.693	0.822	0.454	0.671	0.750		0.824	1.210	0.654	0.911	0.875		1.121	1.465	0.891	1.188	1.000		1.465	1.855	1.163	1.501	1.125		1.854	2.291	1.472	1.851	1.250		2.228	2.773	1.817	2.237	1.375		2.769	3.300	2.199	2.659	1.500		3.295	3.873	2.617	3.118	1.750					4.144	2.000					5.316	
MATERIAL SPECIFICATION	Diameter (d _a) (in)	Bearing area (A _{brg} in ²) welded headed stud	Bearing area (A _{brg} in ²) square head bolt	Bearing area (A _{brg} in ²) heavy square bolt	Bearing area (A _{brg} in ²) hex head bolt	Bearing area (A _{brg} in ²) heavy hex head bolt																																																																																															
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Results N_{sb}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{sb} = \alpha_{group} N_{sb}$	17.4.4.1 For a single headed anchor with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$), the nominal side-face blowout strength, N_{sb}, shall not exceed $N_{sb} = 160c_{a1} \sqrt{A_{brg}} \lambda_a / f'_c \quad (17.4.4.1)$ If c_{a2} for the single headed anchor is less than $3c_{a1}$, the value of N_{sb} shall be multiplied by the factor $(1 + c_{a2}/c_{a1})/4$, where $1.0 \leq c_{a2}/c_{a1} \leq 3.0$. 17.4.4.2 For multiple headed anchors with deep embedment close to an edge ($h_{ef} > 2.5c_{a1}$) and anchor spacing less than $6c_{a1}$, the nominal strength of those anchors susceptible to a side-face blowout failure N_{sb} shall not exceed $N_{sb} = \left(1 + \frac{s}{6c_{a1}}\right) N_{sb} \quad (17.4.4.2)$ where s is the distance between the outer anchors along the edge, and N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance. PROFIS Engineering permits h_{ef}-values ranging between 4danchor and 25" to be input for the cast-in anchors in its portfolio. PROFIS Engineering designates the factor $(1 + s/6c_{a1})$ noted in Eq. (17.4.4.2) as "α_{group}". PROFIS Engineering calculation for N_{sb}: where N_{sb} is calculated per Eq. (17.4.4.1) without the modification factor $(1 + c_{a2}/c_{a1})/4$ for corner conditions. For the illustration below, PROFIS Engineering would calculate the parameter α_{group} as follows: $\alpha_{group} = [1 + (s_{y1} + s_{y2})/6c_{a1}]$. Plan View Section A-A	When modeling a group of anchors in tension, the side-face blowout strength for a single anchor (N_{sb}) is calculated per Eq. (17.4.4.1), and modified by the factor $(1 + s/6c_{a1})$. PROFIS Engineering designates this group modification factor "α_{group}". The parameter "s" corresponds to the distance between the outer anchors (e.g. $s_{y1} + s_{y2}$ in the illustration to the left) along the fixed edge being considered for side-face blowout. PROFIS Engineering limits the value of "s" to "$6c_{a1}$", which means that PROFIS Engineering permits "α_{group}" values in the range: $1.0 \leq \alpha_{group} \leq 2.0$ Per Section 17.4.4.2: "N_{sb} is obtained from Eq. (17.4.4.1) without modification for a perpendicular edge distance". The modification factor "for a perpendicular edge distance" is defined in 17.4.4.1 as $(1 + c_{a2}/c_{a1})/4$, and is designated "α_{corner}" in PROFIS Engineering. The PROFIS Engineering report will not include α_{corner} when calculating side-face blowout for a group of anchors in tension. α_{corner} is only considered when calculating side-face blowout for a single anchor in tension. Reference the Variables section of the report for more information on the parameters c_{a1}, c_{a2}, A_{brg}, λ_a, f'_c and s. Reference the Equations section of the report for more information on the parameter N_{sb}. Reference the Equations and Calculations section of the report for more information on the parameter N_{sb} when calculating N_{sb} for an anchor group Reference the Equations and Calculations section of the report for more information on the parameter α_{group}. Reference the PROFIS Engineering report section for N_{sb} (single anchor) for information on the parameter α_{corner}.

Results ϕ_{concrete}

Results	ACI 318-14 Chapter 17 Provision		Comments for PROFIS Engineering
ϕ_{concrete}	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used:		
	(c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength		
		Condition A	Condition B
	(ii) Tension loads Cast-in headed studs, headed bolts, or hooked bolts	0.75	0.70
	Post-installed anchors with category as determined from ACI 355.2 or ACI 355.4		
	Category 1 (Low sensitivity to Installation and high reliability)	0.75	0.65
	Category 2 (Medium sensitivity to Installation and medium reliability)	0.65	0.55
	Category 3 (High sensitivity to Installation and lower reliability)	0.55	0.45
	Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths.		
	Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths.		
	ACI 318-14 strength design provisions treat side-face blowout failure in tension as a “concrete” failure mode. The nominal side-face blowout strength (N_{sb} or N_{sbg}) is multiplied by one or more strength reduction factors (ϕ -factors) to obtain a design side-face blowout strength (ϕN_{sb} or ϕN_{sbg}). The ϕ -factors given in ACI 318-14 Section 17.3.3 are used to calculate the design strength for pullout failure, concrete breakout failure and side-face blowout failure in tension. These ϕ -factors are relevant to static load conditions. An additional strength reduction factor (= 0.75) is used to calculate the design strength for these failure modes if the anchorage design is based on seismic load conditions.		
	PROFIS Engineering designates the ϕ -factor corresponding to “concrete” failure modes for static load conditions “ ϕ_{concrete} ”, and applies this ϕ -factor to the nominal pullout strength, concrete breakout strength and side-face blowout strengths in tension to obtain a design strength. If seismic load conditions are being modeled, PROFIS Engineering also applies the 0.75 seismic reduction factor to the design strength.		
	PROFIS Engineering only calculates side-face blowout strength for the cast-in anchors in its portfolio. This portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2” – 1 1/2” nominal diameter)		
	When designing cast-in-place anchors, PROFIS Engineering uses the ϕ -factors given in ACI 318-14 Section 17.3.3(c)(ii) to calculate the design side-face blowout strength.		
	PROFIS Engineering defaults to the Condition B ϕ -factor when calculating design side-face blowout strength. If Condition A is selected as a design parameter, PROFIS Engineering uses the Condition A ϕ -factors given in ACI 318-14 Section 17.3.3 to calculate the design side-face blowout strength in tension.		
	PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions “ ϕ_{seismic} ”.		
	Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: ϕN_{sb} or ϕN_{sbg} : Design side-face blowout strength in tension		
	Reference the Results section of the PROFIS Engineering report for more information on the following parameter: ϕ_{seismic} : Strength reduction factor for seismic tension		

Results ϕ_{seismic}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕ_{seismic}	17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors ϕN_{sa} corresponds to steel failure (tension) in Table 17.3.1.1] (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided $[\phi N_{cb}$ or ϕN_{cbg} correspond to concrete breakout failure (tension) in Table 17.3.1.1] (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{pn}$ corresponds to pullout failure (tension) in Table 17.3.1.1] (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ $[\phi N_{sb}$ or ϕN_{sbg} correspond to side-face blowout failure (tension) in Table 17.3.1.1] (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ ϕN_a or ϕN_{ag} correspond to bond failure (tension) in Table 17.3.1.1] where ϕ is in accordance with 17.3.3. PROFIS Engineering calculations for side-face blowout failure in tension when seismic load conditions are being modeled: single anchor: design side-face blowout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{sb}$ anchor group: design side-face blowout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{sbg}$	ACI 318-14 strength design provisions for side-face blowout failure in tension require calculation of a nominal side-face blowout strength (N_{sb} or N_{sbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design side-face blowout strength (ϕN_{sb} or ϕN_{sbg}). ϕ-factors are relevant to static and seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions "ϕ_{seismic}". This reduction is applied to non-steel failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors. PROFIS Engineering only calculates side-face blowout strength for the cast-in anchors in its portfolio. This portfolio is as follows: • AWS D1.1 Type B headed studs: (1/2" – 7/8" nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 2" nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105: (1/2" – 1 1/2" nominal diameter) When calculating the design side-face blowout strength in tension for cast-in-place anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report is taken from Section 17.3.3, and corresponds to the parameter "ϕ" shown in Section 17.2.3.4.4. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕN_{sb} or ϕN_{sbg}: Design pullout strength in tension ϕ_{concrete}: Strength reduction factor for concrete failure

Results $\phi_{\text{nonductile}}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	ACI 318-14 strength design provisions for side-face blowout failure in tension require calculation of a nominal side-face blowout strength (N_{sb} or N_{sbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design side-face blowout strength (ϕN_{sb} or ϕN_{sbg}). ϕ-factors are relevant to static and seismic load conditions. PROFIS Engineering designates the 0.75 reduction factor noted in ACI 318-14 Section 17.2.3.4.4 for seismic load conditions "ϕ_{seismic}". This reduction is applied to non-steel failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors using ACI 318-14 anchoring-to-concrete provisions. When using ACI 318-14 anchoring-to-concrete provisions to calculate the design side-face blowout strength in tension for cast-in-place anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report corresponds to the parameter "ϕ" shown in ACI 318-14 Section 17.2.3.4.4. The parameter "$\phi_{\text{nonductile}}$" is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor "$\phi_{\text{nonductile}}$". "$\phi_{\text{nonductile}}$" is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

Results ϕN_{sb}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕN_{sb}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Side-Face Blowout Strength in Tension Single Anchor $\phi N_{sb} \geq N_{ua}$ PROFIS Engineering calculations for design side-face blowout failure in tension: single anchor — static load conditions design side-face blowout strength = $\phi_{concrete} N_{sb}$. single anchor — seismic load conditions design side-face blowout strength = $\phi_{seismic} \phi_{concrete} N_{sb}$.	ACI 318-14 strength design provisions for side-face blowout failure in tension require calculation of a nominal side-face blowout strength (N_{sb} or N_{sbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design side-face blowout strength (ϕN_{sb} or ϕN_{sbg}). ϕ-factors are relevant to static and seismic load conditions. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{sb}: Nominal side-face blowout strength in tension $\phi_{concrete}$: Strength reduction factor for side-face blowout failure $\phi_{seismic}$: Strength reduction factor for seismic tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Results ϕN_{sbg}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕN_{sbg}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Side-Face Blowout Strength in Tension Anchor Group $\phi N_{sbg} \geq N_{ua}$ PROFIS Engineering calculations for design side-face blowout failure in tension: anchor group — static load conditions design side-face blowout strength = $\phi_{concrete} N_{sbg}$. anchor group — seismic load conditions design side-face blowout strength = $\phi_{seismic} \phi_{concrete} N_{sbg}$.	ACI 318-14 strength design provisions for side-face blowout failure in tension require calculation of a nominal side-face blowout strength (N_{sb} or N_{sbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design side-face blowout strength (ϕN_{sb} or ϕN_{sbg}). ϕ-factors are relevant to static and seismic load conditions. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{sbg}: Nominal side-face blowout strength in tension $\phi_{concrete}$: Strength reduction factor for side-face blowout failure $\phi_{seismic}$: Strength reduction factor for seismic tension $N_{ua,edge}$: Factored load acting on anchors in tension nearest the fixed edge being considered for side-face blowout A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.

Results N_{ua}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
N_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for side-face blowout failure in tension require calculation of a nominal side-face blowout strength (N_{sb} or N_{sbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_{sb} or ϕN_{sbg}). ϕ-factors are relevant to static and seismic load conditions. Design strength is checked against a factored tension load, defined by the parameter "N_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored tension load parameter "N_{ua}". • N_{ua} = Factored tensile force applied to anchor or individual anchor in a group of anchors (lb) • $N_{ua,i}$ = Factored tensile force applied to most highly stressed anchor in a group of anchors (lb) • $N_{ua,g}$ = Total factored tensile force applied to anchor group (lb) The design side-face blowout strength for a single anchor in tension (ϕN_{sb}) calculated per Section 17.4.4 is checked against the factored tension load acting on the anchor, which is designated "N_{ua}" in Table 17.3.1.1. If $\phi N_{sb} \geq N_{ua}$, the provisions for considering side-face blowout failure in tension have been satisfied per Table 17.3.1.1. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting tension loads. The software only performs tension load checks per Table 17.3.1.1 if tension loads have been input via one of the load input functionalities. If a single anchor in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{sb}, and checks this value against either (a) the factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchor. Reference the Equations section of the PROFIS Engineering report for more information on the parameter ϕN_{sb}.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$																									
Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Results $N_{ua,edge}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
$N_{ua,edge}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for side-face blowout failure in tension require calculation of a nominal side-face blowout strength (N_{sb} or N_{sbg}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_{sb} or ϕN_{sbg}). ϕ-factors are relevant to static and seismic load conditions. Design strength is checked against a factored tension load, defined by the parameter "N_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored tension load parameter "N_{ua}". • N_{ua} = Factored tensile force applied to anchor or individual anchor in a group of anchors (lb) • $N_{ua,i}$ = Factored tensile force applied to most highly stressed anchor in a group of anchors (lb) • $N_{ua,g}$ = Total factored tensile force applied to anchor group (lb) The design side-face blowout strength for a group of anchors in tension (ϕN_{sbg}) calculated per Section 17.4.4 is checked against the portion of the factored tension load acting on the anchors nearest the edge where side-face blowout is being considered. PROFIS Engineering designates this parameter "$N_{ua,edge}$" in the Results section of the report. If $\phi N_{sbg} \geq N_{ua,edge}$, the provisions for considering side-face blowout failure in tension have been satisfied per Table 17.3.1.1. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting tension loads. The software only performs tension load checks per Table 17.3.1.1 if tension loads have been input via one of the load input functionalities. If a group of anchors in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{sbg}, and checks this value against either (a) the factored tension load acting on the anchors nearest the edge where side-face blowout is being considered, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchors nearest the edge where side-face blowout is being considered, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchors nearest the edge where side-face blowout is being considered, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchors nearest the edge where side-face blowout is being considered. Reference the Equations section of the PROFIS Engineering report for more information on the parameter ϕN_{sbg}.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
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Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Equation N_{sa}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																																						
N_{sa}	17.4.1.1 The nominal strength of an anchor in tension as governed by the steel, N_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. 17.4.1.2 The nominal strength of an anchor in tension, N_{sa}, shall not exceed $N_{sa} = A_{se,N} F_{uta} \quad (17.4.1.2)$ Where $A_{se,N}$ is the effective cross-sectional area of an anchor in tension, in.², and f_{uta} shall not be taken greater than the smaller of $1.9 f_{ya}$ and 125,000 psi. PROFIS Engineering cast-in-place anchor portfolio parameters used to calculate N_{sa}. <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_s) (in)</th><th>TENSILE STRENGTH (f_{uta}) (ksi)</th><th>YIELD STRENGTH (f_{ya}) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AES D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td rowspan="4"></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>55</td><td>2.000</td><td>75</td><td>55</td><td>3.142</td><td>2.500</td></tr><tr><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></table> Excerpt from a mechanical anchor ICC-ESR showing the parameter N_{sa}. 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MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ya}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	AES D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307	B	0.750	65	51	0.442	B	0.875	65	51	0.601	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	ASTM F 1554	55	2.000	75	55	3.142	2.500	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900	105	2.000	125	105	3.142	2.500	ACI 318-14 Chapter 2 defines the parameter N_{sa} as follows: “nominal strength of a single anchor or individual anchor in a group of anchors in tension as governed by the steel strength”. N_{sa} is always calculated for a single anchor when designing with the provisions of ACI 318-14. For cast-in-place anchors, PROFIS Engineering calculates N_{sa} using Equation (17.4.1.2). The table to the left shows the cast-in-place anchor portfolio in PROFIS Engineering, and the parameters that are used to calculate N_{sa} for a given anchor type and diameter. Post-installed mechanical anchors can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for N_{sa} are given in mechanical anchor ICC-ESR design tables. Although parameters such as A_{se} and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated N_{sa}-values to define the nominal steel strength in tension. The parameter “N_{sa}” in the Equations section of the PROFIS Engineering report references the “ESR value” in lieu of Equation (17.4.1.2). An excerpt from a mechanical anchor ESR showing N_{sa}-values derived from AC193/ACI 355.2 testing is referenced to the left. Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in the adhesive anchor ICC-ESR. Pre-calculated values for N_{sa} are given in adhesive anchor ICC-ESR design tables. Parameters such as A_{se} and f_{uta} may be given in the ICC-ESR, but PROFIS Engineering uses the pre-calculated N_{sa}-values specific to the anchor element that is being modeled to define the nominal steel strength in tension. The PROFIS Engineering adhesive anchor portfolio includes the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Proprietary elements Reference the adhesive anchor system ICC-ESR for N_{sa} values specific to an anchor element. The parameter “N_{sa}” in the Equations section of the PROFIS Engineering report references the “ICC-ESR value” in lieu of Equation (17.4.1.2). An excerpt from an adhesive anchor ICC-ESR showing N_{sa}-values derived from AC308/ACI 355.4 testing is referenced to the left. Reference the Calculations and Results section of the report for more information on N_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,N}$ and f_{uta}.
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ya}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																																																																																																		
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Equation N_{sa} (continued)

Equation	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																								
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Equation ϕN_{sa}

Equation	ACI 318-14 Chapter 17 Provision		Comments for PROFIS Engineering						
$\phi N_{sa} \geq N_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 <table><tr><th>Failure Mode</th><th>Single Anchor</th><th>Individual Anchor in a Group</th></tr><tr><td>Steel Strength in Tension</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td></tr></table>		Failure Mode	Single Anchor	Individual Anchor in a Group	Steel Strength in Tension	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$	ACI 318-14 strength design provisions for tension check a calculated design strength (ϕN_N) against a factored tension load (N_{ua}). The parameter “design strength” is defined as the product of a “nominal strength” (N_N) and one or more strength reduction factors (ϕ-factors). If $\phi N_N \geq N_{ua}$ for all relevant tension failure modes, the ACI 318-14 tension provisions are satisfied. Nominal steel strength in tension (N_{sa}) is always calculated for a single anchor when designing with the provisions of ACI 318-14. If an application consists of a group of anchors in tension, N_{sa} is calculated for a single anchor, and the design strength is checked against the highest loaded anchor in tension. PROFIS Engineering designates the strength reduction factor for steel failure ϕ_{steel}. ACI 318-08 anchoring-to-concrete provisions include an additional seismic reduction factor that is used to calculate anchor design strengths corresponding to brittle failure modes. Anchor elements can be defined in ACI 318 as “ductile” or “brittle” steel elements. Steel failure for a brittle steel anchor element is a “brittle”, i.e. “nonductile” failure mode; therefore, design steel strength calculated for a brittle steel anchor element using ACI 318-08 seismic provisions includes an additional strength reduction factor. PROFIS Engineering designates this seismic reduction factor “$\phi_{nonductile}$”, and shows it in the results section of the report. Since $\phi_{nonductile}$ is only relevant to seismic calculations with ACI 318-08 provisions, PROFIS Engineering always shows the parameter “$\phi_{nonductile}$” equal to 1.0 in the Results section of reports for ACI 318-14 provisions. When modeling an anchor element in PROFIS Engineering using ACI 318-14 provisions, the calculated design steel strength for both static and seismic load conditions equals $\phi_{steel} N_{sa}$, regardless of whether the anchor element is, by ACI 318 definition, “brittle” or “ductile”. Reference the Calculations and Results section of the PROFIS Engineering report for more information on: N_{sa}: Nominal steel strength in tension Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{steel}: Strength reduction factor for steel failure ϕN_{sa}: Design steel strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.
Failure Mode	Single Anchor	Individual Anchor in a Group							
Steel Strength in Tension	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$							

Variables $A_{se,N}$

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PROFIS Engineering uses these values to calculate N_{sa} per Equation (17.4.1.2). Post-installed anchor ICC-ESR include pre-calculated values for the nominal steel strength of an anchor element (N_{sa}). $A_{se,N}$-values may also be given in the ICC-ESR, however, PROFIS Engineering uses the pre-calculated N_{sa}-values instead of calculating N_{sa} per Equation (17.4.1.2). Reference the Calculations and Results section of the PROFIS Engineering report for more information on: N_{sa}: Nominal steel strength in tension Reference the Variables section of the PROFIS Engineering report for more information on: f_{uta}: Ultimate tensile stress of an anchor element
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Variables $A_{se,N}$ (continued)

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PROFIS Engineering cast-in-place anchor portfolio values for f_{ya} and f_{uta} <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_s) (in)</th><th>TENSILE STRENGTH (f_{uta}) (ksi)</th><th>YIELD STRENGTH (f_{ya}) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AES D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td rowspan="4"></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ya}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	AES D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307	B	0.750	65	51	0.442	B	0.875	65	51	0.601	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900	105	2.000	125	105	3.142	2.500	ACI 318-14 Equation 17.4.1.2 includes the parameter f_{uta} to calculate the nominal steel strength in tension (N_{sa}). ACI 318-14 Chapter 2 defines f_{uta} as the “specified tensile strength of anchor steel”. ICC-ESR for post-installed anchors include values for the “minimum specified ultimate strength”. Unlike reinforced concrete design, which uses bar yield strength (f_y) for calculations; ACI 318 anchoring-to-concrete provisions use the ultimate tensile strength of an anchor element (f_{uta}) to calculate the nominal steel strength in tension (N_{sa}). The ACI 318-14 commentary R17.4.1.2 notes: “The nominal strength of anchors in tension is best represented as a function of f_{uta} rather than f_{ya} because the large majority of anchor materials do not exhibit a well-defined yield point”. The PROFIS Engineering cast-in-place anchor portfolio includes the following anchors: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) The table to the left shows the f_{ya} and f_{uta} values for the PROFIS Engineering cast-in-place anchor portfolio. PROFIS Engineering uses the f_{uta} values to calculate N_{sa} per Equation (17.4.1.2). Post-installed anchor ICC-ESR include pre-calculated values for the nominal steel strength of an anchor element (N_{sa}). f_{uta}-values may also be given in an ICC-ESR, however, PROFIS Engineering uses the pre-calculated N_{sa}-values instead of calculating N_{sa} per Equation (17.4.1.2). Reference the Calculations and Results section of the PROFIS Engineering report for more information on: N_{sa}: Nominal steel strength in tension Reference the Variables section of the PROFIS Engineering report for more information on: $A_{se,N}$: Tensile stress area of an anchor element
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ya}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																																																																																												
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Variables f_{uta} (continued)

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																					
f_{uta}	Excerpt from a mechanical anchor ICC-ESR showing the parameters f_{ya} , f_{uta} and the pre-calculated value for N_{sa}. ICC-ESR-3187 Table 3 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="4">Nominal anchor diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td colspan="2">Min. specified yield strength</td><td>f_y</td><td>lb/in²</td><td>100,000</td><td>84,800</td><td>84,800</td><td>84,800</td></tr><tr><td colspan="2">Min specified ult. strength</td><td>f_{uta}</td><td>lb/in²</td><td>125,000</td><td>106,000</td><td>106,000</td><td>106,000</td></tr><tr><td colspan="2">Effective tensile stress area</td><td>$A_{se,N}$</td><td>in²</td><td>0.052</td><td>0.101</td><td>0.162</td><td>0.237</td></tr><tr><td colspan="2">Steel strength in tension</td><td>N_{sa}</td><td>lb</td><td>6,500</td><td>10,705</td><td>17,170</td><td>25,120</td></tr></table> Excerpt from an adhesive anchor ICC-ESR showing the pre-calculated value for N_{sa}. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td rowspan="2">ASTM F1554 Gr. 36</td><td>Rod effective cross-sectional area</td><td>A_{se}</td><td>in²</td><td>0.0775</td><td>0.1419</td><td>0.2260</td><td>0.3345</td><td>0.4617</td><td>0.6057</td><td>0.9691</td></tr><tr><td></td><td>N_{sa}</td><td>in</td><td>-</td><td>8,230</td><td>13,110</td><td>19,400</td><td>26,780</td><td>35,130</td><td>56,210</td></tr></table> Excerpt from an adhesive anchor ICC-ESR showing the parameters f_{ya}, and f_{uta}. ICC-ESR-3814 Table 2 <table><tr><th colspan="3">THREADED ROD SPECIFICATION</th><th>Minimum specified ultimate strength, f_{uta}</th><th>Minimum specified yield strenght 0.2 percent offset, f_{ya}</th><th>f_{uta}/f_{ya}</th><th>Elongation, min. percent</th><th>Reduction of area, min percent</th><th>Specification for nuts</th></tr><tr><td rowspan="7">CARBON STEEL</td><td>ASTM A193 Grade B7 ≤ 2 1/2 in.</td><td>psi</td><td>125000</td><td>105,000</td><td>1.19</td><td>16</td><td>50</td><td>ASTM A563 Grade DH</td></tr><tr><td>ASTM F566 Class 5.8 M5 (1/4 in.) to M24 (1 in.) (equivalent to ISO 898-1)</td><td>psi</td><td>72500</td><td>58,000</td><td>1.25</td><td>10</td><td>35</td><td>ASTM A563 Grade DH DIN 964 (8-A2K)</td></tr><tr><td>ASTM F1554, Gr. 36</td><td>psi</td><td>58000</td><td>36,000</td><td>1.61</td><td>23</td><td>40</td><td>ASTM A194 or ASTM A563</td></tr><tr><td>ASTM F1554, Gr. 36</td><td>psi</td><td>75000</td><td>55,000</td><td>1.36</td><td>21</td><td>30</td><td>ASTM A194 or ASTM A563</td></tr><tr><td>ASTM F1554, Gr. 36</td><td>psi</td><td>125000</td><td>105,000</td><td>1.19</td><td>15</td><td>42</td><td>ASTM A194 or ASTM A563</td></tr><tr><td>ISO 898-1 Class 5.8</td><td>psi</td><td>72500</td><td>58,000</td><td>1.25</td><td>22</td><td>-</td><td>DIN 934 Grade 6</td></tr><tr><td>ISO 898-1 Class 5.8</td><td>psi</td><td>116000</td><td>92,800</td><td>1.25</td><td>12</td><td>52</td><td>DIN 934 Grade 8</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal anchor diameter (in.)				3/8	1/2	5/8	3/4	Min. specified yield strength		f_y	lb/in²	100,000	84,800	84,800	84,800	Min specified ult. strength		f_{uta}	lb/in²	125,000	106,000	106,000	106,000	Effective tensile stress area		$A_{se,N}$	in²	0.052	0.101	0.162	0.237	Steel strength in tension		N_{sa}	lb	6,500	10,705	17,170	25,120	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	ASTM F1554 Gr. 36	Rod effective cross-sectional area	A_{se}	in²	0.0775	0.1419	0.2260	0.3345	0.4617	0.6057	0.9691		N_{sa}	in	-	8,230	13,110	19,400	26,780	35,130	56,210	THREADED ROD SPECIFICATION			Minimum specified ultimate strength, f_{uta}	Minimum specified yield strenght 0.2 percent offset, f_{ya}	f_{uta}/f_{ya}	Elongation, min. percent	Reduction of area, min percent	Specification for nuts	CARBON STEEL	ASTM A193 Grade B7 ≤ 2 1/2 in.	psi	125000	105,000	1.19	16	50	ASTM A563 Grade DH	ASTM F566 Class 5.8 M5 (1/4 in.) to M24 (1 in.) (equivalent to ISO 898-1)	psi	72500	58,000	1.25	10	35	ASTM A563 Grade DH DIN 964 (8-A2K)	ASTM F1554, Gr. 36	psi	58000	36,000	1.61	23	40	ASTM A194 or ASTM A563	ASTM F1554, Gr. 36	psi	75000	55,000	1.36	21	30	ASTM A194 or ASTM A563	ASTM F1554, Gr. 36	psi	125000	105,000	1.19	15	42	ASTM A194 or ASTM A563	ISO 898-1 Class 5.8	psi	72500	58,000	1.25	22	-	DIN 934 Grade 6	ISO 898-1 Class 5.8	psi	116000	92,800	1.25	12	52	DIN 934 Grade 8	
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	ASTM F1554, Gr. 36	psi	125000	105,000	1.19	15	42	ASTM A194 or ASTM A563																																																																																																																																															
	ISO 898-1 Class 5.8	psi	72500	58,000	1.25	22	-	DIN 934 Grade 6																																																																																																																																															
	ISO 898-1 Class 5.8	psi	116000	92,800	1.25	12	52	DIN 934 Grade 8																																																																																																																																															

Calculations N_{sa}

Calculations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																											
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N_{sa} is always calculated for a single anchor when designing with the provisions of ACI 318-14. For cast-in-place anchors, PROFIS Engineering calculates N_{sa} using Equation (17.4.1.2). The table to the left shows the cast-in-place anchor portfolio in PROFIS Engineering, and the parameters that are used to calculate N_{sa} for a given anchor type and diameter. Post-installed mechanical anchors can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for N_{sa} are given in mechanical anchor ICC-ESR design tables. In lieu of performing calculations per Eq. (17.4.1.2) to determine N_{sa}, PROFIS Engineering uses the pre-calculated N_{sa}-values given in the ICC-ESR to define the nominal steel strength in tension. An excerpt from a mechanical anchor ICC-ESR showing N_{sa}-values derived from AC193/ACI 355.2 testing is referenced to the left. Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in the adhesive anchor ICC-ESR. Pre-calculated values for N_{sa} are given in adhesive anchor ICC-ESR design tables. In lieu of performing calculations per Eq. (17.4.1.2) to determine N_{sa}, PROFIS Engineering uses the pre-calculated N_{sa}-values given in the ICC-ESR, which are specific to the anchor element that is being modeled, to define the nominal steel strength in tension. The PROFIS Engineering adhesive anchor portfolio includes the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Proprietary elements Reference the adhesive anchor system ICC-ESR for N_{sa} -values specific to an anchor element. An excerpt from an adhesive anchor ICC-ESR showing N_{sa} -values derived from AC308/ACI 355.4 testing is referenced to the left. Reference the Equations and Results section of the report for more information on N_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,N}$ and f_{uta}.
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ya}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																																																																																							
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Calculations N_{sa} (continued)

Calculations		ACI 318-14 Chapter 17 Provision							Comments for PROFIS Engineering		
N _{sa}		PROFIS Engineering uses the pre-calculated N _{sa} -values given in the ICC-ESR for the mechanical anchors in its portfolio to define the nominal steel strength in tension. Excerpt from a mechanical anchor ICC-ESR showing N _{sa} -values used in PROFIS Engineering.									
ICC-ESR-3187 Table 3											
DESIGN INFORMATION		Symbol	Units	Nominal anchor diameter (in.)							
				3/8	1/2	5/8	3/4				
Min. specified yield strength		f _y	lb/in ²	100,000	84,800	84,800	84,800				
Min specified ult. strength		f _{uta}	lb/in ²	125,000	106,000	106,000	106,000				
Effective tensile stress area		A _{se,N}	in ²	0.052	0.101	0.162	0.237				
Steel strength in tension		N _{sa}	lb	6,500	10,705	17,170	25,120				

Results N_{sa}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																											
N_{sa}	17.4.1.1 The nominal strength of an anchor in tension as governed by the steel, N_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. 17.4.1.2 The nominal strength of an anchor in tension, N_{sa}, shall not exceed $N_{sa} = A_{se,N} F_{uta} \quad (17.4.1.2)$ Where $A_{se,N}$ is the effective cross-sectional area of an anchor in tension, in.², and f_{uta} shall not be taken greater than the smaller of $1.9f_{ya}$ and 125,000 psi. PROFIS Engineering cast-in-place anchor portfolio parameters $A_{se,N}$ and f_{uta}, which are used to calculate N_{sa} per Eq. (17.4.1.2). <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_a) (in)</th><th>TENSILE STRENGTH (f_{ut}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AES D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td rowspan="4"></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td></td><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	AES D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307	B	0.750	65	51	0.442	B	0.875	65	51	0.601	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900		105	2.000	125	105	3.142	2.500	ACI 318-14 Chapter 2 defines the parameter N_{sa} as follows: “nominal strength of a single anchor or individual anchor in a group of anchors in tension as governed by the steel strength”. N_{sa} is always calculated for a single anchor when designing with the provisions of ACI 318-14. For cast-in-place anchors, PROFIS Engineering calculates N_{sa} using Equation (17.4.1.2). The table to the left shows the cast-in-place anchor portfolio in PROFIS Engineering, and the parameters that are used to calculate N_{sa} for a given anchor type and diameter. Post-installed mechanical anchors can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for N_{sa} are given in ICC-ESR design tables. PROFIS Engineering does not calculate N_{sa} per Eq. (17.4.1.2) for the post-installed anchors in its portfolio. In lieu of performing calculations per Eq. (17.4.1.2), PROFIS Engineering uses the pre-calculated N_{sa}-values given in the anchor ICC-ESR to define the nominal steel strength in tension. An excerpt from a mechanical anchor ICC-ESR showing pre-calculated N_{sa}-values derived from AC193/ACI 355.2 testing is referenced to the left. The PROFIS Engineering adhesive anchor portfolio includes the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Proprietary elements An excerpt from an adhesive anchor system ICC-ESR showing pre-calculated N_{sa}-values derived from AC308/ACI 355.4 testing is referenced to the left. These values are specific to a particular anchor element. Reference the Equations and Calculations section of the report for more information on N_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,N}$ and f_{uta}.
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																																																																																							
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Results N_{sa} (continued)

Results		ACI 318-14 Chapter 17 Provision							Comments for PROFIS Engineering				
N _{sa}		PROFIS Engineering uses the pre-calculated N _{sa} -values given in the ICC-ESR for the mechanical anchors in its portfolio to define the nominal steel strength in tension. Excerpt from a mechanical anchor ICC-ESR showing N _{sa} -values used in PROFIS Engineering.											
ICC-ESR-3187 Table 3													
DESIGN INFORMATION		Symbol	Units	Nominal anchor diameter (in.)									
				3/8	1/2	5/8	3/4						
Min. specified yield strength		f _y	lb/in²	100,000	84,800	84,800	84,800						
Min specified ult. strength		f _{uta}	lb/in²	125,000	106,000	106,000	106,000						
Effective tensile stress area		A _{se,N}	in²	0.052	0.101	0.162	0.237						
Steel strength in tension		N _{sa}	lb	6,500	10,705	17,170	25,120						
		PROFIS Engineering uses the pre-calculated N _{sa} -values given in the ICC-ESR for the adhesive anchor systems in its portfolio to define the nominal steel strength in tension. Excerpt from an adhesive anchor ICC-ESR showing N _{sa} -values used in PROFIS Engineering.											
ICC-ESR-3187 Table 14													
DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)									
				3/8	1/2	5/8	3/4	7/8	1	1-1/4			
ASTM F1554 Gr. 36	Rod effective cross-sectional area	A _{se}	in²	0.0775	0.1419	0.2260	0.3345	0.4617	0.6057	0.9691			
		N _{sa}	in	-	8,230	13,110	19,400	26,780	35,130	56,210			

Results ϕ_{steel}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																														
ϕ_{steel}	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (a) Anchor governed by strength of a ductile steel element (i) Tension loads 0.75 (ii) Shear loads 0.65 (b) Anchor governed by strength of a brittle steel element (i) Tension loads 0.65 (ii) Shear loads 0.60 PROFIS Engineering cast-in-place anchor portfolio. • AWS D1.1: 1/2" – 7/8" diameters • Hex head, square head, heavy square head: 1/2" – 1-1/2" diameters • Heavy hex head: 1/2" – 2" diameters <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_a) (in)</th><th>TENSILE STRENGTH (f_{ut}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (A_g) (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AES 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SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (A _g) (in²)	EFFECTIVE AREA (A _{se}) (in²)	AES D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307		B	0.750	65	51	0.442		B	0.875	65	51	0.601		ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900		105	2.000	125	105	3.142	2.500	ACI 318-14 strength design provisions for steel failure in tension require calculation of a nominal steel strength (N_{sa}). The nominal strength is multiplied by one or more strength reduction factors (φ-factors) to obtain a design strength (φN_{sa}). φ-factors are relevant to static and seismic load conditions. ACI 318 anchoring-to-concrete provisions have traditionally defined ductile steel elements and brittle steel elements as follows: • Ductile steel element — an element with a tensile test elongation of at least 14 percent and reduction in area of at least 30 percent • Brittle steel element — an element with a tensile test elongation of less than 14 percent, or reduction in area of less than 30 percent, or both PROFIS Engineering designates the φ-factor corresponding to steel failure for static load conditions "φ_{steel}". When designing cast-in-place anchors, PROFIS Engineering uses the φ-factors given in ACI 318-14 Section 17.3.3. The φ_{steel}-values for the cast-in-place anchors in the PROFIS Engineering portfolio correspond to the φ-factors given in Section 17.3.3 for ductile steel elements. In the absence of product-specific data, the φ-factors in Section 17.3.3 can be used as guide values for post-installed anchors; however, φ-factors derived from product-specific testing should always be used for the actual design of post-installed anchors. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. PROFIS Engineering uses the φ-factors derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. The φ-factors in the ICC-ESR correspond to the ACI 318 φ-factors for "ductile steel element" and "brittle steel element", as determined by the product testing and material properties for a specific anchor element. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: N_{sa}: Nominal steel strength in tension φN_{sa}: Design steel strength in tension φ_{nonductile}: Seismic strength reduction factor
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (A _g) (in²)	EFFECTIVE AREA (A _{se}) (in²)																																																																																																																																																																																																																										
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Results ϕ_{steel} (continued)

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																						
ϕ_{steel}	Cast-in-place anchor portfolio parameters for elongation and reduction of area. <table><tr><th>Bolt Type</th><th>Grade or Type</th><th>diameter (in)</th><th>f_{ys} (psi)</th><th>futa (psi)</th><th>elongation (min)</th><th>reduction of area (min)</th></tr><tr><td>ASW D1.1</td><td>B</td><td>1/2 – 1</td><td>51,000</td><td>65,000</td><td>20%</td><td>50%</td></tr><tr><td rowspan="3">ASTM F1554</td><td>36</td><td>≤2</td><td>36,000</td><td>58,000</td><td>23%</td><td>40%</td></tr><tr><td>55</td><td>≤2</td><td>55,000</td><td>75,000</td><td>21%</td><td>30%</td></tr><tr><td>105</td><td>≤2</td><td>105,000</td><td>125,000</td><td>15%</td><td>45%</td></tr></table> Excerpt of mechanical anchor ICC-ESR showing (ϕ-factors) for steel failure in tension. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td colspan="3">Strength reduction ϕ factor for tension, steel failure modes</td><td colspan="10">0.75</td></tr></table> Excerpt of adhesive anchor ICC-ESR showing (ϕ-factors) for steel failure in tension. ICC-ESR-3187 Table 11 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td>ISO 898-1 Class 5.8</td><td>Strength reduction factor for ϕ tension</td><td>ϕ</td><td>-</td><td colspan="7">0.65</td></tr><tr><td>ASTM A913 B7</td><td>Strength reduction factor for ϕ tension</td><td>ϕ</td><td>-</td><td colspan="7">0.75</td></tr><tr><td>ASTM F1554 Gr. 36</td><td>Strength reduction factor for ϕ tension</td><td>ϕ</td><td>-</td><td colspan="7">0.75</td></tr><tr><td>ASTM F1554 Gr. 55</td><td>Strength reduction factor for ϕ tension</td><td>ϕ</td><td>-</td><td colspan="7">0.75</td></tr><tr><td>ASTM F1554 Gr. 105</td><td>Strength reduction factor for ϕ tension</td><td>ϕ</td><td>-</td><td colspan="7">0.75</td></tr><tr><td>ASTM F593, CW Stainless</td><td>Strength reduction factor for ϕ tension</td><td>ϕ</td><td>-</td><td colspan="7">0.65</td></tr></table>	Bolt Type	Grade or Type	diameter (in)	f_{ys} (psi)	futa (psi)	elongation (min)	reduction of area (min)	ASW D1.1	B	1/2 – 1	51,000	65,000	20%	50%	ASTM F1554	36	≤2	36,000	58,000	23%	40%	55	≤2	55,000	75,000	21%	30%	105	≤2	105,000	125,000	15%	45%	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8			1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Strength reduction ϕ factor for tension, steel failure modes			0.75										DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	ISO 898-1 Class 5.8	Strength reduction factor for ϕ tension	ϕ	-	0.65							ASTM A913 B7	Strength reduction factor for ϕ tension	ϕ	-	0.75							ASTM F1554 Gr. 36	Strength reduction factor for ϕ tension	ϕ	-	0.75							ASTM F1554 Gr. 55	Strength reduction factor for ϕ tension	ϕ	-	0.75							ASTM F1554 Gr. 105	Strength reduction factor for ϕ tension	ϕ	-	0.75							ASTM F593, CW Stainless	Strength reduction factor for ϕ tension	ϕ	-	0.65							
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Results $\phi_{\text{nonductile}}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	ACI 318-14 strength design provisions for steel failure in tension require calculation of a nominal steel strength (N_{sa}). The nominal strength is multiplied by one or more strength reduction factors (ϕ-factors) to obtain a design strength (ϕN_{sa}). ϕ-factors are relevant to static and seismic load conditions. The parameter "$\phi_{\text{nonductile}}$" is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor "$\phi_{\text{nonductile}}$". "$\phi_{\text{nonductile}}$" is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

Results ϕN_{sa}

Results	ACI 318-14 Chapter 17 Provision		Comments for PROFIS Engineering						
ϕN_{sa}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 <table><tr><th>Failure Mode</th><th>Single Anchor</th><th>Individual Anchor in a Group</th></tr><tr><td>Steel Strength in Tension</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td></tr></table>		Failure Mode	Single Anchor	Individual Anchor in a Group	Steel Strength in Tension	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$	ACI 318-14 strength design provisions for anchors in tension check a calculated design strength (ϕN_{sa}) against a factored tension load (N_{ua}). The parameter “design strength” is defined as the product of a “nominal strength” (N_{sa}) and one or more strength reduction factors (ϕ-factors). If $\phi N_{sa} \geq N_{ua}$ for all relevant tension failure modes, the ACI 318-14 tension provisions are satisfied. When designing with ACI 318-14 anchoring-to-concrete provisions, nominal steel strength in tension (N_{sa}) is always calculated for a single anchor, and multiplied by the ϕ-factor for steel failure. For applications consisting of only one anchor in tension, the design strength (ϕN_{sa}) is checked against the tension load acting on that anchor (N_{ua}). If $\phi N_{sa} \geq N_{ua}$, the ACI 318-14 provisions for steel failure in tension are satisfied. If an application consists of a group of anchors in tension, N_{sa} is calculated for a single anchor, and the design strength (ϕN_{sa}) is checked against the highest individual loaded anchor in tension ($N_{ua,i}$). If $\phi N_{sa} \geq N_{ua,i}$, the ACI 318-14 provisions for steel failure in tension are satisfied. The PROFIS Engineering report section for steel failure in tension uses the generic designation “N_{ua}” to reference either the only tension load acting on an anchor in tension, or the highest tension load acting on an individual anchor within an anchor group in tension. PROFIS Engineering designates the strength reduction factor for steel failure ϕ_{steel}. ACI 318-08 anchoring-to-concrete provisions include an additional seismic reduction factor that is used to calculate anchor design strengths corresponding to brittle failure modes. Anchor elements can be defined in ACI 318 as “ductile” or “brittle” steel elements. Steel failure for a brittle steel anchor element is a “brittle”, i.e. “nonductile” failure mode; therefore, design steel strengths calculated for a brittle steel anchor element using ACI 318-08 seismic provisions would include an additional strength reduction factor. PROFIS Engineering designates this seismic reduction factor “$\phi_{nonductile}$”, and shows it in the results section of the report. Since $\phi_{nonductile}$ is only relevant to seismic calculations with ACI 318-08 provisions, PROFIS Engineering always shows the parameter “$\phi_{nonductile}$” equal to 1.0 in the Results section of reports for ACI 318-14 provisions. When modeling an anchor element in PROFIS Engineering using ACI 318-14 provisions, the calculated design steel strength in tension for both static and seismic load conditions equals $\phi_{steel} N_{sa}$. No additional strength reduction factors are applied to the nominal steel strength. Reference the Equations section of the PROFIS Engineering report for more information on: ϕN_{sa}: Design steel strength in tension Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{steel}: Strength reduction factor for steel failure $\phi_{nonductile}$: Seismic strength reduction factor N_{sa}: Nominal steel strength in tension N_{ua}: Factored load acting on anchors in tension A summary of calculated tension design strength versus the factored tension load for each tension failure mode relevant to the application is given in Part 3 Tension Load of the PROFIS Engineering report.
Failure Mode	Single Anchor	Individual Anchor in a Group							
Steel Strength in Tension	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$							

Results N_{ua}

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
N_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_b \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_b \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 strength design provisions for steel failure in tension require calculation of a nominal steel strength (N_{sa}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕN_{sa}). Design strength is checked against a factored tension load, defined by the parameter "N_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored tension load parameter "N_{ua}". • N_{ua} = factored tensile force applied to anchor or individual anchor in a group of anchors (lb) • $N_{ua,i}$ = factored tensile force applied to most highly stressed anchor in a group of anchors (lb) • $N_{ua,g}$ = total factored tensile force applied to anchor group (lb) The design steel strength for a single anchor in tension (ϕN_{sa}) calculated per Section 17.4.1 is checked against the factored tension load acting on the anchor, which is designated "N_{ua}" in Table 17.3.1.1. If $\phi N_{sa} \geq N_{ua}$, the provisions for considering steel failure in tension have been satisfied per Table 17.3.1.1. If an application consists of a group of anchors in tension, N_{sa} is calculated for a single anchor, and the design strength (ϕN_{sa}) is checked against the highest individually loaded anchor in tension, which is designated "$N_{ua,i}$" in Table 17.3.1.1. If $\phi N_{sa} \geq N_{ua,i}$, the provisions for considering steel failure in tension have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation "N_{ua}" to reference either the only tension load acting on an anchor, or the highest tension load acting on an individual anchor within an anchor group. The PROFIS Engineering Load Engine permits users to input service loads that are factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting tension loads. The software only performs tension load checks per Table 17.3.1.1 if tension loads have been input via one of the load input functionalities. If a single anchor in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{sa}, and checks this value against either (a) the factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchor. If a group of anchors in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{sa}, and checks this value against either (a) the highest factored tension load acting on an individual anchor, which has been calculated using the loads input via the Load Engine, (b) the highest factored tension load acting on an individual anchor, which has been calculated using the loads imported from a spreadsheet or (c) the highest factored tension load acting on an individual anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the highest factored tension load determined to be acting on an individual anchor within the anchor group. Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameter ϕN_{sa}.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
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Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_b \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

Equations ϕN_{ba}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$0.55 \phi N_{ba} \geq N_{ua,s}$	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ PROFIS Engineering parameters for calculating N_{ba}: $N_{ba} = \lambda_a \tau_{k,c} \alpha_{N,seis} \pi d_a h_{ef}$ PROFIS Engineering calculations for N_{ba} when used to calculate the sustained load parameter 0.55 ϕN_{ba} for threaded rods, reinforcing bars and HIS-N and HIS-RN inserts: $N_{ba} = \frac{(\lambda_a \tau_{xxxx} \alpha_{N,seis} \pi d_a h_{ef})}{\alpha_{N,seis}}$ PROFIS Engineering calculations for N_{ba} when used to calculate the sustained load parameter 0.55 ϕN_{ba} for HIT-HY 200 used with HIT-Z and HIT-Z-R threaded rods: $N_{ba} = \lambda_a N_p$	The provisions given in ACI 318-14 Section 17.3.1.2 are used to perform a check for adhesive anchors subjected to sustained tension loads. The check consists of calculating a capacity (0.55ϕN_{ba}), and comparing it to the highest (factored) sustained tension load ($N_{ua,s}$) acting on a single anchor within the anchor group. The strength reduction factor (ϕ-factor) in Eq. (17.3.1.2) corresponds to the parameter "ϕ_{bond}" in the PROFIS Engineering report. The parameter "N_{ba}" corresponds to the "basic bond strength" for a single adhesive anchor without any fixed edge influences. N_{ba} is calculated per Eq. (17.4.5.2); but an additional seismic modification factor that is derived from testing per the ICC-ES acceptance criteria AC308 is not given in Eq. (17.4.5.2), and must also be considered in the N_{ba}-calculation. This seismic modification factor is designated "$\alpha_{N,seis}$", and is included in PROFIS Engineering N_{ba}-calculations when seismic conditions are being modeled. However, since seismic load is not considered a sustained load, PROFIS Engineering divides out any $\alpha_{N,seis}$-value when calculating N_{ba} per Eq. (17.3.1.2). Reference the Equations, Calculations and Results section of the report for more information on: N_{ba}: Basic bond strength parameters and calculations for the sustained tension load check Reference the Results section of the report for more information on: ϕ_{bond}: Strength reduction factor for bond $N_{ua,s}$: Sustained factored tension load Reference the Design Guide sections about pullout for more information about the HY 200/HIT-Z parameter N_p.

Equations N_{ba}

Equations	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																																										
$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2. $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed Table 17.4.5.2 — Minimum characteristic bond stresses [1] [2] <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4. PROFIS Engineering parameters for calculating N_{ba}: $N_{ba} = \lambda_a \tau_{kxxx} \alpha_{N,seis} \pi d_a h_{ef}$ PROFIS Engineering calculations for N_{ba} when used to calculate the sustained load parameter 0.55 ϕN_{ba}: $N_{ba} = \frac{(\lambda_a \tau_{kxxx} \alpha_{N,seis} \pi d_a h_{ef})}{\alpha_{N,seis}}$ Example: Example of a table in an ICC-ESR showing characteristic bond stress values (τ_{kcr} and $\tau_{k,uncr}$), the seismic reduction value $\alpha_{N,seis}$, and strength reduction factors (ϕ-factors) for bond strength. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,max}$</td><td>in</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>5</td></tr><tr><td colspan="2"></td><td></td><td>(mm)</td><td>60</td><td>70</td><td>79</td><td>89</td><td>89</td><td>102</td><td>127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,min}$</td><td>in</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/5</td><td>20</td><td>25</td></tr><tr><td colspan="2"></td><td></td><td>(mm)</td><td>(191)</td><td>(254)</td><td>(318)</td><td>(381)</td><td>(445)</td><td>(508)</td><td>(635)</td></tr><tr><td rowspan="2">Temperature Range A</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi</td><td>1045</td><td>1135</td><td>1170</td><td>1260</td><td>1290</td><td>1325</td><td>1380</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(7.2)</td><td>(7.8)</td><td>(8.1)</td><td>(8.7)</td><td>(8.9)</td><td>(9.1)</td><td>(9.5)</td></tr><tr><td rowspan="2"></td><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td></tr><tr><td rowspan="2">Temperature Range B</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi</td><td>1045</td><td>1135</td><td>1170</td><td>1260</td><td>1290</td><td>1325</td><td>1380</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(7.2)</td><td>(7.8)</td><td>(8.0)</td><td>(8.67)</td><td>(9.0)</td><td>(9.0)</td><td>(9.5)</td></tr><tr><td rowspan="2"></td><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td></tr><tr><td rowspan="2">Temperature Range C</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi</td><td>855</td><td>930</td><td>960</td><td>1035</td><td>1055</td><td>1085</td><td>1130</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(5.0)</td><td>(6.4)</td><td>(6.6)</td><td>(7.1)</td><td>(7.3)</td><td>(7.5)</td><td>(7.8)</td></tr><tr><td rowspan="2"></td><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td></tr><tr><td rowspan="3">Permissible Installation Conditions</td><td rowspan="3">Dry and water saturated concrete</td><td>Anchor Category</td><td>-</td><td colspan="7">1</td></tr><tr><td>ϕ_{cr}, ϕ_{ws}</td><td>-</td><td colspan="7">0.65</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table>	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,max}$	in	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	5				(mm)	60	70	79	89	89	102	127	Maximum Embedment		$h_{ef,min}$	in	7-1/2	10	12-1/2	15	17-1/5	20	25				(mm)	(191)	(254)	(318)	(381)	(445)	(508)	(635)	Temperature Range A	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380			(Mpa)	(7.2)	(7.8)	(8.1)	(8.7)	(8.9)	(9.1)	(9.5)		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	Temperature Range B	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380			(Mpa)	(7.2)	(7.8)	(8.0)	(8.67)	(9.0)	(9.0)	(9.5)		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	Temperature Range C	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	855	930	960	1035	1055	1085	1130			(Mpa)	(5.0)	(6.4)	(6.6)	(7.1)	(7.3)	(7.5)	(7.8)		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	1820	1820	1820	1820	1820	1820	1820			(Mpa)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	Permissible Installation Conditions	Dry and water saturated concrete	Anchor Category	-	1							ϕ_{cr}, ϕ_{ws}	-	0.65							Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	0.97	1.0	The parameter N_{ba} corresponds to the “basic bond strength” for a single adhesive anchor element without any fixed edge or spacing influences. N_{ba} is calculated per Eq. 17.4.5.2; and is predicated on the following parameters: • τ_{xxxx} — characteristic bond stress of the adhesive product; designated in ACI 318-14 as “τ_{cr}” for cracked concrete conditions, and “τ_{uncr}” for uncracked concrete conditions • πd_a — anchor element circumference based on the nominal diameter of the element • h_{ef} — effective embedment depth of the anchor • λ_a — modification factor for lightweight concrete Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values (τ_{xxxx}) that are provided in an ICC-ESR. The parameter designated “τ_{k,cr}” in the report corresponds to the characteristic bond stress in cracked concrete, and the parameter designated “τ_{k,uncr}” in the report corresponds to the characteristic bond stress in uncracked concrete. The τ-values given in ACI 318-14 Table 17.4.5.2 are intended to be used as guide values in the absence of product-specific data. PROFIS Engineering calculates N_{ba} with the τ_{k,cr} and τ_{k,uncr} values given in the adhesive anchor ICC-ESR. The parameter “α_{N,seis}” is a reduction factor derived from testing per the ICC-ES acceptance criteria AC308. It is used to calculate N_{ba} when seismic load conditions are assumed. Adhesive anchor systems can be shown compliance under the International Building Code (IBC) via testing per AC308 in conjunction with the ACI test standard ACI 355.4, but ACI 355.4 does not include any provisions for determining α_{N,seis}. Since ACI 355.4 does not reference α_{N,seis}, ACI 318-14 Eq. (17.4.5.2) does not reference α_{N,seis}. Since AC308 includes provisions for determining α_{N,seis}, adhesive anchor ICC-ESR derived from AC308 testing include α_{N,seis} as a parameter for calculating N_{ba}. Therefore, PROFIS Engineering, which uses the adhesive anchor ICC-ESR data for calculating bond strength, likewise includes α_{N,seis} as a parameter for calculating N_{ba}. The provisions in Section 17.3.1.2 are relevant to sustained load conditions. Seismic loads are not considered sustained loads; therefore, any seismic-specific parameters such as α_{N,seis} do not need to be considered when calculating N_{ba} per Eq. (17.3.1.2). PROFIS Engineering divides out any α_{N,seis}-value when calculating N_{ba} per Eq. (17.3.1.2). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor τ_{k,xxxx}: Characteristic bond stress d_a: Anchor element diameter h_{ef}: Effective embedment depth Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi																																																																																																																																																																																																																																								
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			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)																																																																																																																																																																																																																																		
Temperature Range B	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380																																																																																																																																																																																																																																		
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Temperature Range C	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	855	930	960	1035	1055	1085	1130																																																																																																																																																																																																																																		
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		Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	0.97	1.0																																																																																																																																																																																																																																	

Variables λ_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85 ⁽¹⁾</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33</td><td>0.85 to 1 ⁽²⁾</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> ¹ Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. ² Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}}{6.7 / f_{cm}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi_{da} h_{ef} \quad (17.4.5.2)$	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ⁽²⁾	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	ACI 318 anchoring-to-concrete provisions consider the following tension failure modes with respect to adhesive anchor systems: • Steel failure in tension • Concrete breakout failure in tension • Bond failure in tension λ_a is a modification factor for lightweight concrete that is used to calculate various parameters for design with ACI 318 anchoring-to-concrete provisions. ACI 318-14 Section 17.2.6 references how λ_a is calculated for various anchoring-to-concrete failure modes. When considering bond failure in tension for an adhesive anchor application, the λ_a-value that is calculated equals 0.6λ. Generally speaking, with respect to concrete failure modes, ACI 318 applies a multiplier designated “λ” to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete”. The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to “anchoring-to-concrete” calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ-determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the anchor failure mode being considered, to obtain the parameter λ_a. Therefore, when calculating the basic bond strength (N_{ba}) for an adhesive anchor system per Eq. (17.4.5.2), a lightweight concrete multiplier ($\lambda_a = 0.6\lambda$) is applied to the parameter “τ” corresponding to the characteristic bond stress of the adhesive product. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a-provisions for a specific adhesive anchor system are derived from this testing and will be given in the ICC-ESR for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. When modeling an adhesive anchor application in PROFIS Engineering, the λ_a-value (or provisions) referenced in the adhesive anchor ICC-ESR are used to calculate N_{ba}. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. Per ACI 318 provisions for determining λ_a, when designing adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.6 to obtain the λ_a-value used to calculate N_{ba}. Reference the Equations, Calculations and Results sections of the PROFIS Engineering report for more information on the parameter N_{ba}.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ⁽²⁾																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

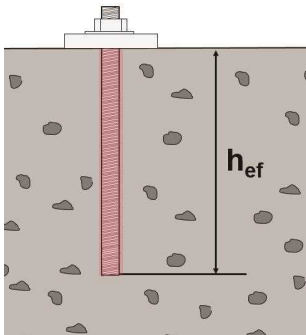
Variables $\tau_{k,c}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																							
$\tau_{k,c}$	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1][2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4. Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,cr}$ and $\tau_{k,uncr}$). ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A¹</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.0)</td><td>1260 (8.67)</td><td>1290 (9.0)</td><td>1325 (9.0)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C³</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.0)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr></table> ¹ Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. ² Temperature Range A: Maximum short term temperature = 130°F. Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F. Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F. Maximum long term temperature = 162°F.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,max}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,min}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ¹	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.0)	1260 (8.67)	1290 (9.0)	1325 (9.0)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ³	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.0)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	The parameter "$\tau_{k,c}$" shown in the PROFIS Engineering report section for sustained tension load corresponds to the characteristic bond stress in either cracked or uncracked concrete. It is used to calculate the parameter "N_{ba}", which is given in ACI 318-14 Equation (17.3.1.2), and defined in Equation (17.4.5.2). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist; however, N_{ba} can be calculated for either cracked or uncracked concrete conditions. PROFIS Engineering users can select either "cracked" or "uncracked" conditions when modeling an adhesive anchor system for sustained tension load. PROFIS Engineering calculates N_{ba} using the characteristic bond stress corresponding to the concrete condition selected, as given in the ICC-ESR for the adhesive anchor system. The ICC-ESR designates the ACI 318 parameter "τ_{uncr}" as "$\tau_{k,uncr}$", and the ACI 318 parameter "τ_{cr}" as "$\tau_{k,cr}$". The PROFIS Engineering report section for sustained tension load designates the characteristic bond stress parameter as a generic "$\tau_{k,c}$" for either cracked or uncracked conditions. τ-values given in the ICC-ESR are relevant to testing in concrete having a compressive strength of 2500 psi. These values can be increased for compressive strengths $2500 \text{ psi} < f'_c < 8000 \text{ psi}$ using the factor noted in the bond strength table footnotes. PROFIS Engineering increases the τ-values for both cracked and uncracked concrete that are given in the ICC-ESR by this factor when concrete compressive strengths $> 2500 \text{ psi}$ are being modeled. τ-values in the ICC-ESR are also dependent on the "temperature range" corresponding to "long term" and "short term" concrete temperatures. The ICC-ESR defines "long term" concrete temperatures as being "roughly constant" over time. "Short term" concrete temperatures are elevated temperatures "that occur over brief intervals". Both types of temperature are relevant to the concrete temperature during the service life of the anchor, not the concrete temperature at the time anchors are installed. Long term and short term temperature ranges are defined in footnotes for the bond strength tables of an adhesive anchor ICC-ESR τ-values corresponding to a particular temperature range are given in the bond strength table. Reference the Variables section of the PROFIS Engineering report for Bond Strength for more information on: $\tau_{k,c,uncr}$: Characteristic bond stress in uncracked concrete $\tau_{k,c}$: Characteristic bond stress in cracked concrete Reference the Calculations section of the PROFIS Engineering report for Sustained Tension Load — Bond Strength for more information on: N_{ba}: Basic bond strength for a single adhesive anchor
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi																																																																																																																					
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Variables d_a

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d_a	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ Example: Example of a bond strength table in an ICC-ESR showing parameters that are dependent on the anchor element diameter ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,umcr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.0)</td><td>1260 (8.67)</td><td>1290 (9.0)</td><td>1325 (9.0)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,umcr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.0)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,umcr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,max}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,min}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,umcr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.0)	1260 (8.67)	1290 (9.0)	1325 (9.0)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,umcr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.0)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,umcr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	The parameter d_a is defined in ACI 318-14 Chapter 2 as the “outside diameter” of an anchor or the “shaft diameter” of a headed stud, headed bolt or hooked bolt. Therefore, d_a corresponds to the external diameter of an anchor element. When calculating the sustained load strength defined by Equation (17.3.1.2), d_a is used to calculate the parameter “N_{ba}” that is defined in Equation (17.4.5.2). Other parameters given in Eq. 17.4.5.2 such as effective embedment depth (h_{ef}), characteristic bond stress (τ_k), and $\alpha_{N,seis}$ are also dependent on the diameter of the anchor element being used. The PROFIS Engineering adhesive anchor portfolio permits bond strength calculations with the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Specialty anchor elements Information about these anchor element types is given in the ICC-ESR for an adhesive anchor system. PROFIS Engineering uses the anchor diameter parameter referenced in the ICC-ESR bond strength tables for an adhesive anchor system to calculate N_{ba} for a specific anchor element. When design with a threaded rod or reinforcing bar is selected, PROFIS Engineering uses the nominal diameter of the anchor element to calculate N_{ba}. When design with Hilti HIS-N and HIS-RN internally threaded inserts is selected, PROFIS Engineering uses the outside diameter of the insert to calculate N_{ba}. Below are illustrations showing how the parameter d_a for calculating N_{ba} can be defined for various anchor elements. The parameter “d_{hole}” noted in the illustrations corresponds to the diameter of the drilled hole into which the adhesive product and anchor element are inserted. reinforcing bar threaded rod internally threaded element Reference the Variables section of the PROFIS Engineering report for more information on: h_{ef}: Effective embedment depth $\tau_{k,c}$: Characteristic bond stress Reference the Calculations section of the PROFIS Engineering report for more information on: N_{ba}: Basic bond strength for a single adhesive anchor
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in.)																																																																																																													
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Variables h_{ef}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																								
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ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>7-1/2 (191.00)</td><td>10 (254.00)</td><td>12-1/2 (318.00)</td><td>15 (381.00)</td><td>17-1/5 (445.00)</td><td>20 (508.00)</td><td>25 (635.00)</td></tr><tr><td rowspan="2">Temperature Range A¹</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.10)</td><td>1260 (8.70)</td><td>1290 (8.90)</td><td>1325 (9.10)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range C³</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.90)</td><td>930 (6.40)</td><td>960 (6.60)</td><td>1035 (7.10)</td><td>1055 (7.30)</td><td>1085 (7.50)</td><td>1130 (7.80)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.5}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. 3 Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. 4 Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,max}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,min}$	in (mm)	7-1/2 (191.00)	10 (254.00)	12-1/2 (318.00)	15 (381.00)	17-1/5 (445.00)	20 (508.00)	25 (635.00)	Temperature Range A ¹	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.10)	1260 (8.70)	1290 (8.90)	1325 (9.10)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	Temperature Range C ³	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	855 (5.90)	930 (6.40)	960 (6.60)	1035 (7.10)	1055 (7.30)	1085 (7.50)	1130 (7.80)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	The parameter h_{ef} is defined as the “effective embedment depth of an anchor”. This parameter corresponds to the embedded portion of the anchor that is “effective” in transferring tension load from the anchor into the concrete. When calculating the sustained load strength defined by Equation (17.3.1.2), h_{ef} is used to calculate the parameter “N_{ba}” that is defined in Equation (17.4.5.2), The PROFIS Engineering adhesive anchor portfolio permits bond strength calculations with the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Specialty anchor elements Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive product-specific data that is used in ACI 318-14 bond strength calculations for an adhesive anchor system. Data derived from this testing, as well as some of the parameters used to develop this data, are provided in an ICC-ESR. The minimum effective embedment depth ($h_{ef,min}$) derived from this testing is specific to the anchor element (e.g. threaded rod, rebar, internally threaded insert), and to the adhesive product. AC308 limits the maximum effective embedment depth ($h_{ef,max}$) for adhesive anchor systems to a value of 20 times the anchor diameter ($20d_a$). For post-installed adhesive anchors, PROFIS Engineering permits users to input h_{ef} values that are within the embedment depth range given in the ICC-ESR for a specific anchor element, diameter, and adhesive product. post-installed adhesive anchor where $h_{ef,min}$ and $h_{ef,max}$ ($=20d_a$) are given in the anchor ICC-ESR 
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in).																																																																																																		
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	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)																																																																																																
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It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. Example: Example of a table in an ICC-ESR showing the following parameters for calculating N_{ba}: • τ_{kcr} and $\tau_{k,uncr}$ — characteristic bond stress values • $\alpha_{N,seis}$ — seismic reduction value • d_a — anchor element diameter • h_{ef} — anchor effective embedment depth ICC-ESR-3187 Table 14 <table><tr><th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,max}$</td><td>in</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>5</td></tr><tr><td colspan="2"></td><td></td><td>(mm)</td><td>60</td><td>70</td><td>79</td><td>89</td><td>89</td><td>102</td><td>127</td></tr><tr><td colspan="2">Maximum 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concrete</td><td>$\tau_{k,uncr}$</td><td>psi</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td></tr><tr><td rowspan="2">Temperature Range C</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi</td><td>1045</td><td>1135</td><td>1170</td><td>1260</td><td>1290</td><td>1325</td><td>1380</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(7.2)</td><td>(7.8)</td><td>(8.0)</td><td>(8.67)</td><td>(9.0)</td><td>(9.0)</td><td>(9.5)</td></tr><tr><td rowspan="2">Temperature Range D</td><td>Characteristic bond strength in uncracked 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Embedment		$h_{ef,min}$	in	7-1/2	10	12-1/2	15	17-1/5	20	25				(mm)	(191)	(254)	(318)	(381)	(445)	(508)	(635)	Temperature Range A	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380			(Mpa)	(7.2)	(7.8)	(8.1)	(8.7)	(8.9)	(9.1)	(9.5)	Temperature Range B	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	Temperature Range C	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380			(Mpa)	(7.2)	(7.8)	(8.0)	(8.67)	(9.0)	(9.0)	(9.5)	Temperature Range D	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	Temperature Range E	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	855	930	960	1035	1055	1085	1130			(Mpa)	(5.0)	(6.4)	(6.6)	(7.1)	(7.3)	(7.5)	(7.8)	Temperature Range F	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	1820	1820	1820	1820	1820	1820	1820			(Mpa)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	Permissible Installation Conditions	Dry and water saturated concrete	Anchor Category	-	1							ϕ_{cr} , ϕ_{ws}	-	0.65							Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	The parameter N_{ba} corresponds to the “basic bond strength” for a single adhesive anchor element without any fixed edge or spacing influences. N_{ba} is calculated per Eq. 17.4.5.2; and is predicated on the following parameters: • $\tau_{k,xxx}$ — characteristic bond stress of the adhesive product; designated in ACI 318-14 as “τ_{cr}” for cracked concrete conditions, and “τ_{uncr}” for uncracked concrete conditions • πd_a — anchor element circumference based on the nominal diameter of the element • h_{ef} — effective embedment depth of the anchor • λ_a — modification factor for lightweight concrete Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values ($\tau_{k,xxx}$) that are provided in an ICC-ESR. The parameter designated “$\tau_{k,cr}$” in the report corresponds to the characteristic bond stress in cracked concrete, and the parameter designated “$\tau_{k,uncr}$” in the report corresponds to the characteristic bond stress in uncracked concrete. PROFIS Engineering calculates N_{ba} with the $\tau_{k,cr}$ and $\tau_{k,uncr}$ values given in the adhesive anchor ICC-ESR. The parameter “$\alpha_{N,seis}$” is a reduction factor derived from testing per the ICC-ES acceptance criteria AC308. It is used to calculate N_{ba} when seismic load conditions are assumed. Adhesive anchor systems can be shown compliance under the International Building Code (IBC) via testing per AC308 in conjunction with the ACI test standard ACI 355.4, but ACI 355.4 does not include any provisions for determining $\alpha_{N,seis}$. Since ACI 355.4 does not reference $\alpha_{N,seis}$, ACI 318-14 Eq. (17.4.5.2) does not reference $\alpha_{N,seis}$. Since AC308 includes provisions for determining $\alpha_{N,seis}$, adhesive anchor ICC-ESR derived from AC308 testing include $\alpha_{N,seis}$ as a parameter for calculating N_{ba}. 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$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ PROFIS Engineering parameters for calculating N_{ba}: $N_{ba} = \lambda_a \tau_{k,xxx} \alpha_{N,seis} \pi d_a h_{ef}$ PROFIS Engineering calculations for N_{ba} when used to calculate the sustained load parameter 0.55 ϕN_{ba}: $N_{ba} = \frac{(\lambda_a \tau_{k,xxx} \alpha_{N,seis} \pi d_a h_{ef})}{\alpha_{N,seis}}$ 17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. Example: Example of a table in an ICC-ESR showing the following parameters for calculating N_{ba}: $\tau_{k,cr}$ and $\tau_{k,uncr}$ — characteristic bond stress values $\alpha_{N,seis}$ — seismic reduction value d_a — anchor element diameter h_{ef} — anchor effective embedment depth ICC-ESR-3187 Table 14 <table><tr><th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th><th></th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,max}$</td><td>in</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>5</td><td></td></tr><tr><td colspan="2"></td><td></td><td>(mm)</td><td>60</td><td>70</td><td>79</td><td>89</td><td>89</td><td>102</td><td>127</td><td></td></tr><tr><td colspan="2">Maximum 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PROFIS Engineering calculates N_{ba} with the $\tau_{k,cr}$ and $\tau_{k,uncr}$ values given in the adhesive anchor ICC-ESR. The parameter “$\alpha_{N,seis}$” is a reduction factor derived from testing per the ICC-ES acceptance criteria AC308. It is used to calculate N_{ba} when seismic load conditions are assumed. Adhesive anchor systems can be shown compliance under the International Building Code (IBC) via testing per AC308 in conjunction with the ACI test standard ACI 355.4, but ACI 355.4 does not include any provisions for determining $\alpha_{N,seis}$. Since ACI 355.4 does not reference $\alpha_{N,seis}$, ACI 318-14 Eq. (17.4.5.2) does not reference $\alpha_{N,seis}$. Since AC308 includes provisions for determining $\alpha_{N,seis}$, adhesive anchor ICC-ESR derived from AC308 testing include $\alpha_{N,seis}$ as a parameter for calculating N_{ba}. Therefore, PROFIS Engineering, which uses the adhesive anchor ICC-ESR data for calculating bond strength, likewise includes $\alpha_{N,seis}$ as a parameter for calculating N_{ba}. The provisions in Section 17.3.1.2 are relevant to sustained load conditions. Seismic loads are not considered sustained loads; therefore, any seismic-specific parameters such as $\alpha_{N,seis}$ do not need to be considered when calculating N_{ba} per Eq. (17.3.1.2). PROFIS Engineering divides out any $\alpha_{N,seis}$-value when calculating N_{ba} per Eq. (17.3.1.2). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxx}$: Characteristic bond stress d_a: Anchor element diameter h_{ef}: Effective embedment depth Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).																																																																																																																																																																																																																																																				
				3/8	1/2	5/8	3/4	7/8	1	1-1/4																																																																																																																																																																																																																																														
Minimum Embedment		$h_{ef,max}$	in	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	5																																																																																																																																																																																																																																														
			(mm)	60	70	79	89	89	102	127																																																																																																																																																																																																																																														
Maximum Embedment		$h_{ef,min}$	in	7-1/2	10	12-1/2	15	17-1/5	20	25																																																																																																																																																																																																																																														
			(mm)	(191)	(254)	(318)	(381)	(445)	(508)	(635)																																																																																																																																																																																																																																														
Temperature Range A	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380																																																																																																																																																																																																																																														
			(Mpa)	(7.2)	(7.8)	(8.1)	(8.7)	(8.9)	(9.1)	(9.5)																																																																																																																																																																																																																																														
Temperature Range B	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220																																																																																																																																																																																																																																														
			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)																																																																																																																																																																																																																																														
Temperature Range C	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380																																																																																																																																																																																																																																														
			(Mpa)	(7.2)	(7.8)	(8.0)	(8.67)	(9.0)	(9.0)	(9.5)																																																																																																																																																																																																																																														
Temperature Range D	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220																																																																																																																																																																																																																																														
			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)																																																																																																																																																																																																																																														
Permissible Installation Conditions	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi	855	930	960	1035	1055	1085	1130																																																																																																																																																																																																																																														
			(Mpa)	(5.0)	(6.4)	(6.6)	(7.1)	(7.3)	(7.5)	(7.8)																																																																																																																																																																																																																																														
Permissible Installation Conditions	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi	1820	1820	1820	1820	1820	1820	1820																																																																																																																																																																																																																																														
			(Mpa)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)																																																																																																																																																																																																																																														
Anchor Category			-	1																																																																																																																																																																																																																																																				
Dry and water saturated concrete		ϕ_{cr} , ϕ_{ws}	-	0.65																																																																																																																																																																																																																																																				
Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0																																																																																																																																																																																																																																														

Results ϕ_{bond}

Results	ACI 318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																																							
ϕ_{bond}	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Example: Example of an ICC-ESR showing strength reduction factors (ϕ-factors) for bond strength. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{el,max}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{el,min}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.0)</td><td>1260 (8.67)</td><td>1290 (9.0)</td><td>1325 (9.0)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.0)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td rowspan="2">Permissible Installation Conditions</td><td rowspan="2">Dry and water saturated concrete</td><td>Anchor Category</td><td>-</td><td colspan="7">1</td></tr><tr><td>ϕ_{cr}, ϕ_{us}</td><td>-</td><td colspan="7">0.65</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{n,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table>										DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{el,max}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{el,min}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.0)	1260 (8.67)	1290 (9.0)	1325 (9.0)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	855 (5.0)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Permissible Installation Conditions	Dry and water saturated concrete	Anchor Category	-	1							ϕ_{cr}, ϕ_{us}	-	0.65							Reduction for Seismic Tension		$\alpha_{n,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	The provisions given in ACI 318-14 Section 17.3.1.2 are used to perform a check for adhesive anchors subjected to sustained tension loads. The check consists of calculating a capacity (0.55ϕN_{ba}), and comparing it to the highest (factored) sustained tension load ($N_{ua,s}$) acting on a single anchor within the anchor group. The strength reduction factor (ϕ-factor) in Eq. (17.3.1.2) corresponds to the parameter “ϕ_{bond}” in the PROFIS Engineering report. Adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. PROFIS Engineering uses the ϕ-factors derived from AC308/ACI 355.4 testing, as given in the ICC-ESR for the adhesive anchor system, to calculate the parameter 0.55ϕN_{ba} defined by Eq. (17.3.1.2). The ϕ-factor used in this equation is relevant to the condition of the concrete in the drilled hole into which the adhesive and anchor element are inserted. Possible drilled hole installation conditions include dry, water saturated, water filled, and underwater (submerged). Reference the ICC-ESR for ϕ-factors that are specific to these conditions. PROFIS Engineering uses the ϕ-factor corresponding to the drilled hole condition that has been selected to calculate 0.55ϕN_{ba}, and designates this parameter “ϕ_{bond}” in the Results section of the report. Reference the Calculations and Results section of the PROFIS report for more information on: N_{ba}: Basic bond strength Reference the Results section of the PROFIS Engineering report for more information on the following parameters: 0.55ϕN_{ba}: Calculated strength for sustained tension load $N_{ua,s}$: Sustained tension load
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).																																																																																																																																														
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Results $0.55 \phi N_{ba}$

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0.55 φN _{ba}	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Where N_{ba} is determined in accordance with 17.4.5.2. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ PROFIS Engineering parameters for calculating N_{ba}: $N_{ba} = \lambda_a \tau_{kxxx} \alpha_{N,seis} \pi d_a h_{ef}$ PROFIS Engineering calculations for N_{ba} when used to calculate the sustained load parameter 0.55 φN_{ba}: $N_{ba} = \frac{(\lambda_a \tau_{kxxx} \alpha_{N,seis} \pi d_a h_{ef})}{\alpha_{N,seis}}$ 17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. Example: Example of a table in an ICC-ESR showing the following parameters for calculating N_{ba}: • τ_{kcr} and τ_{k,uncr} — characteristic bond stress values • α_{N,seis} — seismic reduction value • d_a — anchor element diameter • h_{ef} — anchor effective embedment depth ICC-ESR-3187 Table 14 <table><tr><th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>h_{ef,max}</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>h_{ef,min}</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A</td><td>Characteristic bond strength in cracked concrete</td><td>τ_{k,cr}</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>τ_{k,uncr}</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B</td><td>Characteristic bond strength in cracked concrete</td><td>τ_{k,cr}</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.0)</td><td>1260 (8.67)</td><td>1290 (9.0)</td><td>1325 (9.0)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>τ_{k,uncr}</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C</td><td>Characteristic bond strength in cracked concrete</td><td>τ_{k,cr}</td><td>psi (Mpa)</td><td>855 (5.0)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>τ_{k,uncr}</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td rowspan="2">Permissible Installation Conditions</td><td>Dry and water saturated concrete</td><td>Anchor Category</td><td>-</td><td colspan="7">1</td></tr><tr><td></td><td>φ_{cr}, φ_{ws}</td><td>-</td><td colspan="7">0.65</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>α_{N,seis}</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).												3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		h _{ef,max}	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		h _{ef,min}	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A	Characteristic bond strength in cracked concrete	τ _{k,cr}	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	τ _{k,uncr}	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B	Characteristic bond strength in cracked concrete	τ _{k,cr}	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.0)	1260 (8.67)	1290 (9.0)	1325 (9.0)	1380 (9.5)	Characteristic bond strength in uncracked concrete	τ _{k,uncr}	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C	Characteristic bond strength in cracked concrete	τ _{k,cr}	psi (Mpa)	855 (5.0)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	τ _{k,uncr}	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Permissible Installation Conditions	Dry and water saturated concrete	Anchor Category	-	1								φ _{cr} , φ _{ws}	-	0.65							Reduction for Seismic Tension		α _{N,seis}	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	The provisions given in ACI 318-14 Section 17.3.1.2 are used to perform a check for adhesive anchors subjected to sustained tension loads. The check consists of calculating a capacity (0.55φN_{ba}), and comparing it to the highest (factored) sustained tension load (N_{ua,s}) acting on a single anchor within the anchor group. The strength reduction factor (φ-factor) in Eq. (17.3.1.2) corresponds to the parameter “φ_{bond}” in the PROFIS Engineering report. The parameter “N_{ba}” corresponds to the “basic bond strength” for a single adhesive anchor without any fixed edge influences. N_{ba} is calculated per Eq. (17.4.5.2); but an additional seismic modification factor that is derived from testing per the ICC-ES acceptance criteria AC308 is not given in Eq. (17.4.5.2), and must also be considered in the N_{ba}-calculation. This seismic modification factor is designated “α_{N,seis}”, and is included in PROFIS Engineering N_{ba}-calculations when seismic conditions are being modeled. However, since seismic load is not considered a sustained load, PROFIS Engineering divides out any α_{N,seis}-value when calculating N_{ba} per Eq. (17.3.1.2). Reference the Equations, Calculations and Results section of the report for more information on: N_{ba}: Basic bond strength parameters and calculations for the sustained tension load check Reference the Results section of the PROFIS Engineering report for more information on the following parameters: φ_{bond}: Strength reduction factor for bond N_{ua,s}: Sustained factored tension load
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).																																																																																																																																										
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Results $N_{ua,s}$

Results	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																									
$N_{ua,s}$	17.3.1.2 For the design of adhesive anchors to resist sustained tension loads, in addition to 17.3.1.1, Eq. (17.3.1.2) shall be satisfied. $0.55 \phi N_{ba} \geq N_{ua,s} \quad (17.3.1.2)$ Excerpt from PROFIS Engineering report showing sustained tension load ($N_{ua,s}$) corresponding to the highest loaded anchor. 3 Tension Load <table><tr><th></th><th>Load</th><th>Capacity</th><th>Utilization</th><th>Status</th></tr><tr><td>Steel Strength</td><td>3000</td><td>14550</td><td>21</td><td>OK</td></tr><tr><td>Bond Strength</td><td>12000</td><td>17088</td><td>71</td><td>OK</td></tr><tr><td>Sustained Tension Load Bond Strength*</td><td>250</td><td>8899</td><td>29</td><td>OK</td></tr><tr><td>Concrete Breakout Failure**</td><td>12000</td><td>14562</td><td>83</td><td>OK</td></tr></table> * highest loaded anchor ** anchor group (anchors in tension) If a single anchor in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{pn}, and checks this value against either (a) the factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the factored tension load determined to be acting on the anchor. If a group of anchors in tension is being modeled, PROFIS Engineering calculates the parameter ϕN_{pn}, and checks this value against either (a) the total factored tension load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored tension load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored tension load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for N_{ua} shown in the report corresponds to the total factored tension load determined to be acting on the anchor group.		Load	Capacity	Utilization	Status	Steel Strength	3000	14550	21	OK	Bond Strength	12000	17088	71	OK	Sustained Tension Load Bond Strength*	250	8899	29	OK	Concrete Breakout Failure**	12000	14562	83	OK	The provisions given in ACI 318-14 Section 17.3.1.2 are used to perform a check for adhesive anchors subjected to sustained tension loads. The check consists of calculating a capacity ($0.55\phi N_{ba}$), and comparing it to the highest (factored) sustained tension load ($N_{ua,s}$) acting on a single anchor within the anchor group. ACI 318-14 anchoring-to-concrete provisions require a design strength to be checked against a factored load. The design strength calculated with respect to sustained tension load is defined in Eq. (17.3.1.2) as $0.55\phi N_{ba}$. This design strength is checked against the parameter $N_{ua,s}$, which corresponds to the highest factored sustained tension load acting on a single anchor within the anchor group. If $0.55\phi N_{ba} \geq N_{ua,s}$, the provisions for considering sustained tension load have been satisfied per Section 17.3.1.1. $N_{ua,s}$ is a factored tension load. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting a sustained tension load. The software only performs a sustained tension load check per Eq. (17.3.1.2) if a sustained load(s) has been input via one of the load input functionalities. If a single adhesive anchor in tension is being modeled, PROFIS Engineering calculates the parameter $0.55\phi N_{ba}$ for a single anchor, and checks this value against either (a) the sustained factored tension load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the sustained factored tension load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the sustained factored tension load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for $N_{ua,s}$ shown in the report corresponds to the sustained factored tension load determined to be acting on the anchor. If a group of adhesive anchors in tension is being modeled, PROFIS Engineering calculates the parameter $0.55\phi N_{ba}$ for a single anchor, and checks this value against either (a) the highest sustained factored tension load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the highest sustained factored tension load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the highest sustained factored tension load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for $N_{ua,s}$ shown in the report corresponds to the highest sustained factored tension load determined to be acting on an individual anchor within the anchor group that is in tension. Reference the Equations and Results section of the PROFIS Engineering report for more information on the parameter $0.55\phi N_{ba}$.
	Load	Capacity	Utilization	Status																							
Steel Strength	3000	14550	21	OK																							
Bond Strength	12000	17088	71	OK																							
Sustained Tension Load Bond Strength*	250	8899	29	OK																							
Concrete Breakout Failure**	12000	14562	83	OK																							

PART 4 PROFIS ENGINEERING REPORT

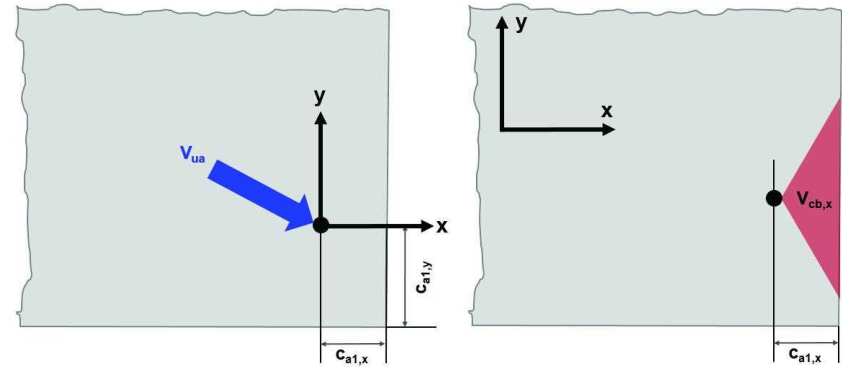
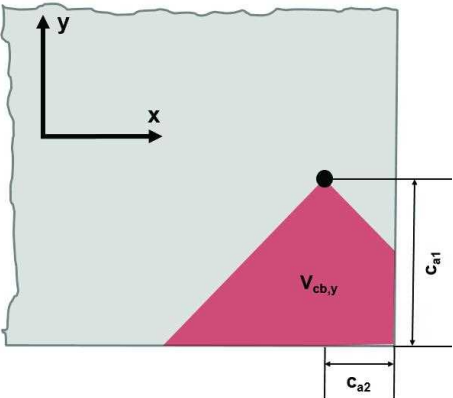


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Equation V_{cb}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b$	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ (c) For shear force parallel to an edge V_{cb} or V_{cbg} shall be permitted to be twice the value of the shear force determined from Eq. (17.5.2.1a) or (17.5.2.1b), respectively, with the shear force assumed to act perpendicular to the edge and with $\psi_{ed,V}$ taken equal to 1.0. (d) For anchors located at a corner, the limiting nominal concrete breakout strength shall be determined for each edge, and the minimum value shall be used. PROFIS Engineering includes an additional modification factor ($\psi_{parallel,V}$) in Eq. (17.5.2.1a) and Eq. (17.5.2.1b). PROFIS Engineering calculations for V_{cb}: $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$ PROFIS Engineering calculations for shear load acting at a corner.	ACI 318-14 provisions for concrete breakout failure in shear include two equations for calculating the “nominal concrete breakout strength” in shear: - Eq. (17.5.2.1a) for calculating the nominal concrete breakout strength for a single anchor in shear (V_{cb}) - Eq. (17.5.2.1b) for calculating the nominal concrete breakout strength for a group of anchors in shear (V_{cbg}) Concrete breakout in shear is calculated for shear load acting towards (i.e. perpendicular to) a fixed edge. If shear load acts parallel to a fixed edge, Section 17.5.2.1(c) requires V_{cb} or V_{cbg} to be calculated as if the shear load acts towards the fixed edge, and the value calculated for V_{cb} or V_{cbg} to be doubled. The PROFIS Engineering parameter that is designated in the report as “$\psi_{parallel,V}$” indicates whether the software is calculating concrete breakout for shear load acting towards a fixed edge ($\psi_{parallel,V} = 1.0$) or parallel to a fixed edge ($\psi_{parallel,V} = 2.0$). If a shear load acts at an angle with respect to two fixed edges, Section 17.5.2.1(d) requires V_{cb} or V_{cbg} to be calculated with respect to each fixed edge. The calculated value for V_{cb} or V_{cbg} is checked against the component of the shear load that acts towards each fixed edge. PROFIS Engineering calculates V_{cb} or V_{cbg} for load acting towards each fixed edge as well as load acting parallel to each fixed edge. The software then checks the calculated V_{cb} or V_{cbg} value for each load condition (towards the edge and parallel to the edge) against the resultant shear load rather than the shear load component acting on each edge. This is a conservative design assumption. Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{vc}: Area of influence for anchors in shear A_{vc0}: Area of influence for single anchor in shear $\psi_{ed,V}$: Shear modification factor for edge distance $\psi_{h,V}$: Modification factor for thin slabs V_b: Basic concrete breakout strength in shear Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,V}$: Modification factor for cracked concrete $\psi_{parallel,V}$: Modification factor for shear parallel to a fixed edge

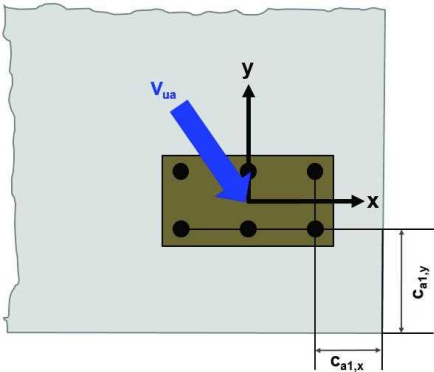
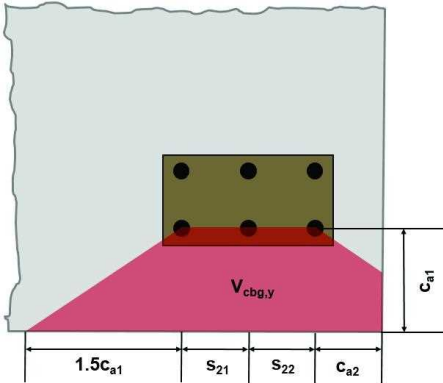
Equation V_{cb} (continued)

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b$	Check $(V_{ua}/V_{cb,x})$ versus $(V_{ua}/V_{cb,y})$ and take the highest utilization (%). calculate $V_{cb,x}$  calculate $V_{cb,y}$ 	

Equation V_{cbg}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ (c) For shear force parallel to an edge V_{cb} or V_{cbg} shall be permitted to be twice the value of the shear force determined from Eq. (17.5.2.1a) or (17.5.2.1b), respectively, with the shear force assumed to act perpendicular to the edge and with $\psi_{ed,V}$ taken equal to 1.0. (d) For anchors located at a corner, the limiting nominal concrete breakout strength shall be determined for each edge, and the minimum value shall be used. PROFIS Engineering includes an additional modification factor ($\psi_{parallel,V}$) in Eq. (17.5.2.1a) and Eq. (17.5.2.1b). PROFIS Engineering calculations for V_{cbg}: $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$ PROFIS Engineering calculations for shear load acting at a corner.	ACI 318-14 provisions for concrete breakout failure in shear include two equations for calculating the “nominal concrete breakout strength” in shear: - Eq. (17.5.2.1a) for calculating the nominal concrete breakout strength for a single anchor in shear (V_{cb}). - Eq. (17.5.2.1b) for calculating the nominal concrete breakout strength for a group of anchors in shear (V_{cbg}). Concrete breakout in shear is calculated for shear load acting towards (i.e. perpendicular to) a fixed edge. If shear load acts parallel to a fixed edge, Section 17.5.2.1(c) requires V_{cb} or V_{cbg} to be calculated as if the shear load acts towards the fixed edge, and the value calculated for V_{cb} or V_{cbg} to be doubled. The PROFIS Engineering parameter that is designated in the report as “$\psi_{parallel,V}$” indicates whether the software is calculating concrete breakout for shear load acting towards a fixed edge ($\psi_{parallel,V} = 1.0$) or parallel to a fixed edge ($\psi_{parallel,V} = 2.0$). If a shear load acts at an angle with respect to two fixed edges, Section 17.5.2.1(d) requires V_{cb} or V_{cbg} to be calculated with respect to each fixed edge. The calculated value for V_{cb} or V_{cbg} is checked against the component of the shear load that acts towards each fixed edge. PROFIS Engineering calculates V_{cb} or V_{cbg} for load acting towards each fixed edge as well as load acting parallel to each fixed edge. The software then checks the calculated V_{cb} or V_{cbg} value for each load condition (towards the edge and parallel to the edge) against the resultant shear load rather than the shear load component acting on each edge. This is a conservative design assumption. Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{vc}: Area of influence for anchors in shear A_{vc0}: Area of influence for single anchor in shear $\psi_{ec,V}$: Shear modification factor for eccentricity $\psi_{ed,V}$: Shear modification factor for edge distance $\psi_{h,V}$: Modification factor for thin slabs V_b: Basic concrete breakout strength in shear Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,V}$: Modification factor for cracked concrete $\psi_{parallel,V}$: Modification factor for shear parallel to a fixed edge

Equation V_{cbg} (continued)

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$	Check $(V_{ua}/V_{cbg,x})$ versus $(V_{ua}/V_{cbg,y})$ and take the highest utilization (%). calculate $V_{cbg,x}$  calculate $V_{cbg,y}$ 	

Equation ϕV_{cb}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi V_{cb} \geq V_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Shear Single Anchor $\phi V_{cb} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cb}: Nominal concrete breakout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure ϕV_{cb}: Design concrete breakout strength in shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

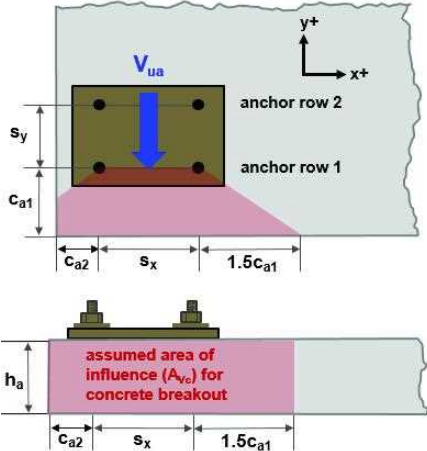
Equation ϕV_{cbg}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi V_{cbg} \geq V_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Shear Anchors as a Group $\phi V_{cbg} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cbg}: Nominal concrete breakout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure ϕV_{cbg}: Design concrete breakout strength in shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

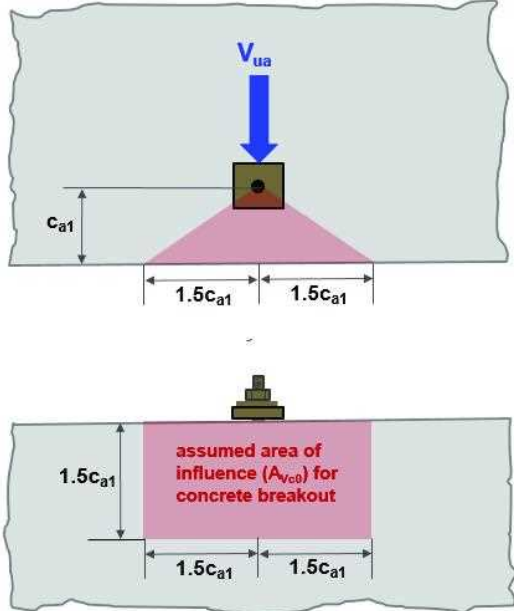
Equation A_{vc}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{vc}	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ A_{vc} is the projected area of the failure surface on the side of the concrete member at its edge for a single anchor or a group of anchors. It shall be permitted to evaluate A_{vc} as the base of a truncated half-pyramid projected on the side face of the member where the top of the half-pyramid is given by the axis of the anchor row selected as critical. The value of c_{a1} shall be taken as the distance from the edge to this axis. 	A_{vc} is a modification factor that accounts for the area of influence assumed to develop at the edge of a concrete member when a shear load acting on a single anchor or a group of anchors is applied towards that edge. A_{vc} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. A_{vc} calculations are predicated on the parameter c_{a1}, which is assumed to be the distance in the direction of the applied shear load from “the axis of the anchor row selected as critical”. ACI anchoring-to-concrete provisions do not set a maximum limit on the value for c_{a1}. The geometry for A_{vc} at the edge where concrete breakout in shear is assumed to occur is defined by (a) projected edge distances perpendicular to the direction of the applied shear load acting on the anchors, (b) anchor spacing perpendicular to the direction of the applied shear load and (c) a projected distance down from the surface of the concrete at the edge where concrete breakout in shear is assumed to occur. The maximum projected distance assumed for (a) and (c) is limited to $1.5c_{a1}$. The maximum spacing assumed for (b) equals $3.0c_{a1}$. Minimum anchor spacing values (s_{min}) are given in ACI 318-14 Section 17.7.1 and in post-installed anchor approvals. Minimum edge distance values (c_{min}) are given in ACI 318-14 Sections 17.7.2, 17.7.3 and in post-installed anchor approvals. The figure below illustrates how A_{vc} can be calculated for a group of four anchors in shear with a fixed edge distance (c_{a1}) in the direction of the applied shear load (V_{ua}), and a fixed edge distance (c_{a2}) perpendicular to the direction of V_{ua}. Concrete breakout in shear is assumed to occur at the y- edge, and c_{a1} is being considered as the distance from anchor row 1 to the y- edge. Only the spacing s_x perpendicular to the direction of V_{ua} is considered when calculating A_{vc} for this application. s_x for this application is assumed to be less than or equal to $3.0c_{a1}$; otherwise, the anchors would not be considered to act as a group with respect to s_x. c_{a2} for this application is assumed to be less than $1.5c_{a1}$. There is no fixed edge perpendicular to V_{ua} in the x+ direction, so the projected distance in the x+ direction used to calculate A_{vc} is limited to a maximum value of $1.5c_{a1}$. The maximum projected distance down from the concrete surface at the y- edge that is considered when calculating A_{vc} equals the smaller of the concrete thickness (h_c) and $1.5c_{a1}$. h_c for this application is assumed to be less than $1.5c_{a1}$. Minimum concrete thickness values for post-installed anchors are given in the anchor approvals.

Equation A_{Vc} (continued)

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Vc}		 The diagram illustrates the assumed area of influence (A_{Vc}) for concrete breakout. It shows two rows of anchors: 'anchor row 1' (bottom) and 'anchor row 2' (top). The vertical spacing between the rows is s_y. The horizontal dimensions are defined as c_{a2} (distance from edge to first anchor), s_x (spacing between anchors), and $1.5c_{a1}$ (distance from last anchor to edge). The total height of the concrete slab is h_a. A shear force V_{ua} is applied to the anchors. A coordinate system with x and y axes is shown. $A_{Vc} = (c_{a2} + s_x + 1.5c_{a1})(h_a)$ where: $c_{min} \leq c_{a2} \leq 1.5c_{a1}$ $s_{min} \leq s_x \leq 3.0c_{a1}$ $h_{a,min} \leq h_a$ Reference the Variables section of the PROFIS Engineering report for more information on c_{a1}, c_{a2} and h_a. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Vc}.

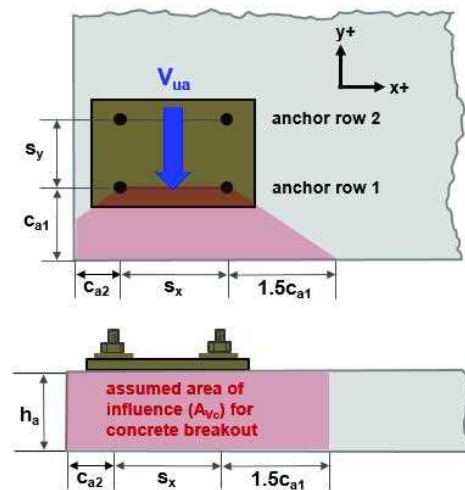
Equation A_{Vc0}

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$A_{Vc0} = 4.5c_{a1}^2$	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{Vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{Vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ A_{Vc0} is the projected area for a single anchor in a deep member with a distance from edges equal or greater than $1.5c_{a1}$ in the direction perpendicular to the shear force. It shall be permitted to evaluate A_{Vc0} as the base of a half-pyramid with side length parallel to the edge of $3c_{a1}$ and a depth of $1.5c_{a1}$.	A_{Vc0} is a modification factor that defines an idealized area of influence assumed to develop in concrete when a shear load acts towards a fixed edge on a single anchor without any perpendicular edge distance influences, any adjacent anchor spacing, in a concrete member of infinite thickness. A_{vc} calculations are predicated on the parameter c_{a1}, which is assumed to be the distance in the direction of the applied shear load from the anchor to the fixed edge. ACI anchoring-to-concrete provisions do not set a maximum limit on the value for c_{a1}. Minimum edge distance values (c_{min}) are given in ACI 318-14 Sections 17.7.2, 17.7.3 and in post-installed anchor approvals. The geometry for A_{Vc0} is modeled as the base of a truncated pyramid defined by projected distances of $1.5c_{a1}$ perpendicular to the direction of the applied shear load, and down from the surface of the concrete. Therefore, the idealized area defined by A_{Vc0} equals $(1.5c_{a1} + 1.5c_{a1})(1.5c_{a1})$ or $4.5c_{a1}^2$. The calculated value for A_{Vc0} will always equal $4.5c_{a1}^2$. The figure below illustrates how A_{Vc0} is calculated.  $AVc0 = (1.5c_{a1} + 1.5c_{a1})(1.5c_{a1})$ $= (4.5c_{a1})^2$ where: $c_{min} \leq c_{a1}$ Reference the Variables section of the PROFIS Engineering report for more information on c_{a1}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Vc0}.

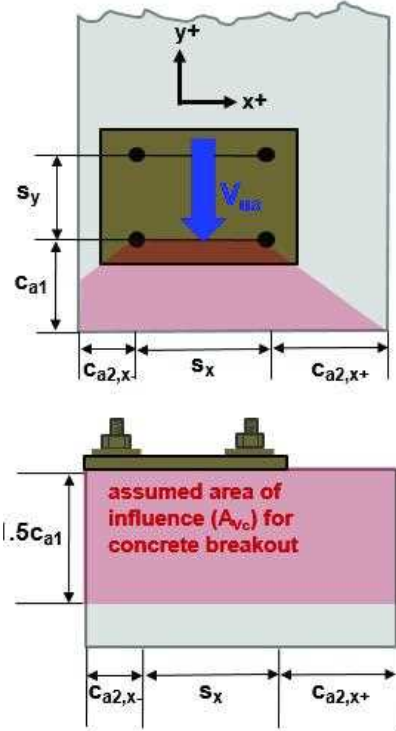
Equation $\psi_{ec,V}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,V} = \frac{1}{\left(1 + \frac{2e'_V}{3c_{a1}}\right)} \leq 1.0$	17.5.2.5 The modification factor for anchor groups loaded eccentrically in shear, $\psi_{ec,V}$, shall be calculated as $\psi_{ec,V} = \frac{1}{\left(1 + \frac{2e'_V}{3c_{a1}}\right)}$ but $\psi_{ec,V}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are loaded in shear in the same direction, only those anchors that are loaded in shear in the same direction shall be considered when determining the eccentricity e'_V for use in Eq. (17.5.2.5) and for the calculation of V_{cbg} according to Eq. (17.5.2.1b).	$\psi_{ec,V}$ is a modification factor that is used to account for a resultant shear load that is eccentric with respect to the centroid of anchors that are loaded in shear. $\psi_{ec,V}$ is only considered when calculating the nominal concrete breakout strength in shear for an anchor group (V_{cbg}). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: e'_V: Parameter for shear eccentricity c_{a1}: Parameter for edge distance in the direction of the applied shear load Reference the Calculations section of the PROFIS Engineering report for more information on $\psi_{ec,V}$.

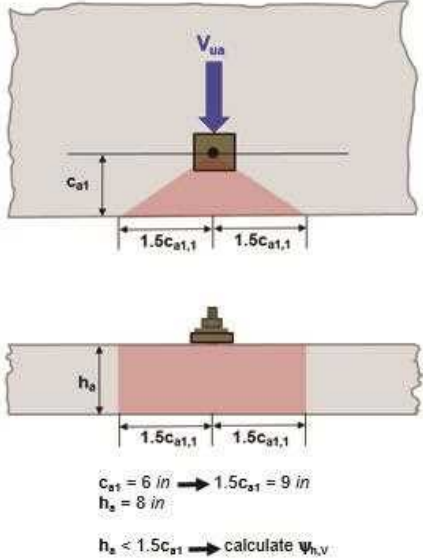
Equation $\psi_{ed,V}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,V} = 0.7 + 0.3 \left(\frac{c_{a2}}{1.5c_{a1}} \right) \leq 1.0$	17.5.2.6 The modification factor for edge effect for a single anchor or group of anchors loaded in shear, $\psi_{ed,V}$, shall be calculated as follows using the smaller value of c_{a2}. If $c_{a2} \geq 1.5c_{a1}$, then $\psi_{ed,V} = 1.0$ (17.5.2.6a) If $c_{a2} < 1.5c_{a1}$, then $\psi_{ed,V} = 0.7 + 0.3 \left(\frac{c_{a2}}{1.5c_{a1}} \right)$ (17.5.2.6b) 17.5.2.4 Where anchors are located in narrow sections of limited thickness such that both edge distances c_{a2} and thickness h_a are less than $1.5c_{a1}$, the value of c_{a1} used for A_{vc} in accordance with 17.5.2.1 as well as for the equations in 17.5.2.1 through 17.5.2.8 shall not exceed the largest of: $c_{a2}/1.5$, where c_{a2} is the largest edge distance $h_a/1.5$ $s/3$, where s is the maximum spacing perpendicular to direction of shear, between anchors within a group.	$\psi_{ed,V}$ is a modification factor that is used to account for fixed edge distances perpendicular to the direction of the applied shear load that are less than $1.5c_{a1}$. Shear concrete breakout failure calculations are predicated on the fixed edge distance in the direction of the applied shear load (c_{a1}). Edge distances perpendicular to the direction of the applied shear load are designated c_{a2}. If c_{a2} is less than $1.5c_{a1}$, $\psi_{ed,V}$ is calculated per Eq. (17.5.2.6b). For the application in the illustration below: $\psi_{ed,V} = 0.7 + 0.3 (c_{a2} / 1.5c_{a1})$ 

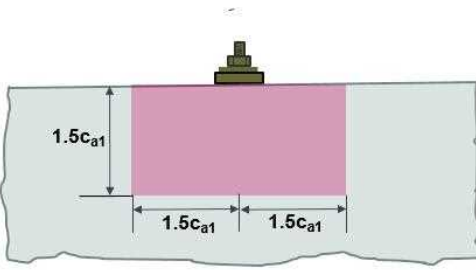
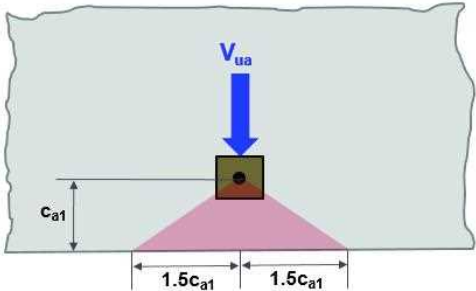
Equation $\psi_{ed,V}$ (continued)

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,V} = 0.7 + 0.3 \left(\frac{c_{a2}}{1.5c_{a1}} \right) \leq 1.0$		If more than one fixed edge perpendicular to the direction of the applied shear load exists, the smallest of these edge distances is used to calculate $\psi_{ed,V}$. For the application in the illustration below, if $c_{a2,x-} < c_{a2,x+}$: $\psi_{ed,V} = 0.7 + 0.3 (c_{a2,x-} / 1.5c_{a1})$ Per Section 17.5.2.4, when anchoring into a narrow section, the checks noted in (a) through (c) should also be made to determine if a modified c_{a1}-value should be used for the shear concrete breakout calculations. For the application below, h_a is greater than $1.5c_{a1}$, so no modified c_{a1}-value would be calculated.  Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Fixed edge distance in the direction of the applied shear load c_{a2}: Fixed edge distance perpendicular to the direction of the applied shear load h_a: Concrete thickness Reference the Calculations section of the PROFIS Engineering report for more information on $\psi_{ed,V}$.

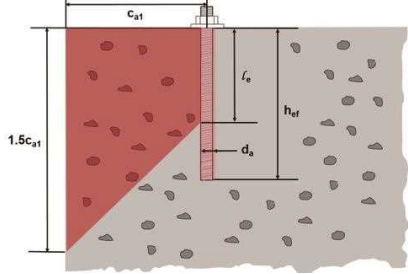
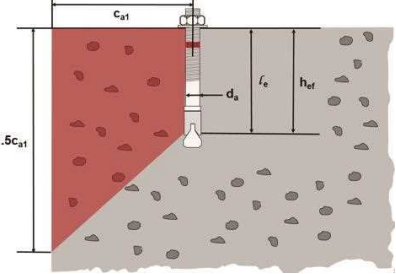
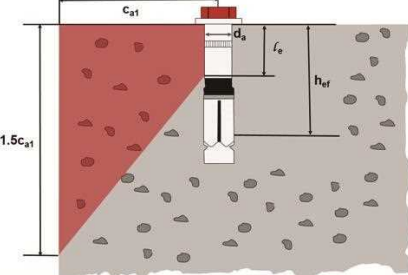
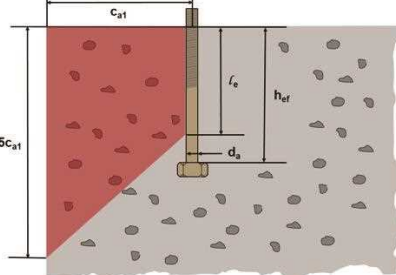
Equation $\psi_{h,v}$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{h,v} = \sqrt{\frac{1.5c_{a1}}{h_a}} \geq 1.0$	17.5.2.8 The modification factor for anchors located in a concrete member where $h_a < 1.5c_{a1}$, $\psi_{h,v}$, shall be calculated as $\psi_{h,v} = \sqrt{\frac{1.5c_{a1}}{h_a}} \quad (17.5.2.8)$ but $\psi_{h,v}$ shall not be taken less than 1.0.	$\psi_{h,v}$ is a modification factor that is used to account for a concrete member thickness h_a that is less than $1.5c_{a1}$. The parameter c_{a1} corresponds to the distance of an anchor, in the direction of the applied shear load, to the fixed edge for which concrete breakout in shear is being calculated. $\psi_{h,v}$ is always ≥ 1.0 per the provisions of Section 17.5.2.8. The figure below illustrates the conditions for which $\psi_{h,v}$ would be calculated.  $c_{a1} = 6 \text{ in} \rightarrow 1.5c_{a1} = 9 \text{ in}$ $h_a = 8 \text{ in}$ $h_a < 1.5c_{a1} \rightarrow \text{calculate } \psi_{h,v}$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Fixed edge distance in the direction of the applied shear load h_a: Concrete thickness Reference the Calculations section of the PROFIS Engineering report for more information on $\psi_{h,v}$.

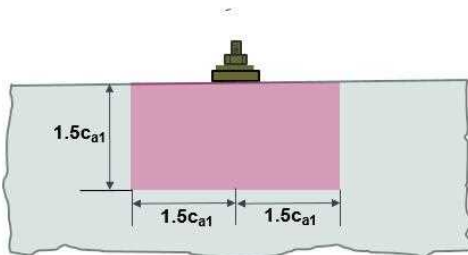
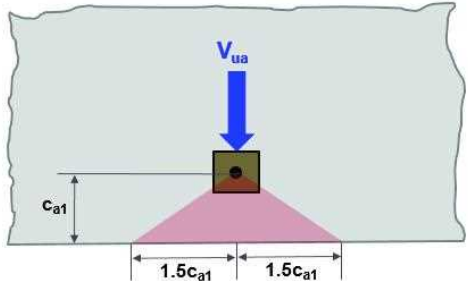
Equation V_b

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_b = \left(7 \left(\frac{l_o}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$	17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $(a) \quad V_b = \left(7 \left(\frac{l_o}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.2a)$ where l_o is the load-bearing length of the anchor for shear: $l_o = h_{ef}$ for anchors with a constant stiffness over the full length of embedded section, such as headed studs and post-installed anchors with one tubular shell over the full length of the embedment depth; $l_o = 2d_a$ for torque-controlled expansion anchors with a distance sleeve separated from expansion sleeve, and $l_o \leq 8d_a$ in all cases. $(b) \quad V_b = 9\lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.2b)$ V_b corresponds to concrete breakout in shear for a single anchor without any geometry influences. 	ACI 318-14 Chapter 2 defines the parameter V_b as the “basic concrete breakout strength in shear of a single anchor in cracked concrete”. V_b calculated using Eq. (17.5.2.2a) can be considered relevant for anchors that are not rigidly attached to the fixture, i.e. an annular space exists between the anchor element and the hole in the fixture through which the anchors are located. V_b calculated using Eq. (17.5.2.2b) is a limiting value. PROFIS Engineering calculates V_b using both equations, and shows the controlling equation in the Equations section of the report, and the V_b-value calculated using the controlling equation in the Calculations section. Consider a single anchor installed near a fixed edge with a shear load acting on the anchor towards that edge. Assuming there are no fixed edges perpendicular to the direction of the applied shear load, and the concrete has an “infinite” thickness; if concrete breakout occurs, it could be defined by the calculated capacity V_b using either Eq. (17.5.2.2a) or Eq. (17.5.2.2b). V_b is calculated using both equations and the smaller calculated value is used to calculate the nominal concrete breakout strength in shear (V_{cb} or V_{cbg}). Geometry influences are considered via the parameters A_{vc}, $\psi_{ed,v}$ and $\psi_{h,v}$. Reference the Design Guide sections for these parameters for more information. ACI 318 anchoring-to-concrete provisions define the parameter l_o as the “load bearing length of anchor for shear”. This “length” corresponds to the embedded portion of an anchor element that is effective in transferring shear load into a concrete member. For anchor elements that have a constant stiffness over their embedded depth, l_o equals the smaller of the anchor element effective embedment depth (h_{ef}) and eight times the nominal diameter of the anchor element (d_a). For anchor elements that do not have a constant stiffness over their embedded depth (i.e. “anchors with a distance sleeve separated from expansion sleeve”), the l_o value equals $2d_a$. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: l_o: Load bearing length of anchor in shear d_a: Anchor element diameter λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength c_{a1}: Edge distance in the direction of the shear load h_s: Concrete thickness Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: V_b calculated per Eq. (17.5.2.2a) V_b calculated per Eq. (17.5.2.2b).

Equation V_b (continued)

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_b = \left(7 \left(\frac{l_o}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (C_{at})^{1.5}$	$l_o = \text{MIN} \{h_{ef} ; 8d_a\}$  adhesive anchor element $l_o = \text{MIN} \{h_{ef} ; 8d_a\}$  mechanical anchor (constant stiffness) $l_o = 2d_a$  mechanical anchor (with distance sleeve) $l_o = \text{MIN} \{h_{ef} ; 8d_a\}$  cast-in headed bolt	

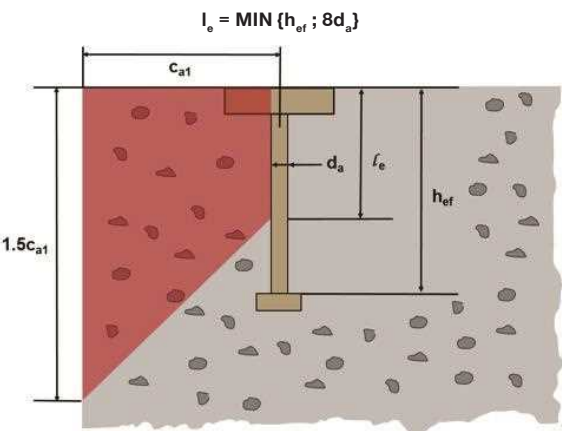
Equation $V_b = 9\lambda_a$

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_b = 9\lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$	17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): (a) $V_b = \left(7\left(\frac{l_e}{d_a}\right)^{0.2} \sqrt{d_a}\right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$ (17.5.2.2a) (b) $V_b = 9\lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$ (17.5.2.2b) V_b corresponds to concrete breakout in shear for a single anchor without any geometry influences. 	ACI 318-14 Chapter 2 defines the parameter V_b as the “basic concrete breakout strength in shear of a single anchor in cracked concrete”. V_b calculated using Eq. (17.5.2.2a) can be considered relevant for anchors that are not rigidly attached to the fixture, i.e. an annular space exists between the anchor element and the hole in the fixture through which the anchors are located. V_b calculated using Eq. (17.5.2.2b) is a limiting value. PROFIS Engineering calculates V_b using both equations, and shows the controlling equation in the Equations section of the report, and the V_b-value calculated using the controlling equation in the Calculations section. Consider a single anchor installed near a fixed edge with a shear load acting on the anchor towards that edge. Assuming there are no fixed edges perpendicular to the direction of the applied shear load, and the concrete has an “infinite” thickness; if concrete breakout occurs, it could be defined by the calculated capacity V_b using either Eq. (17.5.2.2a) or Eq. (17.5.2.2b). V_b is calculated using both equations and the smaller calculated value is used to calculate the nominal concrete breakout strength in shear (V_{cb} or V_{cbg}). Geometry influences are considered via the parameters A_{vc}, $\psi_{ed,v}$ and $\psi_{h,v}$. Reference the Design Guide sections for these parameters for more information. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength c_{a1}: Edge distance in the direction of the shear load Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: V_b calculated per Eq. (17.5.2.2a) V_b calculated per Eq. (17.5.2.2b).

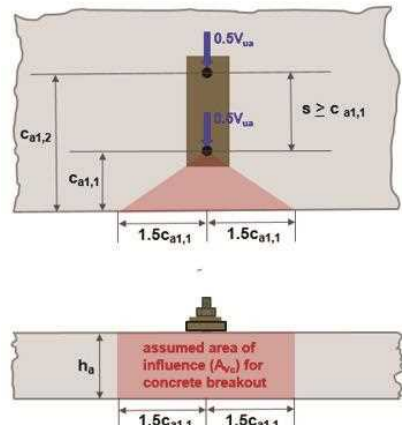
Equation V_b

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_b = \left(8 \left(\frac{l_o}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$	17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments having a minimum thickness equal to the greater of 3/8 in. and half of the anchor diameter, the basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $(a) \quad V_b = \left(8 \left(\frac{l_o}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.3a)$ where l_o is defined in 17.5.2.2 provided that: (a) For groups of anchors, the strength is determined based on the strength of the row of anchors farthest from the edge (b) Anchor spacing s is not less than 2.5 in. (c) Reinforcement is provided at the corners if $c_{a2} \leq 1.5h_{ef}$ 17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): where l_o is the load-bearing length of the anchor for shear: $l_o = h_{ef}$ for anchors with a constant stiffness over the full length of embedded section, such as headed studs and post-installed anchors with one tubular shell over the full length of the embedment depth; $l_o = 2d_a$ for torque-controlled expansion anchors with a distance sleeve separated from expansion sleeve, and $l_o \leq 8d_a$ in all cases. V_b corresponds to concrete breakout in shear for a single anchor without any geometry influences.	ACI 318-14 Chapter 2 defines the parameter V_b as the “basic concrete breakout strength in shear of a single anchor in cracked concrete”. V_b calculated using Eq. (17.5.2.3) is only relevant for anchors that are rigidly attached to the fixture, e.g. a welded head stud. V_b calculated using Eq. (17.5.2.2b) is a limiting value. V_b calculated using Eq. (17.5.2.2a) is not relevant to anchors rigidly attached to a fixture. PROFIS Engineering only calculates V_b using Eq. (17.5.2.3) for the AWS D1.1 headed studs in its anchor portfolio. The V_b-value calculated using Eq. (17.5.2.3) is checked against the V_b-value calculated using Eq. (15.5.2.2b) and the smaller value is used to calculate the nominal concrete breakout strength in shear (V_{cb} or V_{cbg}). The controlling V_b-equation is shown in the Equations section of the report, and the V_b-value calculated using the controlling equation is shown in the Calculations section. Consider a single anchor installed near a fixed edge with a shear load acting on the anchor towards that edge. Assuming there are no fixed edges perpendicular to the direction of the applied shear load, and the concrete has an “infinite” thickness; if concrete breakout occurs, it could be defined by the calculated capacity V_b using either Eq. (17.5.2.3) or Eq. (17.5.2.2b). V_b is calculated using both equations and the smaller calculated value is used to calculate the nominal concrete breakout strength in shear (V_{cb} or V_{cbg}). Geometry influences are considered via the parameters A_{ve}, $\psi_{ed,V}$ and $\psi_{h,V}$. Reference the Design Guide sections for these parameters for more information. ACI 318 anchoring-to-concrete provisions define the parameter l_o as the “load bearing length of anchor for shear”. This “length” corresponds to the embedded portion of an anchor element that is effective in transferring shear load into a concrete member. The cast-in anchor elements in the PROFIS Engineering portfolio have a constant stiffness over their embedded depth; therefore, the l_o-value calculated by PROFIS Engineering for these anchors equals the smaller of the effective embedment depth (h_{ef}) and eight times the nominal diameter of the anchor element (d_a). Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: l_o: Load bearing length of anchor in shear d_a: Anchor element diameter λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength c_{a1}: Edge distance in the direction of the shear load h_a: Concrete thickness Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: V_b calculated per Eq. (17.5.2.2b) V_b calculated per Eq. (17.5.2.3).

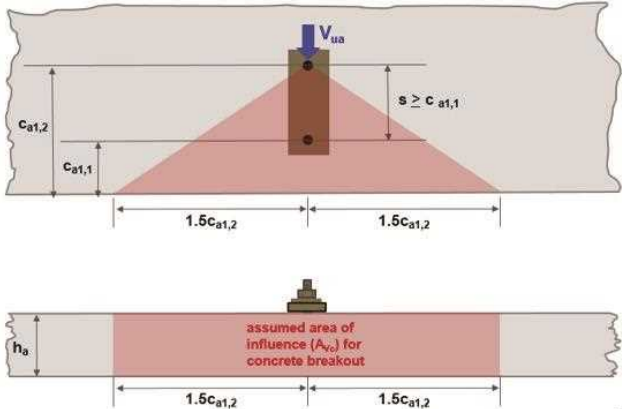
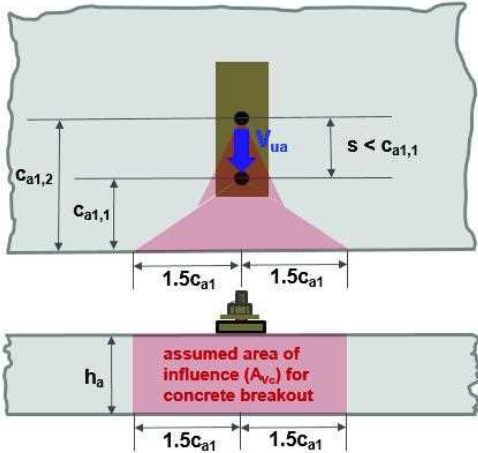
Equation V_b (continued)

Equation	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_b = \left(8 \left(\frac{l_o}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$	 cast-in headed stud	

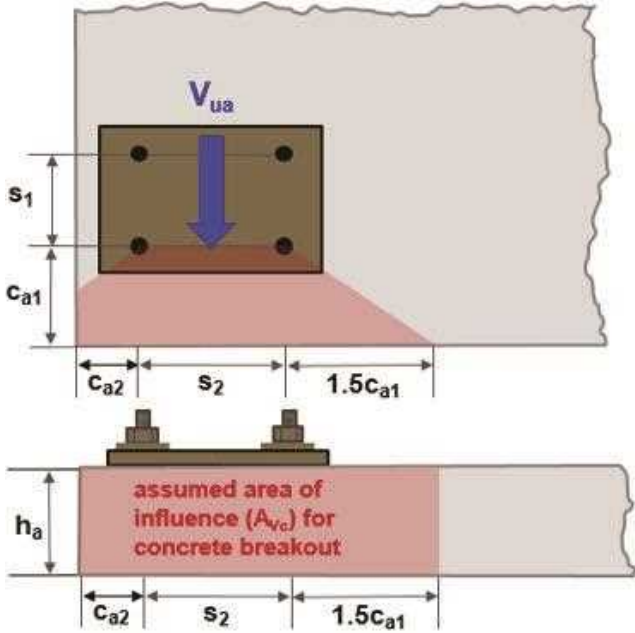
Variables c_{a1}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{a1}	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: A_{vc} is the projected area of the failure surface on the side of the concrete member at its edge for a single anchor or a group of anchors. It shall be permitted to evaluate A_{vc} as the base of a truncated half-pyramid projected on the side face of the member where the top of the half-pyramid is given by the axis of the anchor row selected as critical. The value of c_{a1} shall be taken as the distance from the edge to this axis. A_{vc0} is the projected area for a single anchor in a deep member with a distance from edges equal or greater than $1.5c_{a1}$ in the direction perpendicular to the shear force. It shall be permitted to evaluate A_{vc0} as the base of a half-pyramid with side length parallel to the edge of $3c_{a1}$ and a depth of $1.5c_{a1}$. $A_{vc0} = 4.5c_{a1}^2 \quad (17.5.2.1c)$ 17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $(a) \quad V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.2a)$ $(b) \quad V_b = 9\lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.2b)$ 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments having a minimum thickness equal to the greater of 3/8 in. and half of the anchor diameter, the basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.3a)$ 	The parameter “c_{a1}” corresponds to the distance in the direction of the applied shear load from the center of an anchor, or centerline through a row of anchors, to the fixed edge where concrete breakout in shear is assumed to occur. The ACI 318-14 commentary R17.5.2.1 discusses how the value for c_{a1} can be taken as the distance from the anchor row nearest the fixed edge being considered for concrete breakout (Case 1 and Case 3), or the anchor row farthest from that fixed edge (Case 2). When the anchor configuration consists of more than two rows of anchors in shear, c_{a1} could also be considered from intermediate rows. PROFIS Engineering always uses a c_{a1}-value corresponding to the distance from the anchor row nearest the fixed edge where concrete breakout is assumed to occur unless AWS D1.1 headed studs are being modeled. Per ACI 318-14 Section 17.5.2.3, if the criteria noted in this section with respect to fixture thickness, anchor spacing and corner reinforcement are satisfied; PROFIS Engineering uses a c_{a1}-value corresponding to the distance from the anchor row farthest from the fixed where concrete breakout is assumed to occur. The provisions of Section 17.5.2.3 are only utilized by PROFIS Engineering when AWS D1.1 headed studs are being modeled. The illustration below show examples of how c_{a1} can be determined. Reference ACI 318-14 commentary Fig. R17.5.2.1b (Case 1). 

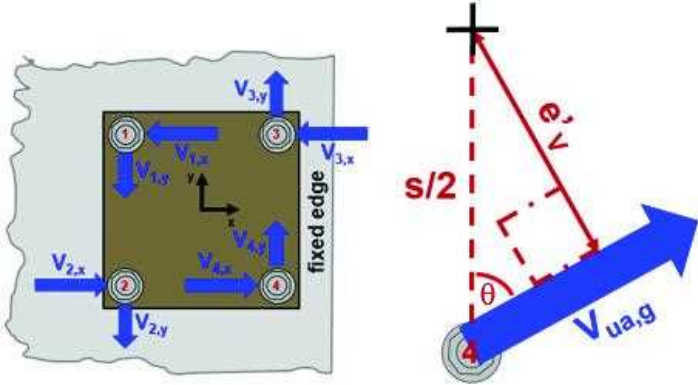
Variables c_{a1} (continued)

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{a1}	17.5.2.5 The modification factor for anchor groups loaded eccentrically in shear, $\psi_{ec,V}$, shall be calculated as $\psi_{ec,V} = \frac{1}{\left(1 + \frac{2e'_V}{3c_{a1}}\right)} \quad (17.5.2.5)$ 17.5.2.6 The modification factor for edge effect for a single anchor or group of anchors loaded in shear, $\psi_{ed,V}$, shall be calculated If $c_{a2} < 1.5c_{a1}$, then $\psi_{ed,V} = 0.7 + 0.3\left(\frac{c_{a2}}{1.5c_{a1}}\right)$ (17.5.2.6b) 17.5.2.8 The modification factor for anchors located in a concrete member where $h_a < 1.5c_{a1}$, $\psi_{h,V}$, shall be calculated as $\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \quad (17.5.2.8)$	Reference ACI 318-14 commentary Fig. R17.5.2.1b (Case 2).  Reference ACI 318-14 commentary Fig. R17.5.2.1b (Case 3). 

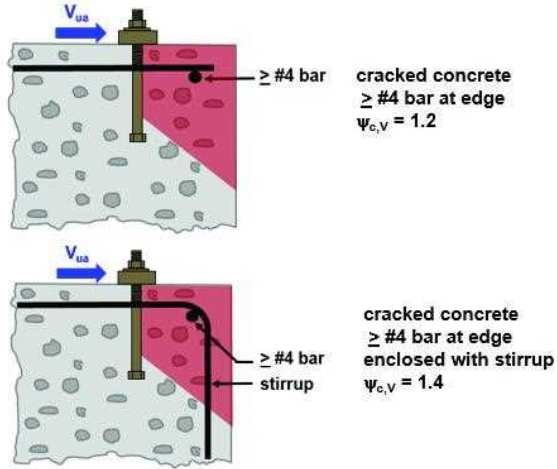
Variables c_{a2}

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{a2}	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: A_{vc} is the projected area of the failure surface on the side of the concrete member at its edge for a single anchor or a group of anchors. It shall be permitted to evaluate A_{vc} as the base of a truncated half-pyramid projected on the side face of the member where the top of the half-pyramid is given by the axis of the anchor row selected as critical. The value of c_{a1} shall be taken as the distance from the edge to this axis. 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments having a minimum thickness equal to the greater of 3/8 in. and half of the anchor diameter, the basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.3)$ where l_e is defined in 17.5.2.2 provided that: (a) For groups of anchors, the strength is determined based on the strength of the row of anchors farthest from the edge (b) Anchor spacing s is not less than 2.5 in. (c) Reinforcement is provided at the corners if $c_{a2} \leq 1.5h_{ef}$ 17.5.2.6 The modification factor for edge effect for a single anchor or group of anchors loaded in shear, $\psi_{ed,V}$, shall be calculated as follows using the smaller value of c_{a2}. If $c_{a2} \geq 1.5c_{a1}$, then $\psi_{ed,V} = 1.0$ (17.5.2.6a) If $c_{a2} < 1.5c_{a1}$, then $\psi_{ed,V} = 0.7 + 0.3 \left(\frac{c_{a2}}{1.5c_{a1}} \right)$ (17.5.2.6b)	The parameter “c_{a2}” corresponds to a fixed edge distance perpendicular to the direction of the applied shear load. c_{a2} is considered when calculating the following parameters: • Shear area of influence (A_{vc}) • Basic concrete breakout strength in shear (V_b) per the provisions of ACI 318-14 Section 17.5.2.3 • Modification for edge effects ($\psi_{ed,V}$) When modeling an application consisting of two fixed edges perpendicular to the direction of the applied shear load, PROFIS Engineering uses the smaller of these edge distances for the c_{a2}-value. The illustration below shows how the parameters c_{a1} and c_{a2} are considered with respect to one another. 

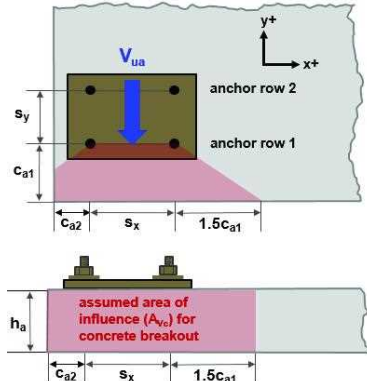
Variables $e_{c,v}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c,v}$	17.5.2.5 The modification factor for anchor groups loaded eccentrically in shear, $\psi_{ec,v}$, shall be calculated as $\psi_{ec,v} = \frac{1}{\left(1 + \frac{2e'_{c,v}}{3c_{a1}}\right)} \quad (17.5.2.5)$ but $\psi_{ec,v}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are loaded in shear in the same direction, only those anchors that are loaded in shear in the same direction shall be considered when determining the eccentricity $e'_{c,v}$ for use in Eq. (17.5.2.5) and for the calculation of V_{cbg} according to Eq. (17.5.2.1b).	$e'_{c,v}$ is an ACI 318 parameter to define shear eccentricity. PROFIS Engineering designates this parameter “$e_{c,v}$”. The value for $e'_{c,v}$ corresponds the distance of a resultant shear load from the centroid of anchors that are loaded in shear. Shear eccentricity is used to calculate the ACI 318 modification factor for shear eccentricity ($\psi_{ec,v}$). PROFIS Engineering calculations for shear eccentricity are as follows: • Calculate a resultant shear load acting on the anchors • Calculate the distance ($e'_{c,v}$) between this load and the centroid of the anchors loaded in shear • Calculate the modification factor for shear eccentricity ($\psi_{ec,v}$) If a torsion moment acts on the anchorage, the direction of the shear load acting on individual anchors will vary. Below is an illustration showing how PROFIS Engineering accounts for shear eccentricity when a torsion moment acts on the anchorage.  $V_s = \sqrt{(V_{2,x})^2 + (V_{4,x})^2} \quad V_y = \sqrt{(V_{3,y})^2 + (V_{4,y})^2} \rightarrow V_{ua,g} = \sqrt{(V_x)^2 + (V_y)^2}$$\tan^{-1} \theta = \left(\frac{V_x}{V_y}\right) \rightarrow e_{c,v} = \left(\frac{s}{2}\right) (\sin \theta)$

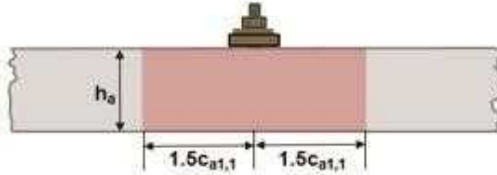
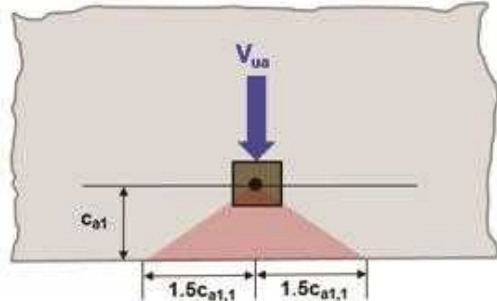
Variables $\psi_{c,v}$

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{c,v}$	17.5.2.7 For anchors located in a region of a concrete member where analysis indicates no cracking at service loads, the following modification factor shall be permitted: $\psi_{c,v} = 1.4$ For anchors located in a region of a concrete member where analysis indicates cracking at service load levels, the following modification factors shall be permitted: $\psi_{c,v} = 1.0$ for anchors in cracked concrete without supplementary reinforcement or with edge reinforcement smaller than a No. 4 bar $\psi_{c,v} = 1.2$ for anchors in cracked concrete with reinforcement of a No. 4 bar or greater between the anchor and the edge $\psi_{c,v} = 1.4$ for anchors in cracked concrete with reinforcement of a No. 4 bar or greater between the anchor and the edge, and with the reinforcement enclosed within stirrups spaced at not more than 4 in	$\psi_{c,v}$ is a modification factor for cracked or uncracked concrete conditions. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. Concrete is typically assumed to crack under service load conditions. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing cast-in-place and post-installed anchors, since cracks in the anchor vicinity can result in a reduced ultimate load capacity and increased displacement at ultimate load, compared to uncracked concrete conditions. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions, and the default $\psi_{c,v}$ -value for this condition equals 1.0. Uncracked concrete conditions are accounted for by increasing $\psi_{c,v}$ to a value of 1.4. When cracked concrete conditions are assumed, ACI 318 anchoring-to-concrete provisions also permit $\psi_{c,v}$ to be increased if supplementary edge reinforcement is present in the concrete member. If cracked concrete conditions exist, and existing reinforcement of #4 bars or greater is present at the fixed edge where concrete breakout is being considered, ACI 318-14 Section 17.5.2.7 permits $\psi_{c,v}$ to be increased to a value of 1.2. If cracked concrete conditions exist, and the existing edge reinforcement in a concrete member consists of #4 bars or greater enclosed by a stirrup, Section 17.5.2.7 permits $\psi_{c,v}$ to be increased to a value of 1.4. The figure below illustrates how $\psi_{c,v}$ can be assumed to equal 1.2 or 1.4 for cracked concrete conditions.  Use of additional, i.e. “supplementary” edge reinforcement for shear calculations permits an increased strength reduction factor (ϕ-factor) to be used when calculating design concrete breakout strength (ϕV_{cb} or ϕV_{cbg}). Reference the Results section of the report for more information on the strength reduction factor $\phi_{concrete}$.

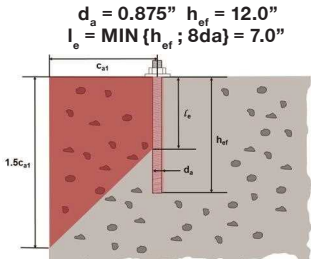
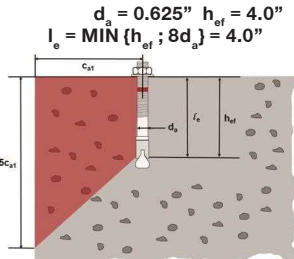
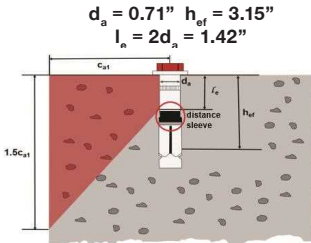
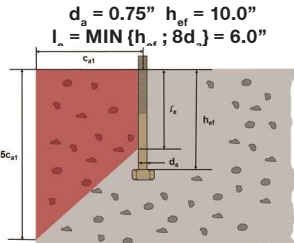
Variables h_a

Variables	ACI 318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																
h_a	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ A_{vc} is the projected area of the failure surface on the side of the concrete member at its edge for a single anchor or a group of anchors. It shall be permitted to evaluate A_{vc} as the base of a truncated half-pyramid projected on the side face of the member where the top of the half-pyramid is given by the axis of the anchor row selected as critical. The value of c_{a1} shall be taken as the distance from the edge to this axis. 17.5.2.8 The modification factor for anchors located in a concrete member where $h_a < 1.5c_{a1}$, $\psi_{h,V}$ shall be calculated as $\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \quad (17.5.2.8)$ For the cast-in anchors in its portfolio, PROFIS Engineering assumes a minimum concrete thickness (h_{min}) as follows: $h_{min} = h_{ef} + t_h + 3/8"$ where h_{ef} = effective embedment depth (in) t_h = anchor head thickness (in) $3/8"$ = assumed minimum concrete cover <table><thead><tr><th>MATERIAL SPECIFICATION</th><th>ANCHOR DIAMETER (d_{anchor}) (in)</th><th>Hex Head (in)</th><th>Heavy Hex Head (t_h) (in)</th><th>Square Head (t_h) (in)</th><th>Heavy Square Head (t_h) (in)</th><th>Minimum Base Material Thickness (h_{a,min}) (in)</th></tr></thead><tbody><tr><td rowspan="10">ASTM F1554 Headed Bolt GR. 36, 55, 105</td><td>0.500</td><td>0.344</td><td>0.344</td><td>0.328</td><td>0.328</td><td rowspan="10">$h_{min} = h_{ef} + t_h + 0.375$ in</td></tr><tr><td>0.625</td><td>0.422</td><td>0.422</td><td>0.422</td><td>0.422</td></tr><tr><td>0.750</td><td>0.500</td><td>0.500</td><td>0.500</td><td>0.500</td></tr><tr><td>0.875</td><td>0.552</td><td>0.552</td><td>0.594</td><td>0.594</td></tr><tr><td>1.000</td><td>0.672</td><td>0.672</td><td>0.656</td><td>0.656</td></tr><tr><td>1.125</td><td>0.750</td><td>0.750</td><td>0.750</td><td>0.750</td></tr><tr><td>1.250</td><td>0.844</td><td>0.844</td><td>0.844</td><td>0.844</td></tr><tr><td>1.375</td><td>0.906</td><td>0.906</td><td>0.906</td><td>0.906</td></tr><tr><td>1.500</td><td>1.000</td><td>1.000</td><td>1.000</td><td>1.000</td></tr><tr><td>1.750</td><td></td><td>1.156</td><td></td><td></td><td></td></tr><tr><td>2.000</td><td></td><td>1.344</td><td></td><td></td><td></td></tr></tbody></table> <table><thead><tr><th>MATERIAL SPECIFICATION</th><th>ANCHOR DIAMETER (d_{anchor}) (in)</th><th>t_h (in)</th><th>Minimum Base Material Thickness (h_{a,min}) (in)</th></tr></thead><tbody><tr><td rowspan="4">AWD D1.1 Headed Stud</td><td>0.500</td><td>0.313</td><td rowspan="4">$h_{min} = h_{ef} + t_h + 0.375$ in</td></tr><tr><td>0.625</td><td>0.313</td></tr><tr><td>0.750</td><td>0.375</td></tr><tr><td>0.875</td><td>0.375</td></tr></tbody></table>	MATERIAL SPECIFICATION	ANCHOR DIAMETER (d _{anchor}) (in)	Hex Head (in)	Heavy Hex Head (t _h) (in)	Square Head (t _h) (in)	Heavy Square Head (t _h) (in)	Minimum Base Material Thickness (h _{a,min}) (in)	ASTM F1554 Headed Bolt GR. 36, 55, 105	0.500	0.344	0.344	0.328	0.328	$h_{min} = h_{ef} + t_h + 0.375$ in	0.625	0.422	0.422	0.422	0.422	0.750	0.500	0.500	0.500	0.500	0.875	0.552	0.552	0.594	0.594	1.000	0.672	0.672	0.656	0.656	1.125	0.750	0.750	0.750	0.750	1.250	0.844	0.844	0.844	0.844	1.375	0.906	0.906	0.906	0.906	1.500	1.000	1.000	1.000	1.000	1.750		1.156				2.000		1.344				MATERIAL SPECIFICATION	ANCHOR DIAMETER (d _{anchor}) (in)	t _h (in)	Minimum Base Material Thickness (h _{a,min}) (in)	AWD D1.1 Headed Stud	0.500	0.313	$h_{min} = h_{ef} + t_h + 0.375$ in	0.625	0.313	0.750	0.375	0.875	0.375	The parameter h_a corresponds to the thickness of the concrete member. The member thickness is considered when calculating the shear area of influence assumed to develop at the edge of a concrete member (A_{vc}) and the shear concrete breakout modification factor for a thin concrete member ($\psi_{h,V}$). The geometry for A_{vc} assumes a projected distance down from the surface of the concrete, at the edge where concrete breakout in shear is assumed to occur, equal to the smaller of the concrete thickness (h_a) and a projected distance defined by $1.5c_{a1}$. The parameter c_{a1} corresponds to the distance from an assumed row of anchors in shear to the fixed edge where concrete breakout in shear is assumed to occur. The figure below illustrates how calculation of A_{vc} considers the concrete thickness (h_a).  if $h_a < 1.5c_{a1}$: $A_{vc} = (c_{a2} + s_x + 1.5c_{a1})(h_a)$ if $h_a > 1.5c_{a1}$: $A_{vc} = (c_{a2} + s_x + 1.5c_{a1})(1.5c_{a1})$ $\psi_{h,V}$ is a modification factor that is used to account for a concrete member thickness h_a that is less than $1.5c_{a1}$. The figure below illustrates how calculation of $\psi_{h,V}$ considers the concrete thickness (h_a).
MATERIAL SPECIFICATION	ANCHOR DIAMETER (d _{anchor}) (in)	Hex Head (in)	Heavy Hex Head (t _h) (in)	Square Head (t _h) (in)	Heavy Square Head (t _h) (in)	Minimum Base Material Thickness (h _{a,min}) (in)																																																																												
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2.000		1.344																																																																																
MATERIAL SPECIFICATION	ANCHOR DIAMETER (d _{anchor}) (in)	t _h (in)	Minimum Base Material Thickness (h _{a,min}) (in)																																																																															
AWD D1.1 Headed Stud	0.500	0.313	$h_{min} = h_{ef} + t_h + 0.375$ in																																																																															
	0.625	0.313																																																																																
	0.750	0.375																																																																																
	0.875	0.375																																																																																

Variables h_a (continued)

Variables	ACI 318-14 Chapter 17 Provision													Comments for PROFIS Engineering																																																																																																																							
h_a	For the post-installed anchors in its portfolio, PROFIS Engineering uses the minimum concrete thickness values (h_{min}) given in the anchor approval. Excerpt from ICC-ESR-1917 (Kwik Bolt-TZ) showing values for h_{min}. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="12">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="3">1/2</th><th colspan="3">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td><td></td></tr><tr><td>Min. member thickness</td><td>h_{min}</td><td>in.</td><td>3-1/4</td><td>4</td><td>5</td><td>5</td><td>4</td><td>6</td><td>6</td><td>8</td><td>5</td><td>6</td><td>8</td><td>5-1/2</td><td>6</td><td>8</td><td>8</td></tr></table> Excerpt from ICC-ESR-3187 (HIT-HY 200) showing values for h_{min}. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1 1/4 or #10</th><th></th></tr><tr><td>Minimum Embedment</td><td>$h_{ef,min}$</td><td>in.</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>4-1/2</td><td>5</td><td></td></tr><tr><td>Maximum Embedment</td><td>$h_{ef,max}$</td><td>in.</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/2</td><td>20</td><td>22-1/2</td><td>25</td><td></td></tr><tr><td>Minimum Concrete Thickness</td><td>h_{min}</td><td>in.</td><td colspan="4">$h_{ef} + 1-1/4$</td><td colspan="6">$h_{ef} + 2d_o$</td></tr></table>														DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)												3/8			1/2			5/8			3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4		Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	6	8	8	DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)										3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1 1/4 or #10		Minimum Embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5		Maximum Embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25		Minimum Concrete Thickness	h_{min}	in.	$h_{ef} + 1-1/4$				$h_{ef} + 2d_o$						 if $h_a < 1.5c_{a1}$: $\psi_{h,v} = \sqrt{1.5c_{a1}/h_a}$ if $h_a \geq 1.5c_{a1}$: $\psi_{h,v} = 1.0$ Reference the Variables section of the PROFIS Engineering report for more information on the parameter c_{a1}. Reference the Calculations section of the PROFIS Engineering report for more information on the parameters A_{vc} and $\psi_{h,v}$.
DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)																																																																																																																																		
			3/8			1/2			5/8			3/4																																																																																																																									
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																																																																									
Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	6	8	8																																																																																																																				
DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)																																																																																																																																		
			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1 1/4 or #10																																																																																																																											
Minimum Embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5																																																																																																																											
Maximum Embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25																																																																																																																											
Minimum Concrete Thickness	h_{min}	in.	$h_{ef} + 1-1/4$				$h_{ef} + 2d_o$																																																																																																																														

Variables l_e

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
l_e	17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2a)$ where l_e is the load-bearing length of the anchor for shear: $l_e = h_{ef}$ for anchors with a constant stiffness over the full length of embedded section, such as headed studs and post-installed anchors with one tubular shell over the full length of the embedment depth; $l_e = 2d_a$ for torque-controlled expansion anchors with a distance sleeve separated from expansion sleeve, and $l_e \leq 8d_a$ in all cases. $V_b = 9\lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2b)$ 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments having a minimum thickness equal to the greater of 3/8 in. and half of the anchor diameter, the basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.3a)$ where l_e is defined in 17.5.2.2..... Examples of how l_e is determined. $d_a = 0.875"$ $h_{ef} = 12.0"$ $l_e = \text{MIN} \{h_{ef}; 8d_a\} = 7.0"$  adhesive anchor element $d_a = 0.625"$ $h_{ef} = 4.0"$ $l_e = \text{MIN} \{h_{ef}; 8d_a\} = 4.0"$  mechanical anchor (constant stiffness) $d_a = 0.71"$ $h_{ef} = 3.15"$ $l_e = 2d_a = 1.42"$  HSL-3 mechanical anchor (with distance sleeve) $d_a = 0.75"$ $h_{ef} = 10.0"$ $l_e = \text{MIN} \{h_{ef}; 8d_a\} = 6.0"$  cast-in headed bolt	ACI 318 anchoring-to-concrete provisions define the parameter l_e as the “load bearing length of anchor for shear”. This “length” corresponds to the embedded portion of an anchor element that is effective in transferring shear load into a concrete member. Per ACI 318-14 Section 17.5.2.2, the l_e value for anchor elements that have a constant stiffness over their embedded depth equals the smaller of the anchor element effective embedment depth (h_{ef}), and eight times the nominal diameter of the anchor element (d_a). The cast-in anchors in the PROFIS Engineering portfolio and all post-installed anchors except the HSL-3 expansion anchor have a constant stiffness over their embedded depth. Per ACI 318-14 Section 17.5.2.2, the l_e value for anchor elements that do not have a constant stiffness over their embedded depth equals $2d_a$. HSL-3 expansion anchors have a “distance sleeve” that is separated from the expansion wedges; therefore, $l_e = 2d_a$ these anchors. PROFIS Engineering uses the pre-calculated l_e values given in Table 3 of ICC-ESR-1545 when HSL-3 anchors are being modeled. These l_e values correspond to two times the anchor external diameter (d_a). Values for d_a are also given in Table 3 of ICC-ESR-1545. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: d_a: Anchor element diameter Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: V_b calculated per Eq. (17.5.2.2a) V_b calculated per Eq. (17.5.2.2b) V_b calculated per Eq. (17.5.2.3).

Variables λ_a

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure. 1.0 λ Expansion and adhesive anchor concrete failure. 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ ^{(1) (2)} <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85 ⁽¹⁾</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, course blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33</td><td>0.85 to 1 ⁽²⁾</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> ¹ Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. ² Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate.	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, course blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ⁽²⁾	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	λ_a is a modification factor for lightweight concrete that is used to calculate the “basic concrete breakout strength in shear” (V_b) per Eq. (17.5.2.2a), Eq. (17.5.2.2b) or Eq. (17.5.2.3). ACI 318 applies a multiplier to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete”, and designates this parameter “λ”. The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to anchoring-to-concrete calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ, determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the type of anchor being used, to obtain the parameter λ_a. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a-provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. For post-installed anchor design, PROFIS Engineering uses a λ_a-value as referenced in the ICC-ESR provisions for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. Per ACI 318 provisions for determining λ_a, when designing cast-in-place anchors and post-installed undercut anchors, PROFIS Engineering uses the λ-value that has been input, for the λ_a-value to calculate V_b. When designing post-installed expansion and adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.8 (for concrete failure) to calculate V_b. Therefore, the PROFIS Engineering λ_a-value for calculating V_b, when designing cast-in-place and undercut anchors, will equal the λ-value that has been input, and the PROFIS Engineering λ_a-value for calculating V_b, when designing expansion and adhesive anchors, will equal 0.8λ. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter V_b.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, course blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ⁽²⁾																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

Variables λ_a (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
λ _a	19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}^{1.5}}{6.7 \sqrt{f_{cm}}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work. 17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $(a) \quad V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2a)$ $(b) \quad V_b = 9 \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2b)$ 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments having a minimum thickness equal to the greater of 3/8 in. and half of the anchor diameter, the basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.3a)$	

Variables d_a

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																									
d_a	17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $(a) \quad V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2a)$ $(b) \quad V_b = 9 \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2b)$ 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.3a)$ PROFIS Engineering AWS D1.1 headed stud portfolio diameter range. <table><tr><th>MATERIAL SPECIFICATION</th><th>ANCHOR DIAMETER (d_{anchor}) (in)</th></tr><tr><td rowspan="4">AWD D1.1 Headed Stud</td><td>0.500</td></tr><tr><td>0.625</td></tr><tr><td>0.750</td></tr><tr><td>0.875</td></tr></table> PROFIS Engineering headed bolt portfolio diameter range. <table><tr><th>MATERIAL SPECIFICATION</th><th>Hex Head Anchor Diameter (d_{anchor}) (in)</th><th>Heavy Hex Head Anchor Diameter (d_{anchor}) (in)</th><th>Square Head Anchor Diameter (d_{anchor}) (in)</th><th>Heavy Square Head Anchor Diameter (d_{anchor}) (in)</th></tr><tr><td rowspan="10">ASTM F1554 Headed Bolt GR. 36, 55, 105</td><td>0.500</td><td>0.500</td><td>0.500</td><td>0.500</td></tr><tr><td>0.625</td><td>0.625</td><td>0.625</td><td>0.625</td></tr><tr><td>0.750</td><td>0.750</td><td>0.750</td><td>0.750</td></tr><tr><td>0.875</td><td>0.875</td><td>0.875</td><td>0.875</td></tr><tr><td>1.000</td><td>1.000</td><td>1.000</td><td>1.000</td></tr><tr><td>1.125</td><td>1.125</td><td>1.125</td><td>1.125</td></tr><tr><td>1.250</td><td>1.250</td><td>1.250</td><td>1.250</td></tr><tr><td>1.375</td><td>1.375</td><td>1.375</td><td>1.375</td></tr><tr><td>1.500</td><td>1.500</td><td>1.500</td><td>1.500</td></tr><tr><td></td><td>1.750</td><td></td><td></td></tr><tr><td></td><td>2.000</td><td></td><td></td></tr></table>	MATERIAL SPECIFICATION	ANCHOR DIAMETER (d_{anchor}) (in)	AWD D1.1 Headed Stud	0.500	0.625	0.750	0.875	MATERIAL SPECIFICATION	Hex Head Anchor Diameter (d_{anchor}) (in)	Heavy Hex Head Anchor Diameter (d_{anchor}) (in)	Square Head Anchor Diameter (d_{anchor}) (in)	Heavy Square Head Anchor Diameter (d_{anchor}) (in)	ASTM F1554 Headed Bolt GR. 36, 55, 105	0.500	0.500	0.500	0.500	0.625	0.625	0.625	0.625	0.750	0.750	0.750	0.750	0.875	0.875	0.875	0.875	1.000	1.000	1.000	1.000	1.125	1.125	1.125	1.125	1.250	1.250	1.250	1.250	1.375	1.375	1.375	1.375	1.500	1.500	1.500	1.500		1.750				2.000			Anchor diameter (d_a) is a parameter that is used to calculate the basic concrete breakout strength in shear (V_b) for both cast-in anchors and post-installed anchors. d_a is included in ACI 318-14 Eq. (17.5.2.2a) and Eq. (17.5.2.3). ACI 318-14 Eq. (17.5.2.2b) is used to calculate a limiting value for V_b, which does not include d_a as parameter. The commentary R17.5.2.2 notes: “The influence of anchor stiffness and diameter is not apparent in large-diameter anchors, resulting in a limitation on the shear breakout strength provided by Eq. (17.5.2.2b)”. Therefore, increasing the anchor “stiffness” (l_a) and diameter (d_a) does not result in a corresponding increase in V_b. This is accounted for in Eq. (17.5.2.2.b) which does not include either l_e or d_a in the V_b calculation. The PROFIS Engineering cast-in anchor portfolio includes anchor diameters ranging from 1/2” to 2”, depending on the anchor type. The diameter ranges utilized by PROFIS Engineering for these anchor types are shown to the left. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. The anchor element diameter range that has been utilized to qualify a specific post-installed anchor via this testing will be given in the ICC-ESR for the anchor. PROFIS Engineering uses the diameter range referenced in the ICC-ESR provisions for a particular anchor element. Reference the ICC-ESR to see whether the d_a-value corresponds to the nominal anchor diameter or to the diameter of the anchor element inclusive of an external sleeve. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter V_b.
MATERIAL SPECIFICATION	ANCHOR DIAMETER (d_{anchor}) (in)																																																										
AWD D1.1 Headed Stud	0.500																																																										
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ASTM F1554 Headed Bolt GR. 36, 55, 105	0.500	0.500	0.500	0.500																																																							
	0.625	0.625	0.625	0.625																																																							
	0.750	0.750	0.750	0.750																																																							
	0.875	0.875	0.875	0.875																																																							
	1.000	1.000	1.000	1.000																																																							
	1.125	1.125	1.125	1.125																																																							
	1.250	1.250	1.250	1.250																																																							
	1.375	1.375	1.375	1.375																																																							
	1.500	1.500	1.500	1.500																																																							
		1.750																																																									
	2.000																																																										

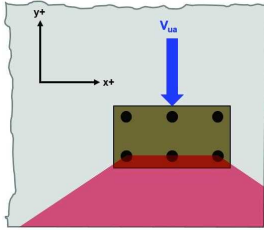
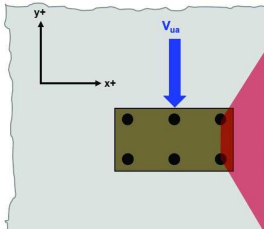
Variables d_a (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																				
d_a	Excerpt from ICC-ESR-3187 (HIT-HY 200 adhesive anchor system) showing the diameter range for threaded rods and rebar. These nominal diameters are used to calculate V_b. Table 12 — Concrete breakout design information for fractional threaded rod and reinforcing bars in holes drilled with a hammer drill and carbide bit (or hilti hollow carbide drill bit) <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1 1/4 or #10</th></tr><tr><td>Minimum Embedment</td><td>$h_{ef,min}$</td><td>in.</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>4-1/2</td><td>5</td></tr><tr><td>Maximum Embedment</td><td>$h_{ef,max}$</td><td>in.</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/2</td><td>20</td><td>22-1/2</td><td>25</td></tr><tr><td>Minimum Concrete Thickness</td><td>h_{min}</td><td>in.</td><td colspan="2">$h_{ef} + 1-1/4$</td><td colspan="6">$h_{ef} + 2d_o$</td></tr></table>  Excerpt from ICC-ESR-1545 (HSL-3 mechanical anchor) showing the anchor diameter range. The diameter in bold text (e.g. M10, M12, etc.) is the nominal diameter of the threaded element in the anchor. The outside anchor diameter ("Anchor O.D.") corresponds to the diameter of the external sleeve. The outside sleeve diameter is used to calculate V_b. ICC-ES ECR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal anchor diameter</th></tr><tr><th>M8</th><th>M10</th><th>M12</th><th>M16</th><th>M20</th><th>M24</th></tr><tr><td rowspan="2">Min. member thickness</td><td rowspan="2">$d_a(d_o)^a$</td><td>mm</td><td>12</td><td>15</td><td>18</td><td>24</td><td>26</td><td>32</td></tr><tr><td>in.</td><td>0.47</td><td>0.59</td><td>0.71</td><td>0.94</td><td>1.10</td><td>1.26</td></tr></table> 	DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)								3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1 1/4 or #10	Minimum Embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5	Maximum Embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25	Minimum Concrete Thickness	h_{min}	in.	$h_{ef} + 1-1/4$		$h_{ef} + 2d_o$						DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter							M8	M10	M12	M16	M20	M24	Min. member thickness	$d_a(d_o)^a$	mm	12	15	18	24	26	32	in.	0.47	0.59	0.71	0.94	1.10	1.26	
DESIGN INFORMATION	Symbol				Units	Nominal Rod Diameter (in.)																																																																																
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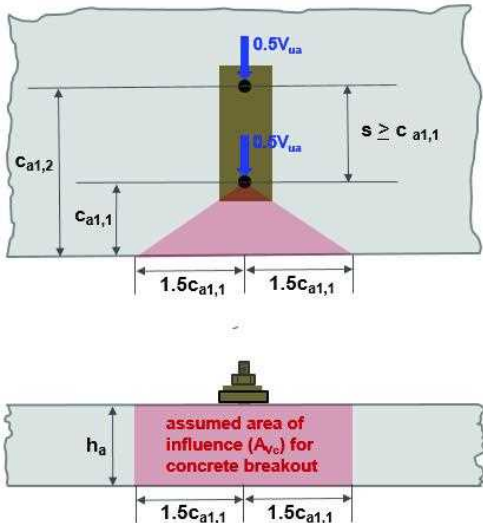
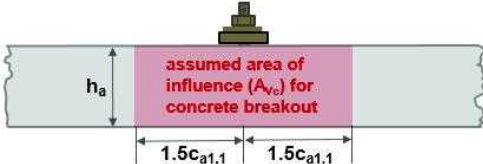
Variables f'_c

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
f'_c	17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors, and 8000 psi for post-installed anchors. Testing is required for post-installed anchors when used in concrete with f'_c greater than 8000 psi. 17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $(a) \quad V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} / \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2a)$ $(b) \quad V_b = 9 \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.2b)$ 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} / \sqrt{d_a} \right) \lambda_a \sqrt{f'_c} (c_{at})^{1.5} \quad (17.5.2.3a)$ Excerpt from ICC-ESR-3187 (HIT-HY 200 adhesive anchor system) showing provisions for f'_c. 5.2 The anchors and post-installed reinforcing bars must be installed in cracked and uncracked normal-weight concrete having a specified compressive strength $f'_c = 2500$ psi to 8500 psi. 5.3 The values of f'_c used for calculation purposes must not exceed 8000 psi except as noted in Sections 4.2.2 and 4.2.5 of this report. Excerpt from ICC-ESR-1917 (Kwik Bolt-TZ expansion anchor) showing provisions for f'_c. 5.2 The anchors must be limited to use in cracked and uncracked normal-weight concrete having a specified compressive strength $f'_c = 2500$ psi to 8500 psi, and cracked and uncracked normal-weight or sand-lightweight concrete over metal deck having a minimum specified compressive strength, f'_c of 3000 psi. 5.3 The values of f'_c used for calculation purposes must not exceed 8000 psi.	f'_c is a parameter used to define concrete compressive strength. This parameter is used to calculate the “basic concrete breakout strength in shear” (V_b) when calculating the nominal concrete breakout strength in shear (V_{cb} or V_{cbs}). Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. f'_c provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. PROFIS Engineering uses these f'_c provisions for post-installed anchor design. The post-installed anchor portfolio in PROFIS Engineering is limited to installation in concrete having a specified compressive strength between 2500 psi and 8500 psi, and design using an f'_c-value less than or equal to 8000 psi. Reference the ICC-ESR for f'_c information specific to a post-installed anchor. PROFIS Engineering users can input an f'_c-value within the range 2500 psi < f'_c < 8500 psi for post-installed anchor design. The maximum f'_c-value for calculations will be limited to 8000 psi. PROFIS Engineering users can input an f'_c-value within the range 2500 psi < f'_c < 10,000 psi for cast-in-place anchor design. The maximum f'_c-value for calculations will be limited to 10,000 psi. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter V_b.

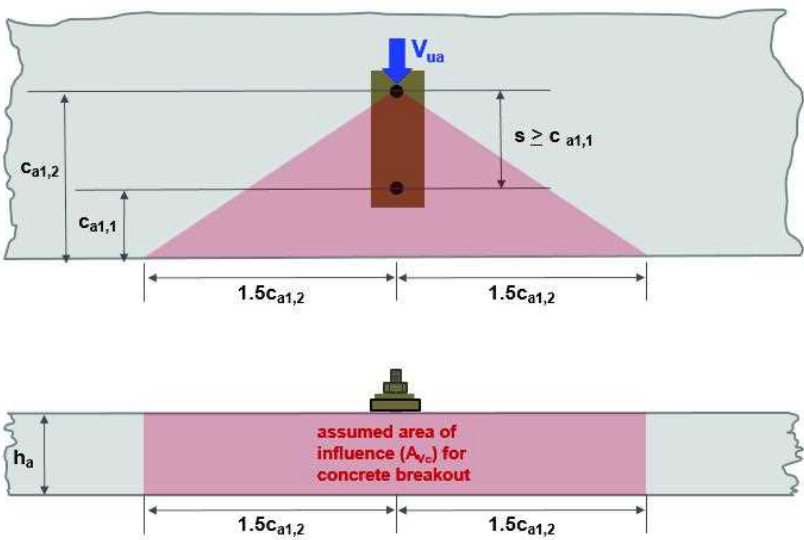
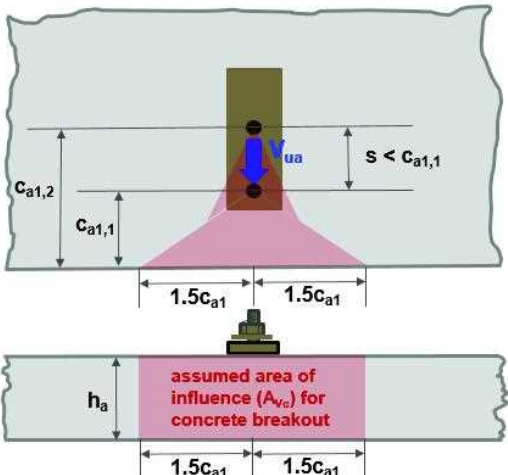
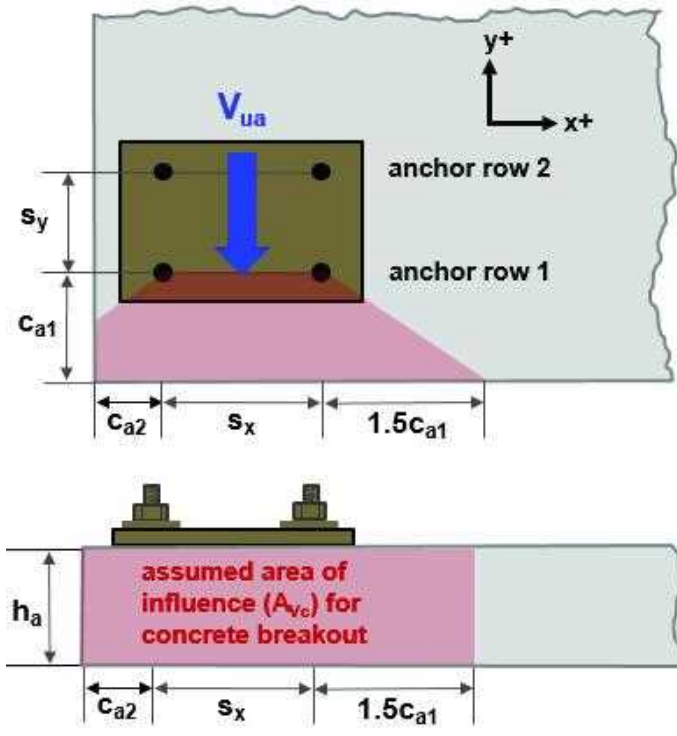
Variables $\psi_{\text{parallel},V}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{\text{parallel},V}$	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ (c) For shear force parallel to an edge V_{cb} or V_{cbg} shall be permitted to be twice the value of the shear force determined from Eq. (17.5.2.1a) or (17.5.2.1b), respectively, with the shear force assumed to act perpendicular to the edge and with $\psi_{ed,V}$ taken equal to 1.0. (d) For anchors located at a corner, the limiting nominal concrete breakout strength shall be determined for each edge, and the minimum value shall be used. PROFIS Engineering includes an additional modification factor ($\psi_{\text{parallel},V}$) when calculating V_{cb} per Eq. (17.5.2.1a) and V_{cbg} per Eq. (17.5.2.1b). For the example below, shear perpendicular to (i.e. towards) the y- edge and shear parallel to the x+ edge need to be considered with respect to concrete breakout failure. PROFIS Engineering calculates V_{cbg} for both conditions. PROFIS Engineering calculates V_{cbg} for the y- edge using $\psi_{\text{parallel},V} = 1.0$. $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} \psi_{\text{parallel},V} V_b$  PROFIS Engineering calculates V_{cbg} for the x+ edge using $\psi_{\text{parallel},V} = 2.0$. $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{\text{parallel},V} V_b$ 	ACI 318 anchoring-to-concrete provisions for concrete breakout in shear are predicated on failure occurring at a fixed edge when a shear load acts towards that edge. Consideration must also be given to concrete breakout failure in shear when the shear load acts parallel to a fixed edge. Per ACI 318-14 Section 17.5.2.1(c), when shear load acts parallel to a fixed edge, the nominal concrete breakout strength for the anchorage (V_{cb} or V_{cbg}) is calculated as if the load acts towards that edge, but the calculated values for either V_{cb} or V_{cbg} are multiplied by 2. PROFIS Engineering considers concrete breakout failure for shear towards an edge and shear parallel to an edge via a modification factor that it designates $\psi_{\text{parallel},V}$. If the nominal concrete breakout strength (V_{cb} or V_{cbg}) is being calculated for shear load applied towards a fixed edge, PROFIS Engineering calculates (V_{cb} or V_{cbg}) using a modified Eq. (17.5.2.1a) or Eq. (17.5.2.1b) that includes the PROFIS Engineering parameter "$\psi_{\text{parallel},V}$", with $\psi_{\text{parallel},V} = 1.0$. $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (PROFIS Engineering) $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} \psi_{\text{parallel},V} V_b$ If the nominal concrete breakout strength (V_{cb} or V_{cbg}) is being calculated for shear load applied parallel to a fixed edge, PROFIS Engineering calculates (V_{cb} or V_{cbg}) using a modified Eq. (17.5.2.1a) or Eq. (17.5.2.1b) that includes the PROFIS Engineering parameter "$\psi_{\text{parallel},V}$", with $\psi_{\text{parallel},V} = 2.0$. $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ (PROFIS Engineering) $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{\text{parallel},V} V_b$ If a corner application is being considered with shear load acting towards one of the corner edges, PROFIS Engineering calculates V_{cb} or V_{cbg} for shear towards that edge and V_{cb} or V_{cbg} for shear parallel to the other edge. The results for the smallest calculated V_{cb} or V_{cbg} value are shown in the report. If a corner application is being considered with shear load acting at an angle to the corner edges, PROFIS Engineering calculates V_{cb} or V_{cbg} for shear towards each edge and V_{cb} or V_{cbg} for shear parallel to each edge. The calculated V_{cb} or V_{cbg} value for each edge is checked against the shear load component being considered for that edge, and the results for the highest utilization ($V_{us}/\phi V_n$) are shown in the report. Reference the Equations and Results sections of the PROFIS Engineering report for more information on the following parameters: V_{cb}: Nominal concrete breakout strength in shear for a single anchor V_{cbg}: Nominal concrete breakout strength in shear for a group of anchors in shear V_{us}: Factored shear load ϕV_{cb} or ϕV_{cbg}: Design concrete breakout strength in shear

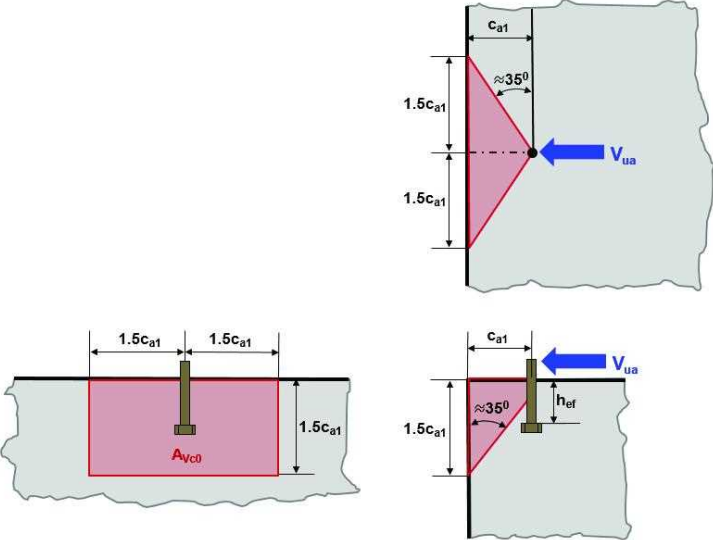
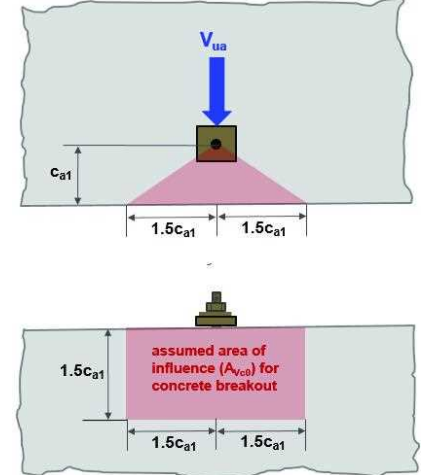
Calculations A_{vc}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{vc}	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ A_{vc} is the projected area of the failure surface on the side of the concrete member at its edge for a single anchor or a group of anchors. It shall be permitted to evaluate A_{vc} as the base of a truncated half-pyramid projected on the side face of the member where the top of the half-pyramid is given by the axis of the anchor row selected as critical. The value of c_{a1} shall be taken as the distance from the edge to this axis. Reference Fig. R17.5.2.1b — Case 1.  Reference Fig. R17.5.2.1b — Case 2.  Reference Fig. R17.5.2.1b — Case 3.	A_{vc} is a modification factor that accounts for the area of influence assumed to develop at the edge of a concrete member when a shear load acting on a single anchor or a group of anchors is applied towards that edge. A_{vc} calculations are predicated on the parameter c_{a1}, which is assumed to be the distance in the direction of the applied shear load from “the axis of the anchor row selected as critical”. ACI anchoring-to-concrete provisions do not set a maximum limit on the value for c_{a1}. Minimum edge distance values (c_{min}) are given in ACI 318-14 Sections 17.7.2, 17.7.3 and in post-installed anchor approvals. Fig. R17.5.2.1b in the commentary R.17.5.2.1 provides some suggestions for determining c_{a1}, and using this value to calculate A_{vc}. PROFIS Engineering always uses a c_{a1}-value corresponding to the distance from the anchor row nearest the fixed edge where concrete breakout is assumed to occur unless AWS D1.1 headed studs are being modeled. AWS D1.1 headed studs are rigidly attached to a fixture. Per Fig. R17.5.2.1b — Case 2, a c_{a1}-value corresponding to the distance from the anchor row farthest from the fixed edge where concrete breakout is assumed to occur can be used to model this type of anchor. The geometry for A_{vc} is defined by (a) projected edge distances perpendicular to the direction of the applied shear load acting on the anchors, (b) anchor spacing perpendicular to the direction of the applied shear load and (c) a projected distance down from the surface of the concrete at the edge where concrete breakout in shear is assumed to occur. The maximum projected distance assumed for (a) and (c) is limited to $1.5c_{a1}$. The maximum spacing assumed for (b) equals $3.0c_{a1}$. Minimum anchor spacing values (s_{min}) are given in ACI 318-14 Section 17.7.1 and in post-installed anchor approvals. The figure below illustrates how A_{vc} can be calculated for a group of four anchors in shear with a fixed edge distance (c_{a1}) in the direction of the applied shear load (V_{ua}), and a fixed edge distance (c_{a2}) perpendicular to the direction of V_{ua}. Concrete breakout in shear is assumed to occur at the y- edge, and c_{a1} is being considered as the distance from anchor row 1 to the y- edge. Only the spacing s_x perpendicular to the direction of V_{ua} is considered when calculating A_{vc} for this application. s_x for this application is assumed to be less than or equal to $3.0c_{a1}$; otherwise, the anchors would not be considered to act as a group with respect to s_x. c_{a2} for this application is assumed to be less than $1.5c_{a1}$. There is no fixed edge perpendicular to V_{ua} in the x+ direction, so the projected distance in the x+ direction used to calculate A_{vc} is limited to a maximum value of $1.5c_{a1}$. The maximum projected distance down from the concrete surface at the y- edge that is considered when calculating A_{vc} equals the smaller of the concrete thickness (h_a) and $1.5c_{a1}$. h_a for this application is assumed to be less than $1.5c_{a1}$. Minimum concrete thickness values for post-installed anchors are given in the anchor approvals.

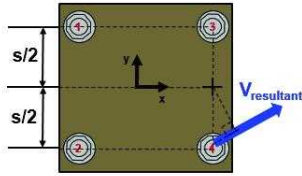
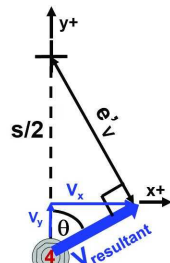
Calculations A_{vc} (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{vc}	Reference Fig. R17.5.2.1b — Case 2.  Reference Fig. R17.5.2.1b — Case 3. 	 $A_{vc} = (c_{a2} + s_x + 1.5c_{a1}) (h_a)$ where: $c_{min} \leq c_{a2} \leq 1.5c_{a1}$ $s_{min} \leq s_x \leq 3.0c_{a1}$ $h_{a,min} \leq h_a$ Reference the Variables section of the PROFIS Engineering report for more information on c_{a1}, c_{a2} and h_a. Reference the Equations section of the PROFIS Engineering report for more information on A_{vc}.

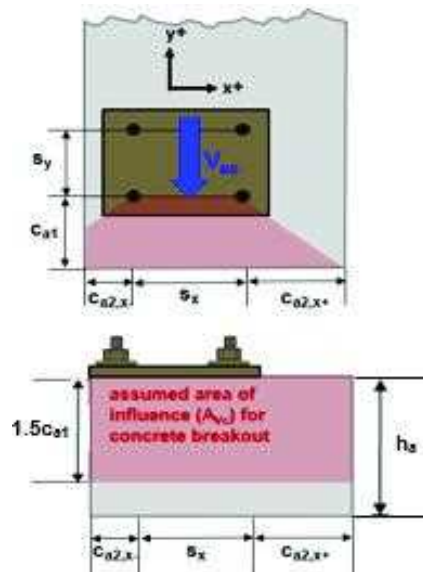
Calculations A_{vc0}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{vc0}	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ A_{vc0} is the projected area for a single anchor in a deep member with a distance from edges equal or greater than $1.5c_{a1}$ in the direction perpendicular to the shear force. It shall be permitted to evaluate A_{vc0} as the base of a half-pyramid with side length parallel to the edge of $3c_{a1}$ and a depth of $1.5c_{a1}$. $A_{vc0} = 4.5c_{a1}^2 \quad (17.5.2.1c)$ The figure below illustrates how A_{vc0} is modeled. Reference ACI 318-14 Fig. R17.5.2.1a. 	A_{vc0} is a modification factor that defines an idealized area of influence assumed to develop in concrete when a shear load acts towards a fixed edge on a single anchor without any perpendicular edge distance influences, any adjacent anchor spacing, in a concrete member of infinite thickness. A_{vc} calculations are predicated on the parameter c_{a1}, which is assumed to be the distance in the direction of the applied shear load from the anchor to the fixed edge. ACI anchoring-to-concrete provisions do not set a maximum limit on the value for c_{a1}. Minimum edge distance values (c_{min}) are given in ACI 318-14 Sections 17.7.2, 17.7.3 and in post-installed anchor approvals. The geometry for A_{vc0} is modeled as the base of a truncated pyramid defined by projected distances of $1.5c_{a1}$ perpendicular to the direction of the applied shear load, and down from the surface of the concrete. Therefore, the idealized area defined by A_{vc0} equals: $(1.5c_{a1} + 1.5c_{a1})(1.5c_{a1}) = 4.5c_{a1}^2$ The calculated value for A_{vc0} will always equal $4.5c_{a1}^2$. The figure below illustrates how A_{vc0} is calculated.  $A_{vc0} = (1.5c_{a1} + 1.5c_{a1})(1.5c_{a1}) = (4.5c_{a1}^2)$ where: $c_{min} \leq c_{a1}$ Reference the Variables section of the PROFIS Engineering report for more information on c_{a1}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{vc0}.

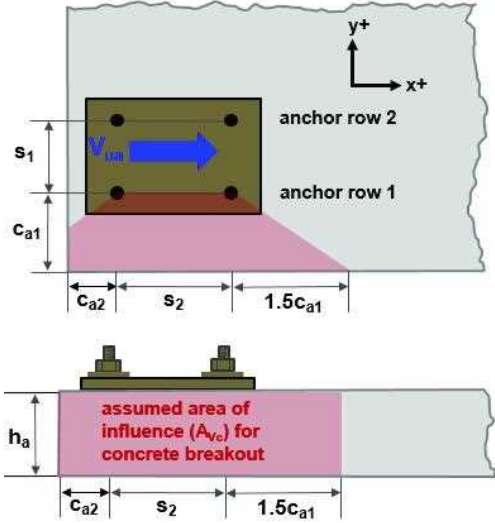
Calculations $\Psi_{ec,V}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\Psi_{ec,V}$	17.5.2.5 The modification factor for anchor groups loaded eccentrically in shear, $\Psi_{ec,V}$, shall be calculated as $\Psi_{ec,V} = \frac{1}{\left(1 + \frac{2e'_V}{3c_{at}}\right)} \quad (17.5.2.5)$ but $\Psi_{ec,V}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are loaded in shear in the same direction, only those anchors that are loaded in shear in the same direction shall be considered when determining the eccentricity e'_V for use in Eq. (17.5.2.5) and for the calculation of V_{cbg} according to Eq. (17.5.2.1b). 17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \Psi_{ed,V} \Psi_{c,y} \Psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \Psi_{ec,V} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_b \quad (17.5.2.1b)$	$\Psi_{ec,V}$ is a modification factor that is used to account for a resultant shear load that is eccentric with respect to the centroid of anchors that are loaded in shear. $\Psi_{ec,V}$ is only considered when calculating the nominal concrete breakout strength in shear for an anchor group (V_{cbg}). The text below explains how PROFIS Engineering would determine the shear eccentricity parameter (e'_V) that is used to calculate $\Psi_{ec,V}$ for an example when a torsion moment acts on four anchors. Assume a fixed edge is present in the x+ direction and that concrete breakout will occur at the x+ edge. The moment creates loads in the x direction as follows: • $V_{2,x}$ (+) on anchor 2 and $V_{4,x}$ (+) on anchor 4 • $V_{1,x}$ (-) on anchor 1 and $V_{3,x}$ (-) on anchor 3 The moment creates loads in the y direction as follows: • $V_{3,y}$ (+) on anchor 3 and $V_{4,y}$ (+) on anchor 4 • $V_{1,y}$ (-) on anchor 1 and $V_{2,y}$ (-) on anchor 2 PROFIS Engineering calculates a resultant shear load ($V_{resultant}$) from the loads acting on anchors 1-4 that influence the x+ fixed edge. PROFIS Engineering would assume only loads $V_{2,x}$ and $V_{4,x}$ influence the fixed edge with respect to loads acting in the x direction. Likewise, PROFIS Engineering would assume only loads $V_{3,y}$ and $V_{4,y}$ influence the fixed edge with respect to loads acting in the y direction. $V_{resultant}$ can be calculated with these loads as shown below. Concrete breakout is assumed to occur from anchors 3 and 4. $V_{resultant}$ is eccentric (e'_V) with respect to the centroid of these anchors. This shear eccentricity (e'_V) can be calculated knowing the angle θ and the spacing (s) between anchors 3 and 4. $V_{resultant} = \frac{[(V_{2,x} + V_{4,x})^2 + (V_{3,y} + V_{4,y})^2]^{0.5}}{[(V_x)^2 + (V_y)^2]^{0.5}}$ $\tan^{-1} \theta = (V_x / V_y)$   $e'_V = (s/2) (\sin \theta)$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: e'_V: Parameter for shear eccentricity c_{at}: Parameter for edge distance in the direction of the applied shear load Reference the Equations section of the PROFIS Engineering report for more information on $\Psi_{ec,V}$.

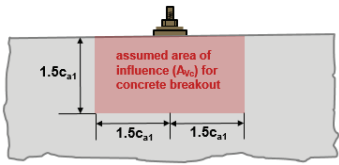
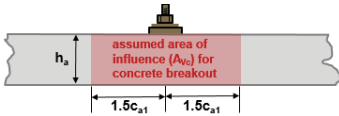
Calculations $\psi_{ed,V}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,V}$	17.5.2.6 The modification factor for edge effect for a single anchor or group of anchors loaded in shear, $\psi_{ed,V}$, shall be calculated as follows using the smaller value of c_{a2}. If $c_{a2} \geq 1.5c_{a1}$, then $\psi_{ed,V} = 1.0$ (17.5.2.6a) If $c_{a2} < 1.5c_{a1}$, then $\psi_{ed,V} = 0.7 + 0.3 \left(\frac{c_{a2}}{1.5c_{a1}} \right)$ (17.5.2.6b) 17.5.2.1 The nominal concrete breakout strength in shear, V_{cb} of a single anchor or V_{cbg} of a group of anchors, shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ (c) For shear force parallel to an edge V_{cb} or V_{cbg} shall be permitted to be twice the value of the shear force determined from Eq. (17.5.2.1a) or (17.5.2.1b), respectively, with the shear force assumed to act perpendicular to the edge and with $\psi_{ed,V}$ taken equal to 1.0 (d) For anchors located at a corner, the limiting nominal concrete breakout strength shall be determined for each edge, and the minimum value shall be used 17.5.2.4 Where anchors are located in narrow sections of limited thickness such that both edge distances c_{a2} and thickness h_a are less than $1.5c_{a1}$, the value of c_{a1} used for A_{vc} in accordance with 17.5.2.1 as well as for the equations in 17.5.2.1 through 17.5.2.8 shall not exceed the largest of: $c_{a2}/1.5$, where c_{a2} is the largest edge distance $h_a/1.5$ $s/3$, where s is the maximum spacing perpendicular to direction of shear, between anchors within a group	$\psi_{ed,V}$ is a modification factor that is used to account for fixed edge distances perpendicular to the direction of the applied shear load that are less than $1.5c_{a1}$. Shear concrete breakout failure calculations are predicated on the fixed edge distance in the direction of the applied shear load (c_{a1}). Edge distances perpendicular to the direction of the applied shear load are designated c_{a2}. If c_{a2} is less than $1.5c_{a1}$, $\psi_{ed,V}$ is calculated per Eq. (17.5.2.6b). If more than one fixed edge perpendicular to the direction of the applied shear load exists, the smallest of these edge distances is used to calculate $\psi_{ed,V}$. For the application in the illustration below, if $c_{a2,x} < c_{a2,y}$: $\psi_{ed,V} = 0.7 + 0.3 (c_{a2,x} / 1.5c_{a1})$ Per Section 17.5.2.4, when anchoring into a narrow section, the checks noted in (a) through (c) should also be made to determine if a modified c_{a1}-value should be used for the shear concrete breakout calculations. For the application below, h_a is greater than $1.5c_{a1}$, so no modified c_{a1}-value would be calculated. 

Calculations $\psi_{ed,V}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,V}$		Per Section 17.5.2.1(c), if shear force acts parallel to a fixed edge, $\psi_{ed,V}$ is taken equal to 1.0. For the application illustrated below, shear load (V_{ua}) acts parallel to the y- edge. the value for c_{a2} would be used to calculate A_{vc}, but $\psi_{ed,V}$ taken equal to 1.0.  Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Fixed edge distance in the direction of the applied shear load c_{a2}: Fixed edge distance perpendicular to the direction of the applied shear load h_a: Concrete thickness Reference the Calculations section of the PROFIS Engineering report for more information on $\psi_{ed,V}$.

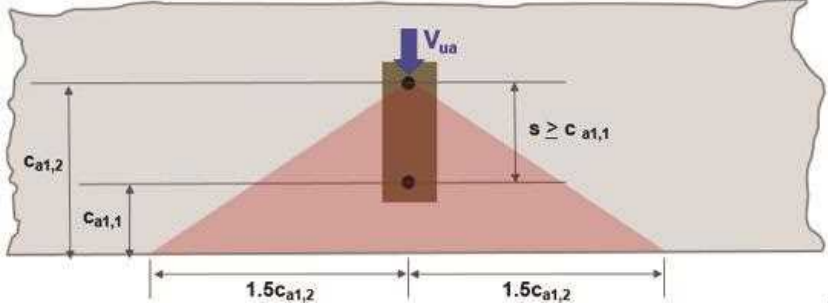
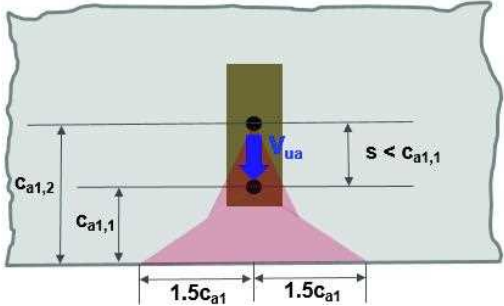
Calculations $\psi_{h,V}$

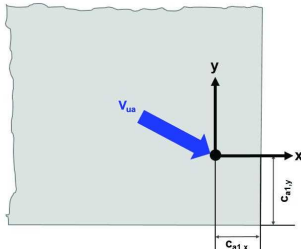
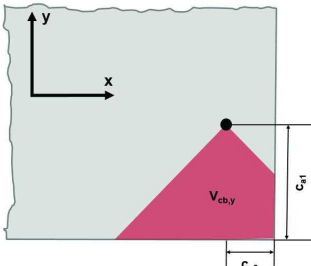
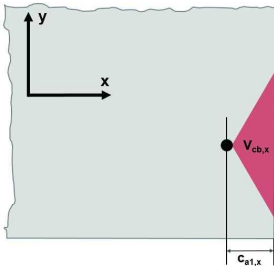
Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{h,V}$	17.5.2.8 The modification factor for anchors located in a concrete member where $h_a < 1.5c_{a1}$, $\psi_{h,V}$ shall be calculated as $\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \quad (17.5.2.8)$ but $\psi_{h,V}$ shall not be taken less than 1.0.	$\psi_{h,V}$ is a modification factor that is used to account for a concrete member thickness h_a that is less than a projected distance of $1.5c_{a1}$ down from the surface of the concrete. The parameter c_{a1} corresponds to the distance of an anchor, in the direction of the applied shear load, to the fixed edge for which concrete breakout in shear is being calculated. $\psi_{h,V}$ is always ≥ 1.0 per the provisions of Section 17.5.2.8. ACI anchoring-to-concrete provisions do not set a maximum limit on the value for c_{a1}. Minimum edge distance values (c_{min}) are given in ACI 318-14 Sections 17.7.2, 17.7.3 and in post-installed anchor approvals. PROFIS Engineering always uses a c_{a1}-value corresponding to the distance from the anchor row nearest the fixed edge where concrete breakout is assumed to occur unless AWS D1.1 headed studs are being modeled. AWS D1.1 headed studs are rigidly attached to a fixture so a c_{a1}-value corresponding to the distance from the anchor row farthest from the fixed edge where concrete breakout is assumed to occur can be used to model this type of anchor. The figures below illustrate conditions for calculating $\psi_{h,V}$.  $h_a > 1.5c_{a1}$ $\psi_{h,V} = 1.0$  $h_a < 1.5c_{a1}$ $\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}}$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Fixed edge distance in the direction of the applied shear load h_a: Concrete thickness Reference the Equations section of the PROFIS Engineering report for more information on $\psi_{h,V}$.

Calculations V_b

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_b	17.5.2.2 The basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of (a) and (b): $(a) \quad V_b = \left(7 \left(\frac{l_e}{d_a} \right)^{0.2} / \sqrt{d_a} \right) \lambda_a / \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.2a)$ $(b) \quad V_b = 9 \lambda_a / \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.2b)$ 17.5.2.3 For cast-in headed studs, headed bolts, or hooked bolts that are continuously welded to steel attachments having a minimum thickness equal to the greater of 3/8 in. and half of the anchor diameter, the basic concrete breakout strength in shear of a single anchor in cracked concrete, V_b, shall be the smaller of Eq. (17.5.2.2b) and Eq. (17.5.2.3) $V_b = \left(8 \left(\frac{l_e}{d_a} \right)^{0.2} / \sqrt{d_a} \right) \lambda_a / \sqrt{f'_c} (c_{a1})^{1.5} \quad (17.5.2.3a)$ Reference ACI 318-14 Fig. R17.5.2.1b. Case 1: One assumption of the distribution of forces indicates that half of the shear force would be critical on the front anchor and the projected area. For the calculation of concrete breakout, c_{a1} is taken as $c_{a1,1}$.	ACI 318-14 Chapter 2 defines the parameter V_b as the “basic concrete breakout strength in shear of a single anchor in cracked concrete”. V_b calculated using Eq. (17.5.2.2a) can be considered relevant for anchors that are not rigidly attached to the fixture, i.e. an annular space exists between the anchor element and the hole in the fixture through which the anchors are located. When calculating V_b with this equation, the value for c_{a1} can be determined from the near-edge anchors per Case 1 or Case 3 in the ACI 318-14 commentary Fig. R17.5.2.1b. V_b calculated using Eq. (17.5.2.2b) is a limiting value. If calculating V_b with Eq. (17.5.2.2a), the value for c_{a1} used in that equation would also be used to calculate V_b with Eq. (17.5.2.2b). For all of the post-installed anchors in the PROFIS Engineering portfolio, and all of the cast-in anchors except AWS D1.1 headed studs; PROFIS Engineering calculates V_b using Eq. (17.5.2.2a) and Eq. (17.5.2.2b), and shows the lesser V_b-value in the Calculations section of the report. V_b calculated using Eq. (17.5.2.3) is only relevant for anchors that are rigidly attached to the fixture, e.g. a welded head stud. When calculating V_b with this equation, the value for c_{a1} can be determined from the far-edge anchors per Case 2 in the ACI 318-14 commentary Fig. R17.5.2.1b. If calculating V_b with Eq. (17.5.2.3), the value for c_{a1} used in that equation would also be used to calculate V_b with Eq. (17.5.2.2b). PROFIS Engineering only calculates V_b using Eq. (17.5.2.3) for the AWS D1.1 headed studs in its anchor portfolio, and checks this value against V_b calculated per Eq. (17.5.2.2b). The lesser V_b-value is shown in the Calculations section of the report. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: l_e: Load bearing length of anchor in shear d_a: Anchor element diameter λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength c_{a1}: Edge distance in the direction of the shear load Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: V_b calculated per Eq. (17.5.2.2a) V_b calculated per Eq. (17.5.2.2b) V_b calculated per Eq. (17.5.2.3)

Calculations V_b (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_b	Case 2: Another assumption of the distribution of forces indicates that the total shear force would be critical on the rear anchor and its projected area. Only this assumption needs to be considered when anchors are welded to a common plate independent of s. For the calculation of concrete breakout, c_{a1} is taken as $c_{a1,2}$.  Case 3: Where $s < c_{a1,1}$, apply the entire shear load V_{ua} to the front anchor. This case does not apply for anchors welded to a common plate. For the calculation of concrete breakout, c_{a1} is taken as $c_{a1,1}$. 	

Results V_{cb}	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cb}	17.5.2.1 The nominal concrete breakout strength in shear, V_{cb}, of a single anchor shall not exceed: (a) For shear force perpendicular to the edge on a single anchor $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,y} \psi_{h,V} V_b \quad (17.5.2.1a)$ (c) For shear force parallel to an edge V_{cb} shall be permitted to be twice the value of the shear force determined from Eq. (17.5.2.1a) with the shear force assumed to act perpendicular to the edge and with $\psi_{ed,V}$ taken equal to 1.0 (d) For anchors located at a corner, the limiting nominal concrete breakout strength shall be determined for each edge, and the minimum value shall be used PROFIS Engineering includes an additional modification factor ($\psi_{parallel,V}$) in Eq. (17.5.2.1a). PROFIS Engineering calculations for V_{cb}: $V_{cb} = \frac{A_{vc}}{A_{vc0}} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$ PROFIS Engineering calculations for shear load acting at a corner. Check $(V_{ua}/V_{cb,x})$ versus $(V_{ua}/V_{cb,y})$ and take the highest utilization (%).  calculate $V_{cb,x}$ calculate $V_{cb,y}$ 	ACI 318-14 Eq. (17.5.2.1a) is used to calculate the nominal concrete breakout strength in shear for a single anchor (V_{cb}). Concrete breakout in shear is calculated for shear load acting towards (i.e. perpendicular to) a fixed edge. If shear load acts parallel to a fixed edge, Section 17.5.2.1(c) requires V_{cb} to be calculated as if the shear load acts towards the fixed edge, and the value calculated for V_{cb} to be doubled. The PROFIS Engineering parameter that is designated in the report as "$\psi_{parallel,V}$" indicates whether the software is calculating concrete breakout for shear load acting towards a fixed edge ($\psi_{parallel,V} = 1.0$) or parallel to a fixed edge ($\psi_{parallel,V} = 2.0$). If a shear load acts at an angle with respect to two fixed edges, Section 17.5.2.1(d) requires V_{cb} to be calculated with respect to each fixed edge. The calculated value for V_{cb} is checked against the component of the shear load that acts towards each fixed edge as well as load acting parallel to each fixed edge. The software then checks the calculated V_{cb} value for each load condition (towards the edge and parallel to the edge) against the resultant shear load rather than the shear load component acting on each edge. This is a conservative design assumption. Reference the Equations section of the PROFIS Engineering report for more information on V_{cb}. Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{vc}: Area of influence for anchors in shear A_{vc0}: Area of influence for single anchor in shear $\psi_{ed,V}$: Shear modification factor for edge distance $\psi_{h,V}$: Modification factor for thin slabs V_b: Basic concrete breakout strength in shear Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,V}$: Modification factor for cracked concrete $\psi_{parallel,V}$: Modification factor for shear parallel to a fixed edge

ACI 318-14 Eq. (17.5.2.1a) is used to calculate the nominal concrete breakout strength in shear for a single anchor (V_{cb}).

Concrete breakout in shear is calculated for shear load acting towards (i.e. perpendicular to) a fixed edge. If shear load acts parallel to a fixed edge, Section 17.5.2.1(c) requires V_{cb} to be calculated as if the shear load acts towards the fixed edge, and the value calculated for V_{cb} to be doubled. The PROFIS Engineering parameter that is designated in the report as " $\psi_{parallel,V}$ " indicates whether the software is calculating concrete breakout for shear load acting towards a fixed edge ($\psi_{parallel,V} = 1.0$) or parallel to a fixed edge ($\psi_{parallel,V} = 2.0$).

If a shear load acts at an angle with respect to two fixed edges, Section 17.5.2.1(d) requires V_{cb} to be calculated with respect to each fixed edge. The calculated value for V_{cb} is checked against the component of the shear load that acts towards each fixed edge as well as load acting parallel to each fixed edge. The software then checks the calculated V_{cb} value for each load condition (towards the edge and parallel to the edge) against the resultant shear load rather than the shear load component acting on each edge. This is a conservative design assumption.

Reference the **Equations** section of the PROFIS Engineering report for more information on V_{cb} .

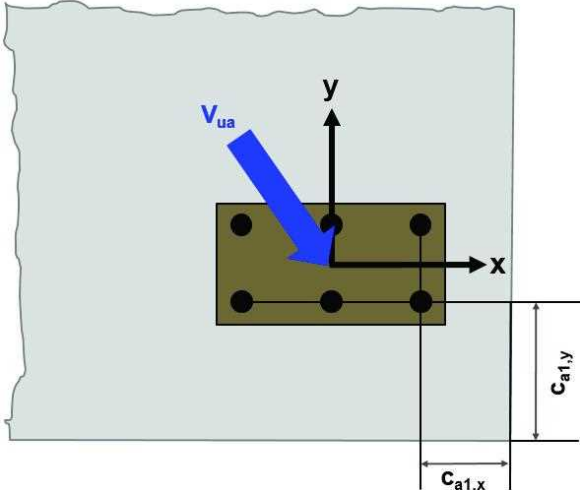
Reference the **Calculations** section of the PROFIS Engineering report for more information on the following parameters:

- A_{vc} : Area of influence for anchors in shear
- A_{vc0} : Area of influence for single anchor in shear
- $\psi_{ed,V}$: Shear modification factor for edge distance
- $\psi_{h,V}$: Modification factor for thin slabs
- V_b : Basic concrete breakout strength in shear

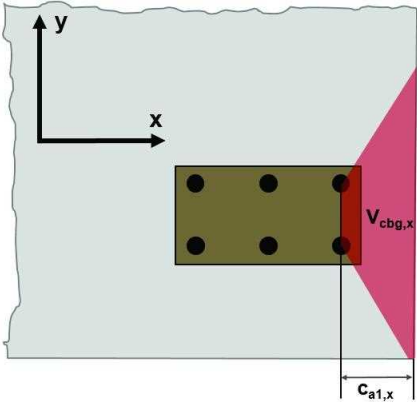
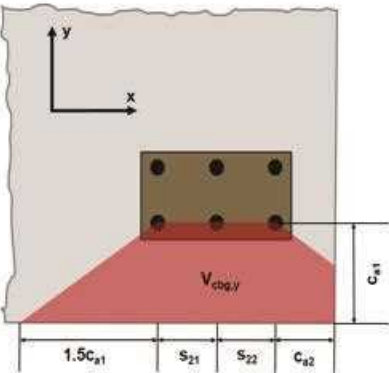
Reference the **Variables** section of the PROFIS Engineering report for information on:

- $\psi_{c,V}$: Modification factor for cracked concrete
- $\psi_{parallel,V}$: Modification factor for shear parallel to a fixed edge

Results V_{cbg}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cbg}	17.5.2.1 The nominal concrete breakout strength in shear, ... V_{cbg} of a group of anchors, shall not exceed: (b) For shear force perpendicular to the edge on a group of anchors $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b \quad (17.5.2.1b)$ (c) For shear force parallel to an edge V_{cbg} shall be permitted to be twice the value of the shear force determined from.....Eq. (17.5.2.1b)..... with the shear force assumed to act perpendicular to the edge and with $\psi_{ed,V}$ taken equal to 1.0 (d) For anchors located at a corner, the limiting nominal concrete breakout strength shall be determined for each edge, and the minimum value shall be used PROFIS Engineering includes an additional modification factor ($\psi_{parallel,V}$) in Eq. (17.5.2.1b). PROFIS Engineering calculations for V_{cbg}: $V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$ PROFIS Engineering calculations for shear load acting at a corner. Check ($V_{ua}/V_{cbg,x}$) versus ($V_{ua}/V_{cbg,y}$) and take the highest utilization (%).  calculate $V_{cbg,x}$ calculate $V_{cbg,y}$	ACI 318-14 Eq. (17.5.2.1b) is used to calculate the nominal concrete breakout strength for a group of anchors in shear (V_{cbg}). Concrete breakout in shear is calculated for shear load acting towards (i.e. perpendicular to) a fixed edge. If shear load acts parallel to a fixed edge, Section 17.5.2.1(c) requires V_{cbg} to be calculated as if the shear load acts towards the fixed edge, and the value calculated for V_{cbg} to be doubled. The PROFIS Engineering parameter that is designated in the report as "$\psi_{parallel,V}$" indicates whether the software is calculating concrete breakout for shear load acting towards a fixed edge ($\psi_{parallel,V} = 1.0$) or parallel to a fixed edge ($\psi_{parallel,V} = 2.0$). If a shear load acts at an angle with respect to two fixed edges, Section 17.5.2.1(d) requires V_{cbg} to be calculated with respect to each fixed edge. The calculated value for V_{cbg} is checked against the component of the shear load that acts towards each fixed edge. PROFIS Engineering calculates V_{cbg} for load acting towards each fixed edge as well as load acting parallel to each fixed edge. The software then checks the calculated V_{cbg} value for each load condition (towards the edge and parallel to the edge) against the resultant shear load rather than the shear load component acting on each edge. This is a conservative design assumption. Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{vc}: Area of influence for anchors in shear A_{vc0}: Area of influence for single anchor in shear $\psi_{ec,V}$: Shear modification factor for eccentricity $\psi_{ed,V}$: Shear modification factor for edge distance $\psi_{h,V}$: Modification factor for thin slabs V_b: Basic concrete breakout strength in shear Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,V}$: Modification factor for cracked concrete $\psi_{parallel,V}$: Modification factor for shear parallel to a fixed edge

Results V_{cbg} (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cbg}	calculate $V_{cbg,x}$  calculate $V_{cbg,y}$ 	

Results ϕ_{concrete}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																						
ϕ_{concrete}	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength <table><tr><th></th><th>Condition A</th><th>Condition B</th></tr><tr><td>(i) Shear loads</td><td>0.75</td><td>0.70</td></tr></table> Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths. Example: Example of a post-installed mechanical anchor strength reduction factor (ϕ-factor) corresponding to concrete breakout failure in shear. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td colspan="3">Strength reduction o factor for shear, concrete failure modes, Condition B</td><td colspan="10">0.70</td></tr></table> Example: Example of a post-installed adhesive anchor system strength reduction factor (ϕ-factor) corresponding to concrete breakout failure in shear. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="9">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8or #7</th><th>1 or #8</th><th>#9</th><th>1/4 or #10</th></tr><tr><td>Strength reduction o factor for shear, concrete failure modes, Condition B</td><td>ϕ</td><td>-</td><td colspan="9">0.70</td></tr></table>		Condition A	Condition B	(i) Shear loads	0.75	0.70	DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Strength reduction o factor for shear, concrete failure modes, Condition B			0.70										DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)									3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8or #7	1 or #8	#9	1/4 or #10	Strength reduction o factor for shear, concrete failure modes, Condition B	ϕ	-	0.70									ACI 318-14 strength design provisions for concrete breakout failure in shear require calculation of a nominal concrete breakout strength (V_{cb} or V_{cbg}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{cb} or ϕV_{cbg}). Only one ϕ-factor is applied to V_{cb} or V_{cbg}. The 0.75 seismic strength reduction factor required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cb} or V_{cbg} when the anchorage is being designed for seismic shear load conditions. PROFIS Engineering designates the ϕ-factor corresponding to concrete breakout failure for shear load conditions "ϕ_{concrete}". When designing cast-in-place anchors, PROFIS Engineering uses the ϕ-factors given in ACI 318-14 Section 17.3.3. The ϕ-factors in Section 17.3.3 are only intended to be used as guide values for post-installed anchors in the absence of product-specific data. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. When Condition B is selected as a post-installed anchor design parameter, PROFIS Engineering uses the ϕ-factors derived from AC193/ ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. The ϕ-factors in the ICC-ESR correspond to Condition B. PROFIS Engineering defaults to Condition B when calculating concrete breakout strength in shear. If Condition A is selected as a design parameter for either cast-in-place or post-installed anchors, PROFIS Engineering uses the Condition A ϕ-factor given in ACI 318-14 Section 17.3.3(c) (i) to calculate the design concrete breakout strength in shear. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cb} or V_{cbg}: Nominal concrete breakout strength in shear ϕV_{cb} or ϕV_{cbg}: Design concrete breakout strength in shear
	Condition A	Condition B																																																																																						
(i) Shear loads	0.75	0.70																																																																																						
DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)																																																																																					
			3/8		1/2		5/8		3/4																																																																															
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																												
Strength reduction o factor for shear, concrete failure modes, Condition B			0.70																																																																																					
DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)																																																																																					
			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8or #7	1 or #8	#9	1/4 or #10																																																																														
Strength reduction o factor for shear, concrete failure modes, Condition B	ϕ	-	0.70																																																																																					

Results ϕ_{seismic}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering						
ϕ_{seismic}	17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors ϕN_{sa} corresponds to steel failure (tension) in Table 17.3.1.1] (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided $[\phi N_{cb}$ or ϕN_{cbg} correspond to concrete breakout failure (tension) in Table 17.3.1.1] (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{pn}$ corresponds to pullout failure (tension) in Table 17.3.1.1] (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ $[\phi N_{sb}$ or ϕN_{sbg} correspond to side-face blowout failure (tension) in Table 17.3.1.1] (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ ϕN_a or ϕN_{ag} correspond to bond failure (tension) in Table 17.3.1.1] where ϕ is in accordance with 17.3.3. 17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: <table> <tr> <th></th><th>Condition A</th><th>Condition B</th></tr> <tr> <td>(i) Shear loads</td><td>0.75</td><td>0.70</td></tr> </table> PROFIS Engineering calculations for concrete breakout failure in tension when seismic load conditions are being modeled: single anchor: design concrete breakout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{cb}$ anchor group: design concrete breakout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{cbg}$ PROFIS Engineering calculations for concrete breakout failure in shear when seismic load conditions are being modeled: single anchor: Design concrete breakout strength = $\phi_{\text{concrete}} V_{cb}$ anchor group: Design concrete breakout strength = $\phi_{\text{concrete}} V_{cbg}$		Condition A	Condition B	(i) Shear loads	0.75	0.70	When designing an anchorage for seismic tension load conditions, ACI 318-14 provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by two strength reduction factors (ϕ-factors): one ϕ-factor for concrete breakout failure in tension, and one ϕ-factor for seismic tension load conditions, to obtain a design strength ($0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$). PROFIS Engineering designates the 0.75 seismic tension reduction factor noted in ACI 318-14 Section 17.2.3.4.4 "ϕ_{seismic}". This reduction is only considered with respect to non-steel tension failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors subjected to seismic tension loads. When designing an anchorage for seismic shear load conditions, ACI 318-14 strength design provisions for concrete breakout failure in shear require calculation of a nominal concrete breakout strength (V_{cb} or V_{cbg}) that is only multiplied by one ϕ-factor to obtain a shear design strength (ϕV_{cb} or ϕV_{cbg}). PROFIS Engineering designates this ϕ-factor "ϕ_{concrete}". The 0.75 seismic strength reduction factor (ϕ_{seismic}) required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cb} or V_{cbg} when the anchorage is being designed for seismic shear load conditions. The PROFIS Engineering report always shows ϕ_{seismic} equal to 1.0 for shear concrete breakout calculations when seismic shear load conditions are being modeled. When calculating the design concrete breakout strength in shear for cast-in-place anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report is taken from Section 17.3.3(c)(i). When calculating the design concrete breakout strength in shear for post-installed anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report is taken as follows: • If "Condition B" is selected as a design parameter, "ϕ_{concrete}" is taken from the ϕ-factor for shear given in the ICC-ESR for the anchor • If "Condition A" is selected as a design parameter, "ϕ_{concrete}" is taken from Section 17.3.3(c)(i) Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cb} or V_{cbg}: Nominal concrete breakout strength in shear ϕV_{cb} or ϕV_{cbg}: Design concrete breakout strength in shear ϕ_{concrete}: Strength reduction factor for shear concrete failure
	Condition A	Condition B						
(i) Shear loads	0.75	0.70						

Results $\phi_{\text{nonductile}}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	When designing an anchorage for seismic tension load conditions, ACI 318-14 provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by two strength reduction factors (ϕ-factors): one ϕ-factor for concrete breakout failure in tension, and one ϕ-factor for seismic tension load conditions, to obtain a design strength ($0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$). PROFIS Engineering designates the 0.75 seismic tension reduction factor noted in ACI 318-14 Section 17.2.3.4.4 “ϕ_{seismic}”. This reduction is only considered with respect to non-steel tension failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors subjected to seismic tension loads. When designing an anchorage for seismic shear load conditions, ACI 318-14 strength design provisions for concrete breakout failure in shear require calculation of a nominal concrete breakout strength (V_{cb} or V_{cbg}) that is only multiplied by one ϕ-factor to obtain a shear design strength (ϕV_{cb} or ϕV_{cbg}). PROFIS Engineering designates this ϕ-factor “ϕ_{concrete}”. The 0.75 seismic strength reduction factor (ϕ_{seismic}) required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cb} or V_{cbg} when the anchorage is being designed for seismic shear load conditions. The parameter “$\phi_{\text{nonductile}}$” is a reduction factor for seismic tension and seismic shear load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor “$\phi_{\text{nonductile}}$”. “$\phi_{\text{nonductile}}$” is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

Results ϕV_{cb}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cb}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Shear Single Anchor $\phi V_{cb} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cb}: Nominal concrete breakout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

Results ϕV_{cbg}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cbg}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Breakout Strength in Shear Anchors as a Group $\phi V_{cbg} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cbg}: Nominal concrete breakout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

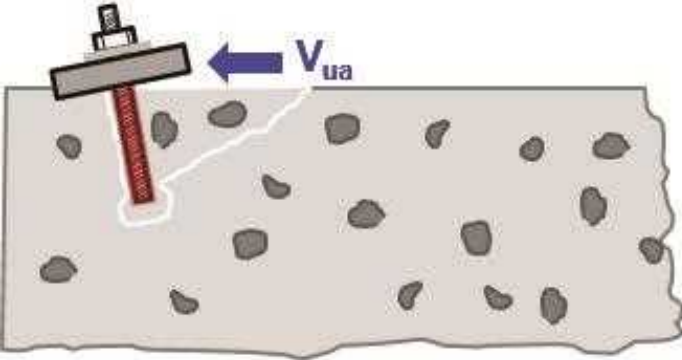
Results V_{ua}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
V_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the shear failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi V_{sa} \geq V_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi V_{cb} \geq V_{ua}$</td><td></td><td>$\phi V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi V_{cn} \geq V_{ua}$</td><td></td><td>$\phi V_{cng} \geq V_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi V_{sa} \geq V_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi V_{cb} \geq V_{ua}$		$\phi V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi V_{cn} \geq V_{ua}$		$\phi V_{cng} \geq V_{ua,g}$	ACI 318-14 strength design provisions for concrete breakout failure in shear require calculation of a nominal concrete breakout strength (V_{cb} or V_{cbg}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{cb} or ϕV_{cbg}). Design strength is checked against a factored shear load, defined by the parameter "V_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored shear load parameter "V_{ua}". • V_{ua} = factored shear force applied to a single anchor or group of anchors (lb) • $V_{ua,i}$ = factored shear force applied to most highly stressed anchor in a group of anchors (lb) • $V_{ua,g}$ = total factored shear force applied to anchor group (lb) The design concrete breakout strength for a single anchor in shear (ϕV_{cb}) calculated per Section 17.5.2 is checked against the factored shear load acting on the anchor, which is designated "V_{ua}" in Table 17.3.1.1. If $\phi V_{cb} \geq V_{ua}$, the provisions for considering concrete breakout failure in shear have been satisfied per Table 17.3.1.1. The design concrete breakout strength for a group of anchors in shear (ϕV_{cbg}) calculated per Section 17.5.2 is checked against the total factored shear load acting on the anchors that are in shear, which is designated "$V_{ua,g}$" in Table 17.3.1.1. If $\phi V_{cbg} \geq V_{ua,g}$, the provisions for considering concrete breakout failure in shear have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation "V_{ua}" to define the factored shear load being checked against the calculated design concrete breakout strength ϕV_{cb} or ϕV_{cbg}. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting shear loads. The software only performs shear load checks per Table 17.3.1.1 if shear loads have been input via one of the load input functionalities. If a single anchor in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{cb}, and checks this value against either (a) the factored shear load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored shear load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored shear load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the factored shear load determined to be acting on the anchor. If a group of anchors in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{cbg}, and checks this value against either (a) the total factored shear load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored shear load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored shear load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the total factored shear load determined to be acting on the anchor group.
Failure Mode	Single Anchor			Anchor Group																
		Individual anchor in a Group	Anchors as a group																	
Steel strength in shear (17.5.1)	$\phi V_{sa} \geq V_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																		
Concrete breakout strength in shear (17.5.2)	$\phi V_{cb} \geq V_{ua}$		$\phi V_{cbg} \geq V_{ua,g}$																	
Concrete pryout strength in shear (17.5.3)	$\phi V_{cn} \geq V_{ua}$		$\phi V_{cng} \geq V_{ua,g}$																	

Results V_{ua} (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{ua}		Reference the Results section of the PROFIS Engineering report for more information on the following parameters: • V_{cb}: Nominal shear concrete breakout strength for a single anchor • V_{cbg}: Nominal shear concrete breakout strength an anchor group • $\phi_{concrete}$: Strength reduction factor for concrete failure modes • $\phi_{seismic}$: Strength reduction factor for seismic loads • $\phi_{nonductile}$: Strength reduction factor for non-ductile failure modes

Equation V_{cp}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cp} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Na0}} \right) \psi_{ed,Na} \psi_{cp,Na} N_{ba} \right]$	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cb} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a single adhesive anchor (V_{cp}) as the product of k_{cp} and the smaller of N_{cb} calculated per Eq. (17.4.2.1a) and N_a calculated per Eq. (17.4.5.1a). Nominal pryout strength (N_{cp}) is predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. For the example illustrated below, a single adhesive anchor is subjected to only a shear load. No tension load acts on the anchor; therefore, neither nominal concrete breakout strength (N_{cb}) nor nominal bond strength (N_a) are considered as tension design parameters, but a pryout parameter "N_{cp}" corresponding to the smaller of N_{cb} calculated per Eq. (17.4.2.1a) and N_a calculated per Eq. (17.4.5.1a) is considered. adhesive anchor systems No tension load applied: N_{cb} and $N_a = 0$. Shear load applied, so calculate concrete breakout pryout ($k_{cp} N_{cp}$). adhesive anchor system: $V_{cp} = k_{cp} \text{MIN} \{N_{cb} ; N_a\}$.  Reference the Variables section of the PROFIS Engineering report for information on: k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic bond strength in tension

PART 4 SHEAR LOAD / Pryout Failure Mode (Pryout Bond)

Equation V_{cpg}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cpg} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Na0}} \right) \psi_{ec1,Na} \psi_{ec2,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \right]$	17.5.3.1 The nominal pryout strength, ... V_{cpg} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, ... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{cn} \psi_{cp,Na} N_{ba} \quad (17.4.2.1b)$ 17.4.5.1 The nominal bond strength in tension..... N_{ag} of a group of adhesive anchors, shall not exceed (b) For a group of adhesive anchors: $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ Summary of ACI 318-14 adhesive anchor system pryout calculations: $V_{cpg} = k_{cp} \text{ MIN } \{ N_{cbg} ; N_{ag} \}.$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. When designing post-installed adhesive anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a group of anchors (V_{cpg}) as the product of the coefficient for pryout strength (k_{cp}) and the smaller of N_{cbg} calculated per Eq. (17.4.2.1b) and N_{ag} calculated per Eq. (17.4.5.1b). Nominal pryout strength for an anchor group (N_{cpg}) is predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. For the example illustrated below, four anchors are subjected to a tension load, but all six anchors are subjected to a shear load. Therefore, with respect to tension, concrete breakout (N_{cbg}) and bond strength (N_{ag}) are calculated for anchors 1,2,3 and 4; but with respect to shear, a pryout parameter "N_{cpg}" corresponding to the lesser of N_{cbg} and N_{ag} is calculated for anchors 1,2,3,4,5 and 6.

Equation V_{cpg} (continued)

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cpg} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Na0}} \right) \psi_{ec1,Na} \psi_{ec2,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \right]$		anchors in red are in shear assumed area of influence for pryout (concrete breakout) assumed area of influence for pryout (bond) Reference the Variables section of the PROFIS Engineering report for information on: k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for information on: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ec1,Na}$: Modification factor for eccentricity in x direction $\psi_{ec2,Na}$: Modification factor for eccentricity in y direction $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_{ba}: Basic bond strength in tension

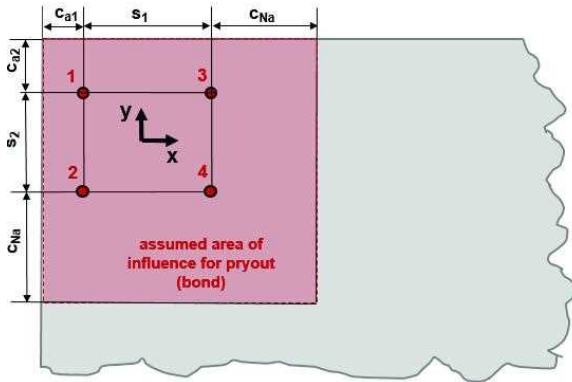
Equation ϕV_{cp}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cp}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Single Anchor $\phi V_{cp} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic shear ϕV_{cp}: Design concrete pryout strength in shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

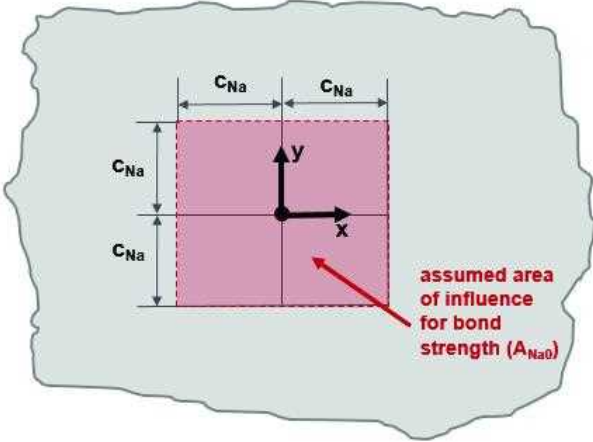
Equation ϕV_{cpg}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cpg}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Anchors as a Group $\phi V_{cpg} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cpg}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic shear ϕV_{cpg}: Design concrete pryout strength in shear V_{ua}: factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

Equation A_{Na}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Na}	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors..... 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor or N_{ag} of a group of adhesive anchors, shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$ (b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ 	When calculating the nominal concrete pryout strength in shear (V_{cp} or $V_{cp\gamma}$), the parameter A_{Na} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor or a group of anchors creates a prying (i.e. tension) action on the anchor(s). A_{Na} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Na} is defined by projected distances from the anchors that are in shear. The maximum projected distance from an anchor that is considered when calculating A_{Na} is limited to the parameter “c_{Na}”. Therefore, the maximum edge distance parameter used to calculate A_{Na} equals c_{Na} and the maximum spacing parameter used to calculate A_{Na} equals $2.0c_{Na}$. The figure below illustrates how A_{Na} is calculated for pryout when a shear load acts on a group of four anchors with fixed edge distances equal to c_{a1} and c_{a2}, and spacing parameters equal to s_1 and s_2. Note that the maximum edge distance parameter used to calculate A_{Na} equals c_{Na}. Anchors spaced greater than $2.0c_{Na}$ from one another would not be considered to act as a group with respect to that spacing.  $A_{Na} = (c_{a1} + s_1 + c_{Na}) (c_{a2} + s_2 + c_{Na})$ where: c_{a1} and c_{a2} are $\leq c_{Na}$ s_1 and s_2 are $\leq 2.0c_{Na}$ It is important to understand that “A_{Na}” calculated for bond failure in tension is not necessarily the same as “A_{Na}” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Calculations section of the PROFIS Engineering report for more information on c_{Na} and A_{Na}.

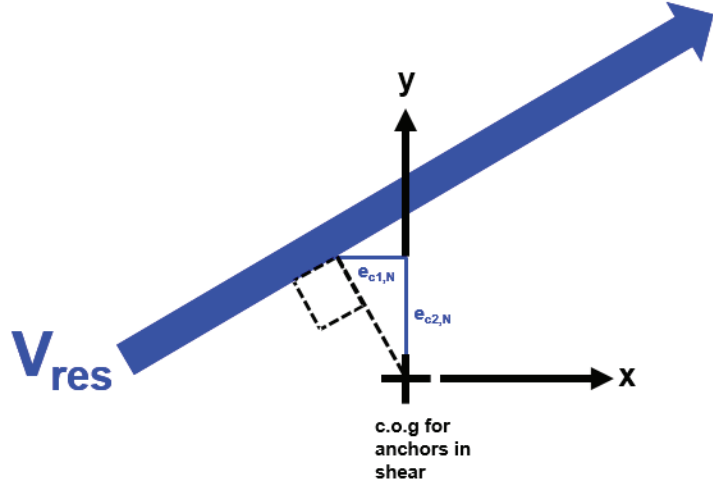
Equation A_{Na0}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$A_{Na0} = (2c_{Na})^2$	17.4.5.1 A_{Na0} is the projected influence area of a single anchor with an edge distance equal to or greater than c_{Na} : $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and constant 1100 carries the unit of lb/in². 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor or N_{ag} of a group of adhesive anchors, shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$ (b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ 	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Na0} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor without the influence of any fixed edges creates a prying (i.e. tension) action on the anchor. A_{Na0} is calculated with the parameter “c_{Na}”, which is defined in ACI 318-14 Chapter 2 as the “projected distance from center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor”. The geometry for A_{Na0} is defined by a projected distance of c_{Na} from the anchor in the x and y directions. The figure below illustrates how A_{Na0} is calculated.  $A_{Na0} = (c_{Na} + c_{Na}) (c_{Na} + c_{Na})$$= (2.0 c_{Na})^2$ Reference the Calculations section of the PROFIS Engineering report for more information on c_{Na} and A_{Na0}.

Equation C_{Na}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}}$	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors.....A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na} . $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in².	ACI 318-14 Chapter 17 bond strength calculations are predicated on the parameter “c_{Na}”, which is defined in Chapter 2 as the “projected distance from the center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor”. c_{Na} is calculated per Equation (17.4.5.1d). The parameter “d_a” corresponds to the diameter of the anchor element selected for the PROFIS Engineering application being modeled. The parameter “τ_{uncr}” corresponds to the characteristic bond stress in uncracked concrete of the adhesive product selected for the PROFIS Engineering application being modeled. The modification factor A_{Na} accounts for the area of influence assumed to develop with respect to bond failure, for the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. Per the provisions for A_{Na} given in Section 17.4.5.1, PROFIS Engineering limits the geometry used to define A_{Na} to a maximum projected distance from an anchor of c_{Na}. A_{Na0} is a modification factor that accounts for the area of influence assumed to develop in concrete, with respect to bond failure, when a prying (i.e. tension) load is applied to a single anchor without the influence of any fixed edges. Per the provisions for A_{Na0} given in Section 17.4.5.1, PROFIS Engineering defines the geometry for A_{Na0} as a projected distance of “c_{Na}” from the anchor in the +x, -x, +y and -y directions. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: d_a: Diameter of anchor element τ_{uncr}: Characteristic bond stress of an adhesive anchor in uncracked concrete Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence modification factor A_{Na0}: Idealized area of influence modification factor for a single anchor c_{Na}: Projected distance from the center of an adhesive anchor

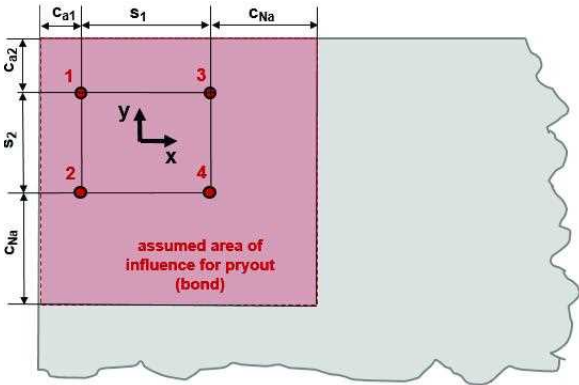
Equation $\psi_{ec,Na}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{C_{Na}}\right)} \leq 1.0$	17.5.3.1 The nominal pryout strength, ... V_{cp} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cp} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.5.1 The nominal bond strength in tension..... N_{ag} of a group of adhesive anchors, shall not exceed: (b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1 b)$ 17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{C_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	Concrete pryout strength for a group of anchors in shear (V_{cp}) is calculated per Eq. (17.5.3.1b). The parameter "N_{cp}" in this equation corresponds to the nominal bond strength (N_{ag}), calculated per Eq. (17.4.5.1b), but with respect to concrete pryout failure. It is important to understand that "N_{ag}" calculated for bond failure in tension is not necessarily the same as "N_{ag}" calculated for concrete pryout failure in shear. Reasons for this can include: • The number of anchors in tension is not the same as the number of anchors in shear • The tension load may be eccentric with the anchors in tension but the shear load may not be eccentric with the anchors in shear • The shear load may be eccentric with the anchors in shear but the tension load may not be eccentric with the anchors in tension • Tension and shear eccentricities are not necessarily equal When considering concrete pryout failure, the parameter "$\psi_{ec,Na}$" in Eq. (17.4.5.1b) is a modification factor that accounts for shear load eccentricity. Therefore, when calculating the nominal concrete pryout strength in shear using Eq. (17.4.5.1b), the parameter $\psi_{ec,Na}$ accounts for a resultant shear load that is eccentric with respect to the centroid of the anchors that are loaded in shear. $\psi_{ec,Na}$ is only considered for an anchor group loaded in shear when calculating the nominal concrete pryout strength (V_{cp}). The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cp}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$". 

Equation $\psi_{ec,Na}$ (continued)

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)}$		If shear eccentricity exists in more than one direction, PROFIS Engineering calculates a ψ-modification factor for each direction using Eq. (17.4.5.3). PROFIS Engineering designates the ψ-modification factor for eccentricity in the x-direction “$\psi_{ec1,Na}$”, and the ψ-modification factor for eccentricity in the y-direction “$\psi_{ec2,Na}$”. Per Section 17.4.5.3, PROFIS Engineering uses the product of these modification factors in Eq. (17.4.5.1b) to calculate the pryout parameter (N_{cpb}) per Eq. (17.5.3.1b) when shear eccentricity exists in both the x and y directions. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for shear eccentricity with respect to the x direction $e_{c2,N}$: Parameter for shear eccentricity with respect to the y direction Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: c_{Na}: Edge distance parameter for adhesive anchors $\psi_{ec1,Na}$: Modification factor for shear eccentricity with respect to the x direction $\psi_{ec2,Na}$: Modification factor for shear eccentricity with respect to the y direction

Equation $\psi_{ed,Na}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \leq 1.0$	17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) If $c_{a,min} < c_{Na}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b) 17.4.5.1..... $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in².	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter $\psi_{ed,Na}$ is a modification factor that accounts for fixed edge distances less than c_{Na}, where c_{Na} corresponds to a calculated value representing a projected distance from the center of an adhesive anchor. The illustration below shows how the assumed area of influence with respect to pryout (A_{Na}) would be defined for an anchoring application being modeled with two fixed edges (c_{a1} and c_{a2}) that are both less than c_{Na}, and with c_{a1} being less than c_{a2}. The smallest edge distance (c_{a1}) corresponds to the parameter $c_{a,min}$, and would be used to calculate the modification factor $\psi_{ed,Na}$.  $\psi_{ed,Na} = 0.7 + 0.3 (c_{a1} / c_{Na})$ It is important to understand that “$\psi_{ed,Na}$” calculated for bond failure in tension is not necessarily the same as “$\psi_{ed,Na}$” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Variables section of the PROFIS Engineering report for more information on the following parameter: $c_{a,min}$: Parameter for the smallest fixed edge being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: c_{Na}: Edge distance parameter for adhesive anchors $\psi_{ed,Na}$: Modification factor for edge distance

Equation $\psi_{cp,Na}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering								
$\psi_{cp,Na} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}} \right) \leq 1.0$	17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}}$ (17.4.5.5b) but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0. 17.4.5.1..... $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². 17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors.....</td><td>.2h_{ef}</td></tr><tr><td>Undercut anchors.....</td><td>.2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors.....</td><td>.4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchor.....</td><td>.4h_{ef}</td></tr></table>	Adhesive anchors.....	.2h_{ef}	Undercut anchors.....	.2.5h_{ef}	Torque-controlled expansion anchors.....	.4h_{ef}	Displacement-controlled expansion anchor.....	.4h_{ef}	When calculating the nominal concrete pryout strength in shear (V_{cp} or $V_{cp,g}$), the parameter $\psi_{cp,Na}$ is a modification factor that considers splitting failure for an adhesive anchor. Since ACI 318 anchoring-to-concrete provisions do not specifically consider concrete splitting as a failure mode, splitting is addressed through the $\psi_{cp,Na}$ modification factor. The parameter $\psi_{cp,Na}$ is only considered when designing adhesive anchors installed in uncracked concrete. Splitting failure will typically not occur for cast-in-place anchors, and is not considered in PROFIS Engineering when these anchors are being modeled. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\psi_{cp,Na}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” $\psi_{cp,Na}$ does not need to be calculated if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}, or if cracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR. ACI 318-14 Section 17.7.6 provides c_{ac}-values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the c_{ac}-value that is given in the ICC-ES evaluation report for an adhesive anchor to calculate $\psi_{cp,Na}$. The value for $\psi_{cp,Na}$ that PROFIS Engineering calculates will be limited to MAXIMUM { $c_{a,min}/c_{ac} : c_{Na}/c_{ac}$ } where $c_{a,min}$ is the smallest fixed edge distance being modeled in the application and c_{Na} is the adhesive anchor edge distance parameter calculated per Eq. (17.4.5.1d) for the adhesive anchor being modeled. It is important to understand that “$\psi_{cp,Na}$” calculated for bond failure in tension is not necessarily the same as “$\psi_{cp,Na}$” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled c_{ac}: Value derived from testing per AC308/ACI 355.4 for the adhesive anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: c_{Na}: Edge distance parameter for adhesive anchors $\psi_{cp,Na}$: Modification factor for uncracked concrete
Adhesive anchors.....	.2h_{ef}									
Undercut anchors.....	.2.5h_{ef}									
Torque-controlled expansion anchors.....	.4h_{ef}									
Displacement-controlled expansion anchor.....	.4h_{ef}									

Equation N_{ba}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering															
$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. Where analysis indicates cracking at service load levels, adhesive anchors shall be shown compliance for use in cracked concrete in accordance with ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{uncr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age of 21 days (e) Concrete temperature at time of installation shall be at least 50°F Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1][2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), and the anchor element geometry (πd_a and h_{ef}), where d_a corresponds to the nominal diameter of the anchor element and h_{ef} corresponds to the effective embedment depth that has been input into PROFIS Engineering for the selected anchor element. Equation (17.4.5.2) also includes a modification factor for lightweight concrete (λ_a). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist. Concrete is typically assumed to crack under normal service load conditions. If cracked concrete conditions are assumed, the characteristic bond stress for cracked concrete (τ_{cr}) is used to calculate N_{ba}. If uncracked concrete conditions are assumed, the characteristic bond stress for uncracked concrete (τ_{uncr}) is used to calculate N_{ba}. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR and are designated "$\tau_{k,cr}$", corresponding to the characteristic bond stress in cracked concrete, and "$\tau_{k,uncr}$", corresponding to the characteristic bond stress in uncracked concrete. The values given in Table 17.4.5.2 for "τ_{cr}" or "τ_{uncr}" are intended to be used as guide values in the absence of product-specific data. PROFIS Engineering uses the $\tau_{k,cr}$ and $\tau_{k,uncr}$ values given in the ICC-ES evaluation report for the adhesive anchor that has been selected to calculate N_{ba}. Although noted in the ICC-ESR as a "strength", $\tau_{k,cr}$ and $\tau_{k,uncr}$ are stress parameters having units of psi. The parameter "$\alpha_{N,seis}$" is a seismic reduction factor derived from testing per AC308/ACI 354, and is also given in the anchor ICC-ESR. The PROFIS Engineering report includes $\alpha_{N,seis}$ as a parameter used to calculate N_{ba}. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxxx}$: Characteristic bond stress for cracked or uncracked concrete $\alpha_{N,seis}$: Seismic modification factor d_a: Anchor element diameter h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi													
Outdoor	Dry to fully saturated	175	200	650													
Indoor	Dry	110	300	1000													

Equation N_{ba} (continued)

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																			
$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$	Example: Example of a table in an ICC-ESR showing characteristic bond stress values (τ_{kcr} and $\tau_{k,un-cr}$) and the seismic reduction value $\alpha_{N,seis}$. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191.00)</td><td>10 (254.00)</td><td>12-1/2 (318.00)</td><td>15 (381.00)</td><td>17-1/5 (445.00)</td><td>20 (508.00)</td><td>25 (635.00)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.10)</td><td>1260 (8.70)</td><td>1290 (8.90)</td><td>1325 (9.10)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,un-cr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,un-cr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.90)</td><td>930 (6.40)</td><td>960 (6.60)</td><td>1035 (7.10)</td><td>1055 (7.30)</td><td>1085 (7.50)</td><td>1130 (7.80)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,un-cr}$</td><td>psi (Mpa)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.00</td><td>1.00</td><td>1.00</td><td>1.00</td><td>0.97</td><td>1.00</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191.00)	10 (254.00)	12-1/2 (318.00)	15 (381.00)	17-1/5 (445.00)	20 (508.00)	25 (635.00)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.10)	1260 (8.70)	1290 (8.90)	1325 (9.10)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,un-cr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,un-cr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.90)	930 (6.40)	960 (6.60)	1035 (7.10)	1055 (7.30)	1085 (7.50)	1130 (7.80)	Characteristic bond strength in uncracked concrete	$\tau_{k,un-cr}$	psi (Mpa)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.00	1.00	1.00	1.00	0.97	1.00	
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in.)																																																																																																													
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Variables k_{cp}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
k_{cp}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b). In Eq. (17.5.3.1a) and (17.5.3.1b), $k_{cp} = 1.0$ for $h_{ef} < 2.5$ in.; and $k_{cp} = 2.0$ for $h_{ef} \geq 2.5$ in.	The parameter "k_{cp}" is defined in ACI 318-14 as the "coefficient for pryout strength". The commentary R17.5.3.1 states: ".....the pryout shear resistance can be approximated as one to two times the anchor tensile resistance with the lower value appropriate for h_{ef} less than 2.5 in." PROFIS Engineering applies k_{cp} per Section 17.5.3.1 for the cast-in anchors and post-installed anchors in its portfolio.

Variables $\tau_{k,uncr}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\tau_{k,uncr}$	17.4.5.1 where $c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{uncr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age of 21 days (e) Concrete temperature at time of installation shall be at least 50°F	The parameter "τ_{uncr}" corresponds to the characteristic bond stress in uncracked concrete. It is used to calculate the parameter "c_{Na}", which is defined in ACI 318-14 Equation (17.4.5.1d). If uncracked concrete conditions are assumed, τ_{uncr} is also used to calculate the parameter "N_{ba}", which is defined in ACI 318-14 Equation (17.4.5.2). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist; however, c_{Na} is always calculated using τ_{uncr} regardless of whether cracked or uncracked concrete conditions are assumed. N_{ba} can be calculated for either cracked or uncracked concrete conditions. PROFIS Engineering calculates c_{Na} and N_{ba} using the characteristic bond stress values given in the ICC-ESR for the adhesive anchor system. The ICC-ESR designates the ACI 318 parameter "τ_{uncr}" as "$\tau_{k,uncr}$" and the PROFIS Engineering report designates "τ_{uncr}" as "$\tau_{k,c,uncr}$". Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR. Values designated "$\tau_{k,uncr}$" in the ICC-ESR correspond to the characteristic bond stress in uncracked concrete. The values designated "τ_{uncr}" in ACI 318-14 Table 17.4.5.2 are intended to be used as guide values in the absence of product-specific data. When uncracked concrete conditions are assumed, PROFIS Engineering uses the $\tau_{k,uncr}$ values given in the ICC-ESR for adhesive anchor bond strength calculations. Although noted in the ICC-ESR as a "strength", $\tau_{k,uncr}$ is stress parameter having units of psi.

Variables $\tau_{k,uncr}$ (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																							
$\tau_{k,uncr}$	Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1] [2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4. Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,cr}$ and $\tau_{k,uncr}$). ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191.00)</td><td>10 (254.00)</td><td>12-1/2 (318.00)</td><td>15 (381.00)</td><td>17-1/5 (445.00)</td><td>20 (508.00)</td><td>25 (635.00)</td></tr><tr><td rowspan="2">Temperature Range A¹</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.10)</td><td>1260 (8.70)</td><td>1290 (8.90)</td><td>1325 (9.10)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.90)</td><td>930 (6.40)</td><td>960 (6.60)</td><td>1035 (7.10)</td><td>1055 (7.30)</td><td>1085 (7.50)</td><td>1130 (7.80)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191.00)	10 (254.00)	12-1/2 (318.00)	15 (381.00)	17-1/5 (445.00)	20 (508.00)	25 (635.00)	Temperature Range A ¹	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.10)	1260 (8.70)	1290 (8.90)	1325 (9.10)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.90)	930 (6.40)	960 (6.60)	1035 (7.10)	1055 (7.30)	1085 (7.50)	1130 (7.80)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	$\tau_{k,uncr}$-values in the ICC-ESR are relevant to testing in concrete having a compressive strength of 2500 psi. These values can be increased for compressive strengths $2500 \text{ psi} < f'_c \leq 8000 \text{ psi}$ using the factor noted in the bond strength table footnotes. PROFIS Engineering increases the $\tau_{k,uncr}$-values by this factor when concrete compressive strengths $> 2500 \text{ psi}$ are being modeled. $\tau_{k,uncr}$-values in the ICC-ESR are also dependent on the “temperature range” corresponding to “long term” and “short term” concrete temperatures. The ICC-ESR defines “long term” concrete temperatures as being “roughly constant” over time. “Short term” concrete temperatures are elevated temperatures “that occur over brief intervals”. Both types of temperature are relevant to the concrete temperature during the service life of the anchor, not the concrete temperature at the time anchors are installed. Long term and short term temperature ranges are defined in footnotes for the bond strength tables of an adhesive anchor ICC-ESR. $\tau_{k,uncr}$-values corresponding to a particular temperature range are given in the bond strength table. Reference the Variables section of the PROFIS Engineering report for more information on: $\tau_{k,c}$: Characteristic bond stress in cracked concrete Reference the Calculations section of the PROFIS Engineering report for more information on: c_{Na}: Projected distance from an adhesive anchor N_{ba}: Basic bond strength for a single adhesive anchor
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi																																																																																																																					
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Variables $\tau_{k,c}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering															
$\tau_{k,c}$	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{uncr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. It shall be permitted to use the minimum characteristic bond stress values in Table 17.4.5.2 provided (a) through (e) are satisfied: (a) Anchors shall meet the requirements of ACI 355.4 (b) Anchors shall be installed in holes drilled with a rotary impact drill or rock drill (c) Concrete at time of anchor installation shall have a minimum compressive strength of 2500 psi (d) Concrete at time of anchor installation shall have a minimum age of 21 days (e) Concrete temperature at time of installation shall be at least 50°F Table 17.4.5.2 — Minimum characteristic bond stresses ^{[1] [2]} <table><tr><th>Installation and service environment</th><th>Moisture content of concrete at time of anchor installation</th><th>Peak in-service temperature of concrete °F</th><th>τ_{cr} psi</th><th>τ_{uncr} psi</th></tr><tr><td>Outdoor</td><td>Dry to fully saturated</td><td>175</td><td>200</td><td>650</td></tr><tr><td>Indoor</td><td>Dry</td><td>110</td><td>300</td><td>1000</td></tr></table> [1] Where anchor design includes sustained tension loading, multiply values of τ_{cr} and τ_{uncr} by 0.4. [2] Where design includes earthquake loads for structures assigned to SDC C, D, E, or F, multiply values of τ_{cr} by 0.8 and τ_{uncr} by 0.4.	Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi	Outdoor	Dry to fully saturated	175	200	650	Indoor	Dry	110	300	1000	The parameter “τ_{cr}” corresponds to the characteristic bond stress in cracked concrete. If cracked concrete conditions are assumed, τ_{cr} is used to calculate the parameter “N_{ba}”, which is defined in ACI 318-14 Equation (17.4.5.2). ACI 318 anchoring-to-concrete provisions default to a design assumption that cracked concrete conditions exist. N_{ba} can be calculated for either cracked or uncracked concrete conditions. PROFIS Engineering calculates N_{ba} using the characteristic bond stress values given in the ICC-ESR for the adhesive anchor system. The ICC-ESR designates the ACI 318 parameter “τ_{cr}” as “$\tau_{k,cr}$” and the PROFIS Engineering report designates “τ_{cr}” as “$\tau_{k,c}$”. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive characteristic bond stress values for adhesive anchor systems. Values derived from this testing are provided in an ICC-ESR. Values designated “$\tau_{k,cr}$” in the ICC-ESR correspond to the characteristic bond stress in cracked concrete. The values designated “τ_{cr}” in ACI 318-14 Table 17.4.5.2 are intended to be used as guide values in the absence of product-specific data. When cracked concrete conditions are assumed, PROFIS Engineering uses the $\tau_{k,cr}$ values given in the ICC-ESR for adhesive anchor bond strength calculations. Although noted in the ICC-ESR as a “strength”, $\tau_{k,cr}$ is stress parameter having units of psi. $\tau_{k,cr}$ -values in the ICC-ESR are relevant to testing in concrete having a compressive strength of 2500 psi. These values can be increased for compressive strengths 2500 psi < $f'_c \leq 8000$ psi using the factor noted in the bond strength table footnotes. PROFIS Engineering increases the $\tau_{k,cr}$ -values by this factor when concrete compressive strengths > 2500 psi are being modeled. $\tau_{k,cr}$ -values in the ICC-ESR are also dependent on the “temperature range” corresponding to “long term” and “short term” concrete temperatures. The ICC-ESR defines “long term” concrete temperatures as being “roughly constant” over time. “Short term” concrete temperatures are elevated temperatures “that occur over brief intervals”. Both types of temperature are relevant to the concrete temperature during the service life of the anchor, not the concrete temperature at the time anchors are installed. Long term and short term temperature ranges are defined in footnotes for the bond strength tables of an adhesive anchor ICC-ESR. $\tau_{k,cr}$ -values corresponding to a particular temperature range are given in the bond strength table. Reference the Variables section of the PROFIS Engineering report for more information on: $\tau_{k,c,uncr}$: Characteristic bond stress in uncracked concrete Reference the Calculations section of the PROFIS Engineering report for more information on: N_{ba}: Basic bond strength for a single adhesive anchor
Installation and service environment	Moisture content of concrete at time of anchor installation	Peak in-service temperature of concrete °F	τ_{cr} psi	τ_{uncr} psi													
Outdoor	Dry to fully saturated	175	200	650													
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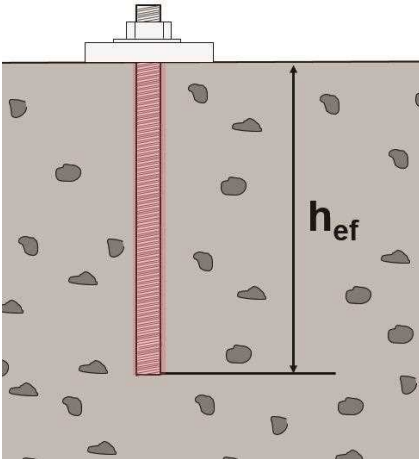
Variables $\tau_{k,c}$ (continued)

Variables	318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																	
$\tau_{k,c}$	Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,cr}$ and $\tau_{k,un-cr}$). ICC-ESR-3187 Table 14 <table> <tr> <th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr> <tr> <th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th><th></th></tr> <tr> <td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td><td></td></tr> <tr> <td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191.00)</td><td>10 (254.00)</td><td>12-1/2 (318.00)</td><td>15 (381.00)</td><td>17-1/5 (445.00)</td><td>20 (508.00)</td><td>25 (635.00)</td><td></td></tr> <tr> <td rowspan="2">Temperature Range A¹</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.10)</td><td>1260 (8.70)</td><td>1290 (8.90)</td><td>1325 (9.10)</td><td>1380 (9.50)</td><td></td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,un-cr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td></td></tr> <tr> <td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td><td></td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,un-cr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td></td></tr> <tr> <td rowspan="2">Temperature Range C³</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.90)</td><td>930 (6.40)</td><td>960 (6.60)</td><td>1035 (7.10)</td><td>1055 (7.30)</td><td>1085 (7.50)</td><td>1130 (7.80)</td><td></td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,un-cr}$</td><td>psi (Mpa)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td></td></tr> </table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time										DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4		Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127		Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191.00)	10 (254.00)	12-1/2 (318.00)	15 (381.00)	17-1/5 (445.00)	20 (508.00)	25 (635.00)		Temperature Range A ¹	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.10)	1260 (8.70)	1290 (8.90)	1325 (9.10)	1380 (9.50)		Characteristic bond strength in uncracked concrete	$\tau_{k,un-cr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)		Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)		Characteristic bond strength in uncracked concrete	$\tau_{k,un-cr}$	psi (Mpa)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)	2220 (15.30)		Temperature Range C ³	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.90)	930 (6.40)	960 (6.60)	1035 (7.10)	1055 (7.30)	1085 (7.50)	1130 (7.80)		Characteristic bond strength in uncracked concrete	$\tau_{k,un-cr}$	psi (Mpa)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)	1820 (12.60)		
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Variables d_a

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																			
d_a	17.4.5.1 where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad (17.4.5.1d)$ and the constant 1100 carries the unit of lb/in². 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ Example: Example of a bond strength table in an ICC-ESR showing parameters that are dependent on the anchor element diameter ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191.00)</td><td>10 (254.00)</td><td>12-1/2 (318.00)</td><td>15 (381.00)</td><td>17-1/5 (445.00)</td><td>20 (508.00)</td><td>25 (635.00)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.10)</td><td>1260 (8.70)</td><td>1290 (8.90)</td><td>1325 (9.10)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td><td>2220 (15.30)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.90)</td><td>930 (6.40)</td><td>960 (6.60)</td><td>1035 (7.10)</td><td>1055 (7.30)</td><td>1085 (7.50)</td><td>1130 (7.80)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td><td>1820 (12.60)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.00</td><td>1.00</td><td>1.00</td><td>1.00</td><td>0.97</td><td>1.00</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. 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Therefore, d_a corresponds to the external diameter of an anchor element. d_a is used to calculate the parameter “c_{Na}”, which is defined in ACI 318-14 Equation (17.4.5.1d); and the parameter “N_{ba}”, which is defined in ACI 318-14 Equation (17.4.5.2). Other parameters such as effective embedment depth (h_{ef}), characteristic bond stress (τ_k) and $\alpha_{N,seis}$, which are used in bond strength calculations, are also dependent on the diameter of the anchor element being used. The PROFIS Engineering adhesive anchor portfolio permits bond strength calculations with the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • Specialty anchor elements Information about these anchor element types is given in the ICC-ESR for an adhesive anchor system. PROFIS Engineering uses the anchor diameter parameter referenced in the ICC-ESR bond strength tables for an adhesive anchor system to calculate c_{Na} and N_{ba} for a specific anchor element. When design with a threaded rod or reinforcing bar is selected, PROFIS Engineering uses the nominal diameter of the anchor element to calculate c_{Na} and N_{ba}. When design with Hilti HIS-N and HIS-RN internally threaded inserts is selected, PROFIS Engineering uses the outside diameter of the insert to calculate c_{Na} and N_{ba}. Below are illustrations showing how the parameter d_a for calculating c_{Na} and N_{ba} can be defined for various anchor elements. The parameter “d_{hole}” noted in the illustrations corresponds to the diameter of the drilled hole into which the adhesive product and anchor element are inserted. reinforcing bar threaded rod internally threaded element
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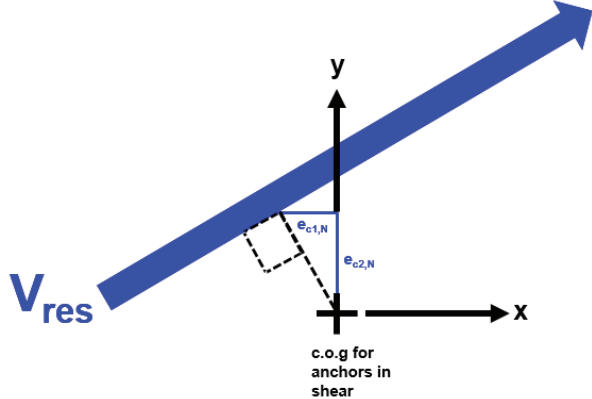
Variables h_{ef}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																								
h_{ef}	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ Example: Example of a table in an ICC-ESR showing effective embedment depth values ($h_{ef,min}$ and $h_{ef,max}$) for threaded rod elements used with an adhesive anchor system. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), the anchor element geometry (πd_a and h_{ef}), and a modification factor for lightweight concrete (λ_a). Adhesive anchor systems tested per the ICC-ES acceptance criteria AC308 can also include an additional seismic modification factor ($\alpha_{N,seis}$). when calculating N_{ba}. h_{ef} is defined as the “effective embedment depth of an anchor”. This parameter corresponds to the embedded portion of the anchor that is “effective” in transferring tension load from the anchor into the concrete. ACI 318-14 Equation (17.4.5.2) includes h_{ef} for calculating N_{ba}. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive product-specific data that is used in ACI 318-14 bond strength calculations for an adhesive anchor system. Data derived from this testing, as well as some of the parameters used to develop this data, are provided in an ICC-ESR. The minimum effective embedment depth ($h_{ef,min}$) derived from this testing is specific to the anchor element (e.g. threaded rod, rebar, internally threaded insert), and to the adhesive product. AC308 limits the maximum effective embedment depth ($h_{ef,max}$) for adhesive anchor systems to a value of 20 times the anchor diameter ($20d_a$). For post-installed adhesive anchors, PROFIS Engineering permits users to input hef values that are within the embedment depth range given in the ICC-ESR for a specific anchor element, diameter, and adhesive product. post-installed adhesive anchor $h_{ef,min} < h_{ef} \leq h_{ef,max}$ where $h_{ef,min}$ and $h_{ef,max}$ ($=20d_a$) are given in the anchor ICC-ESR 
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in.)																																																																																																		
		3/8	1/2	5/8	3/4			7/8	1	1-1/4																																																																																																
Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127																																																																																																
Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)																																																																																																
Temperature Range A ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)																																																																																																
	Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																
Temperature Range B ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)																																																																																																
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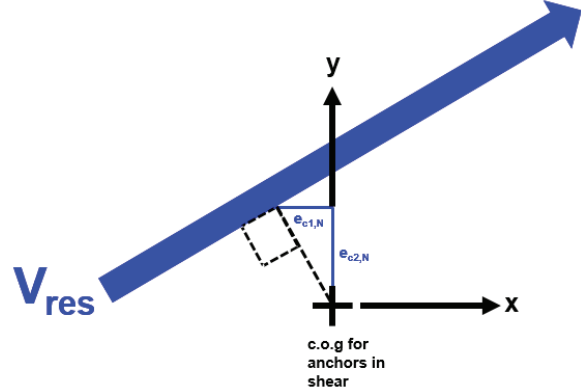
Variables $c_{a,min}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{a,min}$	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors..... 17.4.5.1 A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ 17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) $\text{If } c_{a,min} < c_{Na}, \text{ then } \psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \quad (17.4.5.4b)$ 17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) $\text{If } c_{a,min} < c_{ac}, \text{ then } \psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}} \quad (17.4.5.5b)$ but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0.	$c_{a,min}$ is defined as the “minimum distance from the center of an anchor shaft to the edge of concrete.” When one or more fixed edges are modeled in PROFIS Engineering, the report will show the smallest fixed edge as “$c_{a,min}$” in the Variables section. Excerpted ACI 318-14 anchoring-to-concrete provisions and equations that include $c_{a,min}$ for calculating bond strength in tension are shown to the left. Reference the parameters A_{Na} and A_{Na0} in the Equations section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Distance from the center of an anchor shaft to the edge of concrete in one direction (e.g. the x+ direction). For tension calculations, c_{a1} is the smallest fixed edge distance c_{a2}: Distance from the center of an anchor shaft to the edge of concrete in a direction perpendicular to c_{a1} (e.g. the y+ direction) Reference the parameters $\psi_{ed,Na}$ and $\psi_{cp,Na}$ in the Equations and Calculations sections of the PROFIS Engineering report for more information on how $c_{a,min}$ is used to calculate these parameters.

Variables $e_{c1,N}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c1,N}$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as: $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	$e_{c1,N}$ is a PROFIS Engineering parameter to define pryout eccentricity with respect to the x direction. The value for $e_{c1,N}$ corresponds the distance in the x direction of a resultant shear load from the centroid of anchors that are loaded in shear. When considering concrete pryout strength in shear, PROFIS Engineering uses $e_{c1,N}$ to calculate the ACI 318 modification factor for eccentricity ($\psi_{ec,N}$), and designates this modification factor $\psi_{ec1,N}$ to indicate eccentricity is being considered in the x direction. PROFIS Engineering pryout calculations for shear eccentricity with respect to the x direction are as follows: • Calculate a resultant shear load acting on the anchors • Calculate the distance in the x direction ($e_{c1,N}$) between this load and the centroid of the anchors loaded in shear • Calculate a modification factor for eccentricity ($\psi_{ec1,N}$) with respect to the x direction If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for pryout eccentricity. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cp}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".  Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for pryout eccentricity with respect to the y direction

Variables $e_{c2,N}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c2,N}$	17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as: $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	$e_{c2,N}$ is a PROFIS Engineering parameter to define pryout eccentricity with respect to the y direction. The value for $e_{c2,N}$ corresponds the distance in the y direction of a resultant shear load from the centroid of anchors that are loaded in shear. When considering concrete pryout strength in shear, PROFIS Engineering uses $e_{c2,N}$ to calculate the ACI 318 modification factor for eccentricity ($\psi_{ec,N}$), and designates this modification factor $\psi_{ec2,N}$ to indicate eccentricity is being considered in the y direction. PROFIS Engineering pryout calculations for shear eccentricity with respect to the y direction are as follows: • Calculate a resultant shear load acting on the anchors. • Calculate the distance in the y direction ($e_{c2,N}$) between this load and the centroid of the anchors loaded in shear. • Calculate a modification factor for eccentricity ($\psi_{ec2,N}$) with respect to the y direction. If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for pryout eccentricity. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cp}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".  Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for pryout eccentricity with respect to the x direction

Variables c_{ac}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering								
c_{ac}	17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\Psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\Psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\Psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}}$ (17.4.5.5b) but $\Psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\Psi_{cp,Na}$ shall be taken as 1.0. 17.4.5.1 $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}}$ 17.4.5.1d and the constant 1100 carries the unit of lb/in². 17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors</td><td>.2h_{ef}</td></tr><tr><td>Undercut anchors</td><td>.2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors</td><td>.4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchor</td><td>.4h_{ef}</td></tr></table>	Adhesive anchors	.2h_{ef}	Undercut anchors	.2.5h_{ef}	Torque-controlled expansion anchors	.4h_{ef}	Displacement-controlled expansion anchor	.4h_{ef}	$\Psi_{cp,Na}$ is a modification factor that considers splitting failure for an adhesive anchor when calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}). $\Psi_{cp,Na}$ is only considered when designing adhesive anchors installed in uncracked concrete. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing anchors. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\Psi_{cp,Na}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” Nominal concrete breakout strength in tension (N_{cb} or N_{cbg}) and nominal bond strength (N_a or N_{ag}) are considered when calculating nominal pryout strength in shear. Calculation of these strengths includes the parameter $\Psi_{cp,Na}$ when uncracked concrete conditions are assumed. Therefore, the parameter c_{ac} is also relevant to pryout calculations when uncracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} for adhesive anchor systems is calculated using the effective embedment depth (h_{ef}), and characteristic bond stress in uncracked concrete ($\tau_{k,uncr}$). The c_{ac}-values for post-installed anchors noted in ACI 318-14 Section 17.7.6 are only intended to be used as “guide values” in the absence of c_{ac}-values derived from product-specific testing. PROFIS Engineering always uses the c_{ac}-value that is given (mechanical anchor) or calculated (adhesive anchor system) in the ICC-ES evaluation report for the anchor. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter $\Psi_{cp,Na}$. Reference the Variables section of the PROFIS Engineering report for more information on the parameter h_{ef}. Reference the Variables section of the PROFIS Engineering report for more information on the parameter $\tau_{k,uncr}$.
Adhesive anchors	.2h_{ef}									
Undercut anchors	.2.5h_{ef}									
Torque-controlled expansion anchors	.4h_{ef}									
Displacement-controlled expansion anchor	.4h_{ef}									

Variables c_{ac} (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{ac}	Example of critical edge distance requirements given in an adhesive anchor approval. Reference ICC-ESR-3187 Section 4.1.10.2. 4.1.10.2 Threaded Rod, Steel Reinforcing Bars, and Hilti HIS-N and HIS-RN Inserts: The modification factor $\psi_{cp,Na}$ must be determined in accordance with ACI 318-14 17.4.5.5 or ACI 318-11 D.5.5 as applicable, except as noted below. For all cases where $c_{Na}/c_{ac} < 1.0$, $\psi_{cp,Na}$ determined from ACI 318-14 Eq. 17.4.5.5b or ACI 318-11 Eq. D-27, as applicable, need not be taken less than c_{Na}/c_{ac}. For all other cases $\psi_{cp,Na}$ shall be taken as 1.0. The critical edge distance c_{ac} must be calculated according to Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11, in lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6 as applicable. $c_{ac} = h_{ef} \left(\frac{\tau_{k,uncr}}{1160} \right)^{0.4} * \left[3.1 - 0.7 \frac{h}{h_{ef}} \right]$ (Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11) where $\left[\frac{h}{h_{ef}} \right]$ need not be taken as larger than 2.4; and $\tau_{k,unc}$ is the characteristic bond strength in uncracked concrete, h is the member thickness, and h_{ef} is the embedment depth. $\tau_{k,uncr}$ need not be taken greater than: $\tau_{k,uncr} = \frac{k_{uncr} \sqrt{h_{ef} f'_c}}{\pi_d} \quad \text{Eq. (4-1)}$	

Variables λ_a

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure. 1.0 λ Expansion and adhesive anchor concrete failure. 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ^{[1][2]} <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85^[1]</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33</td><td>0.85 to 1^[2]</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> 1 Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. 2 Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}}{6.7 / f_{cm}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work. 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ^[1]	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ^[2]	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	When calculating nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), λ_a is a modification factor for lightweight concrete that is used to calculate the parameter "N_{ba}" per Eq. (17.4.5.2). Generally speaking, ACI 318 applies a multiplier to the parameter $\sqrt{f'_c}$ to "account for the properties of lightweight concrete", and designates this parameter "λ"; however, λ is also used in the bond strength calculation for N_{ba}. The parameter "λ_a" is a modification of "λ" that specifically "accounts for the properties of lightweight concrete" with respect to anchoring-to-concrete calculations, hence the subscript "a" in "λ_a". Per Section 17.2.6, the modification factor λ, determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the type of anchor being used, to obtain the parameter λ_a. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. For post-installed anchor design, PROFIS Engineering uses a λ_a-value as referenced in the ICC-ESR provisions for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. Per ACI 318 provisions for determining λ_a, when designing post-installed adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.6 (adhesive anchor bond failure), for the λ_a-value to calculate N_{ba}. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_{ba}.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ^[1]																		
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Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ^[2]																		
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Variables $\alpha_{N,seis}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																			
$\alpha_{N,seis}$	ACI 318-14 equation for calculating N_{ba}: 17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ PROFIS Engineering equation for calculating N_{ba}: $N_{ba} = \lambda_a \tau_{k,c} \alpha_{N,seis} \pi d_a h_{ef}$ Example: Example of a table in an ICC-ESR showing the seismic modification factor $\alpha_{N,seis}$. ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr><tr><td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr><tr><td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F; Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F; Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F; Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.	DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127	Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	$\alpha_{N,seis}$ is a seismic modification factor that is used to calculate the basic bond strength of an adhesive anchor (N_{ba}). Values for $\alpha_{N,seis}$ are derived from testing per the ICC-ES acceptance criteria AC308. $\alpha_{N,seis}$-values are specific to the adhesive product, the anchor element being used with that product, and the anchor element diameter. Values for $\alpha_{N,seis}$ are given in the ICC-ESR for an adhesive anchor system. The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), and the anchor element geometry (πd_a and h_{ef}), where d_a corresponds to the nominal diameter of the anchor element and h_{ef} corresponds to the effective embedment depth that has been input into PROFIS Engineering for the selected anchor element. Calculation of N_{ba} also includes a modification factor for lightweight concrete (λ_a). Adhesive anchor systems can be shown compliance under the International Building Code (IBC) via testing per AC308. AC308 references the ACI test standard for qualifying adhesive anchor systems (ACI 355.4), but ACI 355.4 does not include any provisions for determining $\alpha_{N,seis}$. Since ACI 355.4 does not reference $\alpha_{N,seis}$, ACI 318 anchoring-to-concrete provisions do not reference $\alpha_{N,seis}$. However, since AC308 does include provisions for determining $\alpha_{N,seis}$, adhesive anchor systems shown compliance per AC308 to receive recognition under the IBC include $\alpha_{N,seis}$ as a parameter for calculating N_{ba}. PROFIS Engineering uses the $\alpha_{N,seis}$-values given in the ICC-ESR for an adhesive anchor system to calculate N_{ba}. The PROFIS Engineering report therefore shows $\alpha_{N,seis}$ in the Variables section, and as a parameter for calculating N_{ba} in the Equations section. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxxx}$: Characteristic bond stress for cracked or uncracked concrete d_a: Anchor element diameter h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
DESIGN INFORMATION						Symbol	Units	Nominal Rod Diameter (in.)																																																																																																													
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	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																											
Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)																																																																																																											
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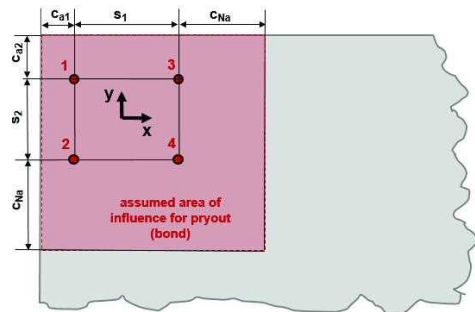
Variables c_{Na}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{Na}	17.4.5.1 A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors.....A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na}. $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². 17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as: $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ 17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) If $c_{a,min} < c_{Na}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b) 17.4.5.5 The modification factor for adhesive anchors designed for uncracked concrete in accordance with 17.4.5.2 without supplementary reinforcement to control splitting, $\psi_{cp,Na}$, shall be calculated as: If $c_{a,min} \geq c_{ac}$, then $\psi_{cp,Na} = 1.0$ (17.4.5.5a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,Na} = \frac{c_{a,min}}{c_{ac}}$ (17.4.5.5b) but $\psi_{cp,Na}$ determined from Eq. (17.4.5.5b) shall not be taken less than c_{Na}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, $\psi_{cp,Na}$ shall be taken as 1.0.	ACI 318-14 Chapter 17 bond strength calculations are predicated on the parameter "c_{Na}", which is defined in Chapter 2 as the "projected distance from the center of an anchor shaft on one side of the anchor required to develop the full bond strength of a single adhesive anchor". c_{Na} is calculated per Equation (17.4.5.1d). The parameter "d_a" corresponds to the diameter of the anchor element selected for the PROFIS Engineering application being modeled. The parameter "τ_{uncr}" corresponds to the characteristic bond stress in uncracked concrete of the adhesive product selected for the PROFIS Engineering application being modeled. The modification factor A_{Na} accounts for the area of influence assumed to develop with respect to bond failure, for the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. Per the provisions for A_{Na} given in Section 17.4.5.1, PROFIS Engineering limits the geometry used to define A_{Na} to a maximum projected distance from an anchor of c_{Na}. c_{Na} is also used to calculate the following bond strength parameters: A_{Na0}: modification factor for the idealized area of influence assumed to develop in concrete, with respect to bond failure, for a single anchor without any edge influences. Reference Equation (17.4.5.1c) $\psi_{ec,Na}$: modification factor for an eccentric tension load acting on a group of anchors. Reference Section 17.4.5.3 $\psi_{ed,Na}$: modification factor for a fixed edge distance less than c_{Na}. Reference Section 17.4.5.4 $\psi_{cp,Na}$: modification factor to consider splitting failure. Reference Section 17.4.5.5 Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: d_a: Diameter of anchor element τ_{uncr}: Characteristic bond stress of an adhesive anchor in uncracked concrete Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence modification factor A_{Na0}: Idealized area of influence modification factor for a single anchor $\psi_{ec,Na}$: Modification factor for tension eccentricity $\psi_{ed,Na}$: Modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting

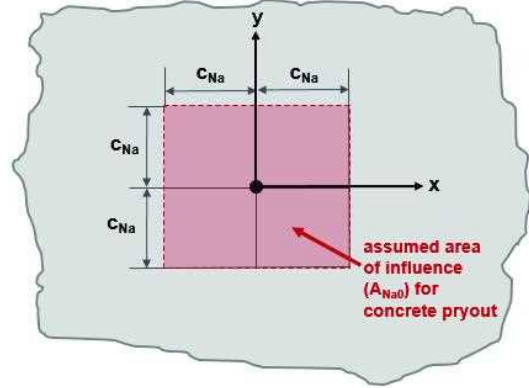
Variables c_{Na} (continued)

Variables	318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																																																																																											
c_{Na}	Example: Example of a bond strength table in an ICC-ESRshowing characteristic bond stress values ($\tau_{k,uncr}$) that could be used to calculate c_{Na} for a given anchor diameter (d_a) using Eq. (17.4.5.1d). ICC-ESR-3187 Table 14 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal Rod Diameter (in).</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>5</td></tr><tr><td colspan="2"></td><td></td><td>(mm)</td><td>60</td><td>70</td><td>79</td><td>89</td><td>89</td><td>102</td><td>127</td></tr><tr><td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/5</td><td>20</td><td>25</td></tr><tr><td colspan="2"></td><td></td><td>(mm)</td><td>(191)</td><td>(254)</td><td>(318)</td><td>(381)</td><td>(445)</td><td>(508)</td><td>(635)</td></tr><tr><td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi</td><td>1045</td><td>1135</td><td>1170</td><td>1260</td><td>1290</td><td>1325</td><td>1380</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(7.2)</td><td>(7.8)</td><td>(8.1)</td><td>(8.7)</td><td>(8.9)</td><td>(9.1)</td><td>(9.5)</td></tr><tr><td rowspan="2"></td><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td></tr><tr><td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi</td><td>1045</td><td>1135</td><td>1170</td><td>1260</td><td>1290</td><td>1325</td><td>1380</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(7.20)</td><td>(7.80)</td><td>(8.00)</td><td>(8.67)</td><td>(9.00)</td><td>(9.00)</td><td>(9.50)</td></tr><tr><td rowspan="2"></td><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td><td>2220</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td><td>(15.3)</td></tr><tr><td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$T_{k,cr}$</td><td>psi</td><td>855</td><td>930</td><td>960</td><td>1035</td><td>1055</td><td>1085</td><td>1130</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(5.9)</td><td>(6.4)</td><td>(6.6)</td><td>(7.1)</td><td>(7.3)</td><td>(7.5)</td><td>(7.8)</td></tr><tr><td rowspan="2"></td><td>Characteristic bond strength in uncracked concrete</td><td>$T_{k,uncr}$</td><td>psi</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td><td>1820</td></tr><tr><td></td><td></td><td>(Mpa)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td><td>(12.6)</td></tr></table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.										DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).							3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	5				(mm)	60	70	79	89	89	102	127	Maximum Embedment		$h_{ef,max}$	in	7-1/2	10	12-1/2	15	17-1/5	20	25				(mm)	(191)	(254)	(318)	(381)	(445)	(508)	(635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380			(Mpa)	(7.2)	(7.8)	(8.1)	(8.7)	(8.9)	(9.1)	(9.5)		Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380			(Mpa)	(7.20)	(7.80)	(8.00)	(8.67)	(9.00)	(9.00)	(9.50)		Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi	2220	2220	2220	2220	2220	2220	2220			(Mpa)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	(15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi	855	930	960	1035	1055	1085	1130			(Mpa)	(5.9)	(6.4)	(6.6)	(7.1)	(7.3)	(7.5)	(7.8)		Characteristic bond strength in uncracked concrete	$T_{k,uncr}$	psi	1820	1820	1820	1820	1820	1820	1820			(Mpa)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)	(12.6)
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in).																																																																																																																																																																																																		
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Temperature Range A ²	Characteristic bond strength in cracked concrete	$T_{k,cr}$	psi	1045	1135	1170	1260	1290	1325	1380																																																																																																																																																																																												
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Calculations A_{Na}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Na}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor or N_{ag} of a group of adhesive anchors, shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$ (b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors..... A_{Na0} is the projected influence area of a single anchor with an edge distance equal to or greater than c_{Na}: $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in².	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Na} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor or a group of anchors creates a prying (i.e. tension) action on the anchor(s). A_{Na} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Na} is defined by projected distances from the anchors that are in shear. The maximum projected distance from an anchor that is considered when calculating A_{Na} is limited to "c_{Na}", where c_{Na} corresponds to the edge distance parameter calculated per Eq. (17.4.5.1d). Therefore, the maximum edge distance parameter used to calculate A_{Na} equals c_{Na} and the maximum spacing parameter used to calculate A_{Na} equals $2.0c_{Na}$. Using these limits for edge distance and spacing, and defining the parameter A_{Na0} per Eq. (17.4.5.1c), the value for A_{Na} will never be greater than nA_{Na0}, where n corresponds to the number of anchors in shear. This limit is described below. The figure below illustrates how A_{Na} is calculated for pryout when a shear load acts on a group of four anchors with fixed edge distances equal to c_{a1} and c_{a2}, and spacing parameters equal to s_1 and s_2. Note that the maximum edge distance parameter used to calculate A_{Na} equals c_{Na}. Anchors spaced greater than $2.0c_{Na}$ from one another would not be considered to act as a group with respect to that spacing.  $A_{Na} = (c_{a1} + s_1 + c_{Na})(c_{a2} + s_2 + c_{Na})$ where: c_{a1} and c_{a2} are $\leq c_{Na}$ s_1 and s_2 are $\leq 2.0c_{Na}$ For the example above, if $c_{a1} = c_{a2} = c_{Na}$ and $s_1 = s_2 = 2.0c_{Na}$, then A_{Na} would equal $(c_{Na} + 2.0c_{Na} + c_{Na})(c_{Na} + 2.0c_{Na} + c_{Na}) = 16c_{Na}^2$. The parameter A_{Na0}/A_{Na0} would equal $16c_{Na}^2/4c_{Na}^2 = 4$. Therefore, since the maximum edge distance parameter (c_{Na}) and maximum spacing parameter ($2.0c_{Na}$) have been assumed, A_{Na} equals nA_{Na0}, where $n = 4$ corresponds to the number of anchors in the group that resist shear. It is important to understand that "A_{Na}" calculated for bond failure in tension is not necessarily the same as "A_{Na}" calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Equations section of the PROFIS Engineering report for more information on A_{Na} and c_{Na}.

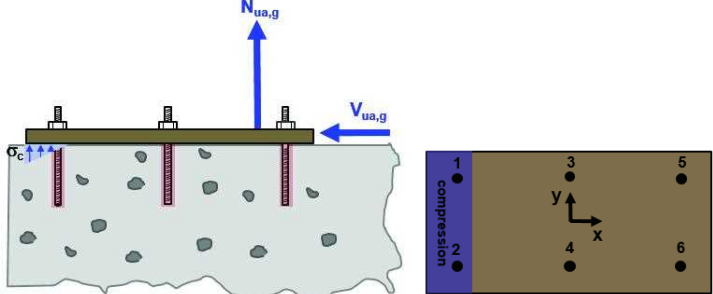
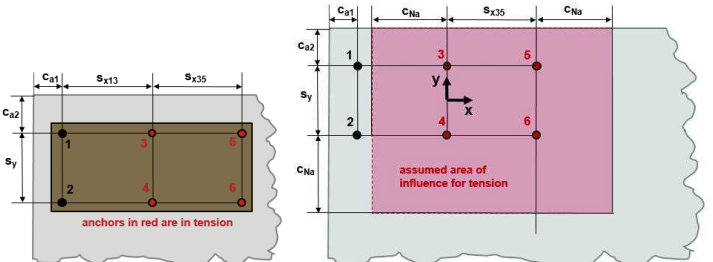
Calculations A_{Na0}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Na0}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b). 17.4.5.1 The nominal bond strength in tension, N_a of a single anchor or N_{ag} of a group of anchors, shall not exceed: a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$ b) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ A_{Na} is the projected influence area of a single adhesive anchor or group of adhesive anchors that shall be approximated as a rectilinear area that projects outward a distance c_{Na} from the centerline of the adhesive anchor, or in the case of a group of adhesive anchors, from a line through a row of adjacent adhesive anchors. A_{Na} shall not exceed nA_{Na0}, where n is the number of adhesive anchors in the group that resist tension loads. A_{Na0} is the projected influence area of a single adhesive anchor with an edge distance equal to or greater than c_{Na} $A_{Na0} = (2c_{Na})^2 \quad (17.4.5.1c)$ where $c_{Na} = 10d_a \sqrt{\frac{\tau_{k,uncr}}{1100}} \quad (17.4.5.1d)$ and constant 1100 carries the unit of lb/in². Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,uncr}$).	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Na0} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor without the influence of any fixed edges creates a prying (i.e. tension) action on the anchor. A_{Na0} is calculated per ACI 318-14 Eq. (17.4.5.1c). The parameter "c_{Na}" in this equation is calculated per Eq. (17.4.5.1d), and corresponds to an assumed projected distance on either side of the anchor in the x and y directions. The figure below illustrates how A_{Na0} is calculated.  $A_{Na0} = (c_{Na} + c_{Na})(c_{Na} + c_{Na}) = (2.0c_{Na})^2$ Adhesive anchor systems can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC308 and the ACI standard ACI 355.4. The parameter "$\tau_{k,uncr}$" in Eq. (17.4.5.1d) corresponds to the characteristic bond stress in uncracked concrete of the adhesive product selected for the PROFIS Engineering application being modeled. Values for $\tau_{k,uncr}$ are derived from AC308/ACI 355.4 testing, and are shown as "$\tau_{k,uncr}$" in the ICC-ESR for the adhesive anchor system. The PROFIS Engineering report designates this parameter "$\tau_{k,c,uncr}$". Reference the Variables section of the PROFIS Engineering report for more information on the parameters $\tau_{k,c,uncr}$ and d_a. Reference the Equations section of the PROFIS Engineering report for more information on A_{Na0} and c_{Na}.

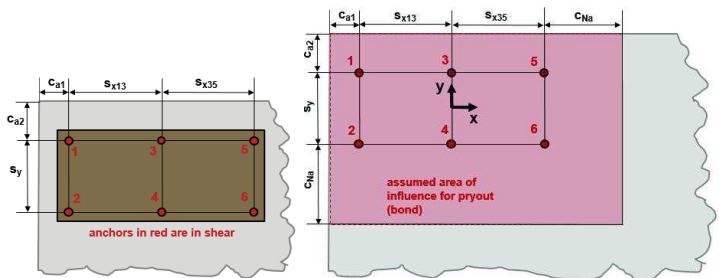
Calculations A_{Na0} (continued)

Calculations	318-14 Chapter 17 Provision										Comments for PROFIS Engineering																																																																																																																	
A_{Na0}	Example: Example of a bond strength table in an ICC-ESR showing characteristic bond stress values ($\tau_{k,uncr}$). ICC-ESR-3187 Table 14 <table> <tr> <th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in.)</th></tr> <tr> <th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th><th></th></tr> <tr> <td colspan="2">Minimum Embedment</td><td>$h_{ef,min}$</td><td>in (mm)</td><td>2-3/8 60</td><td>2-3/4 70</td><td>3-1/8 79</td><td>3-1/2 89</td><td>3-1/2 89</td><td>4 102</td><td>5 127</td><td></td></tr> <tr> <td colspan="2">Maximum Embedment</td><td>$h_{ef,max}$</td><td>in (mm)</td><td>7-1/2 (191)</td><td>10 (254)</td><td>12-1/2 (318)</td><td>15 (381)</td><td>17-1/5 (445)</td><td>20 (508)</td><td>25 (635)</td><td></td></tr> <tr> <td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td><td></td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td></td></tr> <tr> <td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td><td></td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td></td></tr> <tr> <td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td><td></td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td></td></tr> </table> ¹ Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. ² Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.										DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)								3/8	1/2	5/8	3/4	7/8	1	1-1/4		Minimum Embedment		$h_{ef,min}$	in (mm)	2-3/8 60	2-3/4 70	3-1/8 79	3-1/2 89	3-1/2 89	4 102	5 127		Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)		Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)		Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)		Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)		
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)																																																																																																																								
				3/8	1/2	5/8	3/4	7/8	1	1-1/4																																																																																																																		
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Maximum Embedment		$h_{ef,max}$	in (mm)	7-1/2 (191)	10 (254)	12-1/2 (318)	15 (381)	17-1/5 (445)	20 (508)	25 (635)																																																																																																																		
Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)																																																																																																																		
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																																		
Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)																																																																																																																		
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																																		
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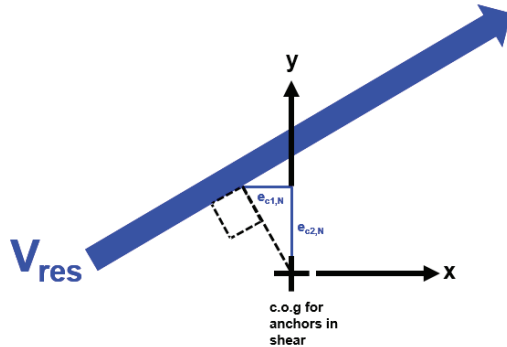
Calculations $\psi_{ed,Na}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,Na}$	17.4.5.4 The modification factor for edge effects for single adhesive anchors or adhesive anchor groups loaded in tension, $\psi_{ed,Na}$, shall be calculated as If $c_{a,min} \geq c_{Na}$, then $\psi_{ed,Na} = 1.0$ (17.4.5.4a) If $c_{a,min} < c_{Na}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right)$ (17.4.5.4b) 17.4.5.1 where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in².	When calculating the nominal concrete pryout strength in shear (V_{cp} or $V_{cp,g}$), the parameter $\psi_{ed,Na}$ is a modification factor that accounts for fixed edge distances less than "c_{Na}", where c_{Na} is the edge distance parameter calculated per Eq. (17.4.5.1d) for the adhesive anchor being modeled in PROFIS Engineering. It is important to understand that "$\psi_{ed,Na}$" calculated for bond failure in tension is not necessarily the same as "$\psi_{ed,Na}$" calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. In the illustration below, a fixture is being attached with six anchors, which are numbered 1-6. Anchors 3, 4, 5 and 6 are subjected to a tension load, but all six anchors are subjected to a shear load. The edge distance c_{a1} is less than the edge distance c_{a2}, and both edge distances are less than c_{Na}.  Since anchors 1 and 2 are in compression, the fixed edge distance in the -x direction from anchors 3 and 4 that is relevant to the bond strength tension calculations equals c_{a1} + the spacing between anchors 1 and 3 (s_{x13}). Assuming $c_{a1} + s_{x13}$ is greater than c_{Na}, the only fixed edge distance that is considered for $\psi_{ed,Na}$ when calculating bond strength in tension is the distance in the +y direction (c_{a2}). $\psi_{ed,Na}$ would be calculated for bond strength in tension as follows: $\psi_{ed,Na} = 0.7 + 0.3 (c_{a2} / c_{Na})$ 

Calculations $\psi_{ed,Na}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,Na}$		All six anchors are in shear, so both c_{a1} and c_{a2} (which are less than c_{Na}) are considered for $\psi_{ed,Na}$ when calculating concrete pryout in shear. Since c_{a1} is less than c_{a2}, $\psi_{ed,Na}$ would be calculated for concrete pryout in shear using c_{a1} as follows: $\psi_{ed,Na} = 0.7 + 0.3 (c_{a1} / c_{Na})$  Reference the Variables section of the PROFIS Engineering report for more information $c_{a,min}$. Reference the Equations section of the PROFIS Engineering report for more information on $\psi_{ed,Na}$. Reference the Equations and Calculations section of the PROFIS Engineering report for more information on c_{Na}.

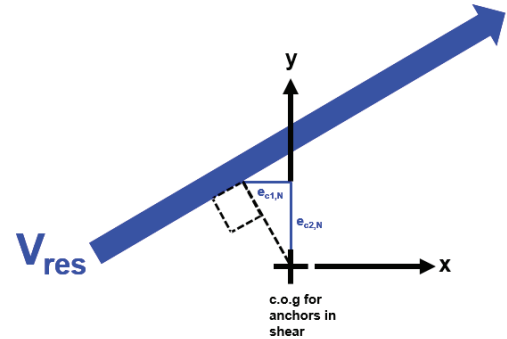
Calculations $\psi_{ec1,Na}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,Na}$	17.5.3.1 The nominal pryout strength, ... V_{cp} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cp} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.5.1 The nominal bond strength in tension..... N_{ag} of a group of anchors, shall not exceed: a) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ where $C_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². 17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{C_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	Concrete pryout strength for a group of anchors in shear (V_{cp}) is calculated per Eq. (17.5.3.1b). The parameter "N_{cp}" in this equation corresponds to the nominal bond strength (N_{ag}), calculated per Eq. (17.4.5.1b), but with respect to concrete pryout failure. The parameter "$\psi_{ec,Na}$" in Eq. (17.4.5.1b) is a modification factor that accounts for a resultant shear load that is eccentric with respect to the centroid of the anchors that are loaded in shear. $\psi_{ec,Na}$ is only considered for an anchor group loaded in shear when calculating V_{cp}. When shear load acting on a group of anchors is eccentric with respect to the x direction, PROFIS Engineering calculates "$\psi_{ec,N}$" per Eq. (17.4.5.3) and designates this parameter "$\psi_{ec1,Na}$". PROFIS Engineering designates the eccentricity parameter e'_N in Eq. (17.4.5.3) "$e_{c1,N}$" to likewise indicate that the software is considering eccentricity with respect to the x direction. If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates "$\psi_{ec,N}$" for both directions. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cp}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".  PROFIS Engineering calculates "$\psi_{ec,Na}$" for both directions. $\psi_{ec1,Na} = \frac{1}{\left(1 + \frac{e_{c1,N}}{C_{Na}}\right)} \quad \psi_{ec2,Na} = \frac{1}{\left(1 + \frac{e_{c2,N}}{C_{Na}}\right)}$ For this example, the value for "$\psi_{ec,Na}$" used in Eq. (17.4.5.1b) equals the product of $\psi_{ec1,Na}$ and $\psi_{ec2,Na}$: $\psi_{ec,Na} = (\psi_{ec1,Na})(\psi_{ec2,Na})$.

Calculations $\psi_{ec1,Na}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,Na}$		Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec,Na}$: Modification factor for shear eccentricity Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for shear eccentricity with respect to the x direction $e_{c2,N}$: Parameter for shear eccentricity with respect to the y direction Reference the Calculations section of the PROFIS Engineering report for more information on: c_{Na}: Edge distance parameter for adhesive anchors $\psi_{ec2,Na}$: Modification factor for shear eccentricity with respect to the y direction

Calculations $\psi_{ec2,Na}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,Na}$	17.5.3.1 The nominal pryout strength, ... V_{cp} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cp} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.5.1 The nominal bond strength in tension N_{ag} of a group of anchors, shall not exceed: a) For a group of adhesive anchors $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ where $c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}} \quad 17.4.5.1d$ and the constant 1100 carries the unit of lb/in². 17.4.5.3 The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$ shall be calculated as $\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)} \quad (17.4.5.3)$ but $\psi_{ec,Na}$ shall not be taken greater than 1.0. If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.5.3) and for the calculation of N_{ag} according to Eq. (17.4.5.1b). In the case where eccentric loading exists about two orthogonal axes, the modification factor, $\psi_{ec,Na}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,Na}$ in Eq. (17.4.5.1b).	Concrete pryout strength for a group of anchors in shear (V_{cp}) is calculated per Eq. (17.5.3.1b). The parameter "N_{cp}" in this equation corresponds to the nominal bond strength (N_{ag}), calculated per Eq. (17.4.5.1b), but with respect to concrete pryout failure. The parameter "$\psi_{ec,Na}$" in Eq. (17.4.5.1b) is a modification factor that accounts for a resultant shear load that is eccentric with respect to the centroid of the anchors that are loaded in shear. $\psi_{ec,Na}$ is only considered for an anchor group loaded in shear when calculating V_{cp}. When shear load acting on a group of anchors is eccentric with respect to the y direction, PROFIS Engineering calculates "$\psi_{ec,N}$" per Eq. (17.4.5.3) and designates this parameter "$\psi_{ec2,Na}$". PROFIS Engineering designates the eccentricity parameter e'_N in Eq. (17.4.5.3) "$e_{c2,N}$" to likewise indicate that the software is considering eccentricity with respect to the y direction. If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates "$\psi_{ec,N}$" for both directions. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cp}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".  PROFIS Engineering calculates "$\psi_{ec,Na}$" for both directions. $\psi_{ec1,Na} = \frac{1}{\left(1 + \frac{e_{c1,N}}{c_{Na}}\right)} \quad \psi_{ec2,Na} = \frac{1}{\left(1 + \frac{e_{c2,N}}{c_{Na}}\right)}$ For this example, the value for "$\psi_{ec,Na}$" used in Eq. (17.4.5.1b) equals the product of $\psi_{ec1,Na}$ and $\psi_{ec2,Na}$: $\psi_{ec,Na} = (\psi_{ec1,Na})(\psi_{ec2,Na})$.

Calculations $\psi_{ec2,Na}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,Na}$		Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec,Na}$: Modification factor for shear eccentricity Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for shear eccentricity with respect to the x direction $e_{c2,N}$: Parameter for shear eccentricity with respect to the y direction Reference the Calculations section of the PROFIS Engineering report for more information on: c_{Na}: Edge distance parameter for adhesive anchors $\psi_{ec2,Na}$: Modification factor for shear eccentricity with respect to the y direction

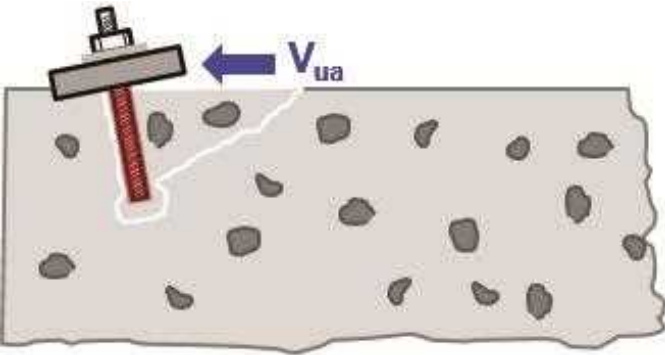
Calculations $\psi_{cp,Na}$

[illegible]

PART 4 SHEAR LOAD / Pryout Failure Mode (Pryout Bond)

Calculations N_{ba}

Calculations	318-14 Chapter 17 Provision									Comments for PROFIS Engineering																																																																																																																																						
N_{ba}	17.4.5.2 The basic bond strength of a single adhesive anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef} \quad (17.4.5.2)$ The characteristic bond stress τ_{cr} shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. Where analysis indicates cracking at service load levels, adhesive anchors shall be shown compliance for use in cracked concrete in accordance with ACI 355.4. For adhesive anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, τ_{uncr} shall be permitted to be used in place of τ_{cr} in Eq. (17.4.5.2) and shall be taken as the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. Example: Example of a table in an ICC-ESR showing characteristic bond stress values that can be used to calculate N_{ba}. ICC-ESR-3187 Table 14 <table> <tr> <th colspan="2">DESIGN INFORMATION</th><th>Symbol</th><th>Units</th><th colspan="7">Nominal Rod Diameter (in.)</th></tr> <tr> <th colspan="2"></th><th></th><th></th><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr> <tr> <td rowspan="2">Minimum Embedment</td><td rowspan="2"></td><td rowspan="2">$h_{ef,min}$</td><td>in</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>5</td></tr> <tr> <td>(mm)</td><td>60</td><td>70</td><td>79</td><td>89</td><td>89</td><td>102</td><td>127</td></tr> <tr> <td rowspan="2">Maximum Embedment</td><td rowspan="2"></td><td rowspan="2">$h_{ef,max}$</td><td>in</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/5</td><td>20</td><td>25</td></tr> <tr> <td>(mm)</td><td>(191)</td><td>(254)</td><td>(318)</td><td>(381)</td><td>(445)</td><td>(508)</td><td>(635)</td></tr> <tr> <td rowspan="2">Temperature Range A²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.2)</td><td>1135 (7.8)</td><td>1170 (8.1)</td><td>1260 (8.7)</td><td>1290 (8.9)</td><td>1325 (9.1)</td><td>1380 (9.5)</td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr> <tr> <td rowspan="2">Temperature Range B²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>1045 (7.20)</td><td>1135 (7.80)</td><td>1170 (8.00)</td><td>1260 (8.67)</td><td>1290 (9.00)</td><td>1325 (9.00)</td><td>1380 (9.50)</td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td><td>2220 (15.3)</td></tr> <tr> <td rowspan="2">Temperature Range C²</td><td>Characteristic bond strength in cracked concrete</td><td>$\tau_{k,cr}$</td><td>psi (Mpa)</td><td>855 (5.9)</td><td>930 (6.4)</td><td>960 (6.6)</td><td>1035 (7.1)</td><td>1055 (7.3)</td><td>1085 (7.5)</td><td>1130 (7.8)</td></tr> <tr> <td>Characteristic bond strength in uncracked concrete</td><td>$\tau_{k,uncr}$</td><td>psi (Mpa)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td><td>1820 (12.6)</td></tr> <tr> <td colspan="2">Reduction for Seismic Tension</td><td>$\alpha_{N,seis}$</td><td>-</td><td>0.88</td><td>1.0</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.97</td><td>1.0</td></tr> </table> 1 Bond strength values correspond to concrete compressive strength $f'_c = 2500$ psi. For concrete compressive strength f'_c between 2500 psi and 800 psi, the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2500)^{0.1}$. 2 Temperature Range A: Maximum short term temperature = 130°F, Maximum long term temperature = 110°F. Temperature Range B: Maximum short term temperature = 176°F, Maximum long term temperature = 110°F. Temperature Range C: Maximum short term temperature = 248°F, Maximum long term temperature = 162°F. Short term elevated concrete temperatures are those which occur over brief intervals, e.g. as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.									DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)											3/8	1/2	5/8	3/4	7/8	1	1-1/4	Minimum Embedment		$h_{ef,min}$	in	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	5	(mm)	60	70	79	89	89	102	127	Maximum Embedment		$h_{ef,max}$	in	7-1/2	10	12-1/2	15	17-1/5	20	25	(mm)	(191)	(254)	(318)	(381)	(445)	(508)	(635)	Temperature Range A ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.2)	1135 (7.8)	1170 (8.1)	1260 (8.7)	1290 (8.9)	1325 (9.1)	1380 (9.5)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	Temperature Range C ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	855 (5.9)	930 (6.4)	960 (6.6)	1035 (7.1)	1055 (7.3)	1085 (7.5)	1130 (7.8)	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0	The parameter N_{ba} corresponds to a calculated bond strength for a single adhesive anchor element without any fixed edge or spacing influences. Calculation of N_{ba} is predicated on the characteristic bond stress of the adhesive product (τ_{cr} or τ_{uncr}), and the anchor element geometry (πd_a and h_{ef}), where d_a corresponds to the nominal diameter of the anchor element and h_{ef} corresponds to the effective embedment depth that has been input into PROFIS Engineering for the selected anchor element. Equation (17.4.5.2) also includes a modification factor for lightweight concrete (λ_a). PROFIS Engineering defaults to a design assumption that cracked concrete conditions exist. If cracked concrete conditions are assumed, PROFIS Engineering uses the characteristic bond stress for cracked concrete (τ_{cr}) to calculate N_{ba}. If uncracked concrete conditions are assumed, PROFIS Engineering uses the characteristic bond stress for uncracked concrete (τ_{uncr}) to calculate N_{ba}. PROFIS Engineering uses the characteristic bond stress values derived from testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 to calculate N_{ba}. Values are provided in an ICC-ESR and are designated "$\tau_{k,cr}$", corresponding to the characteristic bond stress in cracked concrete, and "$\tau_{k,uncr}$", corresponding to the characteristic bond stress in uncracked concrete. PROFIS Engineering uses the $\tau_{k,cr}$ and $\tau_{k,uncr}$ values given in the ICC-ES evaluation report for the adhesive anchor that has been selected to calculate N_{ba}. Although noted in the ICC-ESR as a "strength", $\tau_{k,cr}$ and $\tau_{k,uncr}$ are stress parameters having units of psi. The parameter "$\alpha_{N,seis}$" is a seismic reduction factor derived from testing per AC308/ACI 354, and is also given in the anchor ICC-ESR. The PROFIS Engineering report includes $\alpha_{N,seis}$ as a parameter used to calculate N_{ba}. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: λ_a: Lightweight concrete modification factor $\tau_{k,xxxx}$: Characteristic bond stress for cracked or uncracked concrete $\alpha_{N,seis}$: Seismic modification factor d_a: Anchor element diameter h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Equations section of the PROFIS Engineering report for more information on the parameter N_{ba}.
DESIGN INFORMATION		Symbol	Units	Nominal Rod Diameter (in.)																																																																																																																																												
				3/8	1/2	5/8	3/4	7/8	1	1-1/4																																																																																																																																						
Minimum Embedment		$h_{ef,min}$	in	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	5																																																																																																																																						
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	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)	2220 (15.3)																																																																																																																																						
Temperature Range B ²	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (Mpa)	1045 (7.20)	1135 (7.80)	1170 (8.00)	1260 (8.67)	1290 (9.00)	1325 (9.00)	1380 (9.50)																																																																																																																																						
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	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (Mpa)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)	1820 (12.6)																																																																																																																																						
Reduction for Seismic Tension		$\alpha_{N,seis}$	-	0.88	1.0	1.0	1.0	1.0	0.97	1.0																																																																																																																																						

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cp}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$	When designing adhesive anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a single anchor (V_{cp}) as the product of k_{cp} and the smaller of (N_{cb}) and the nominal bond strength for a single anchor (N_a). The bond strength parameter (N_a) for pryout failure in shear is calculated per ACI 318-14 Eq. (17.4.5.1a), but predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. Note that (17.5.3.1a) denotes the “concrete pryout strength” parameter “N_{cp}” to distinguish it from the bond strength parameter “N_a”. For the example illustrated below, a single anchor is subjected to only a shear load. No tension load acts on the anchor; therefore, nominal bond strength in tension (N_a) is not calculated, but a pryout parameter “N_{cp}” corresponding to N_a calculated per Eq. (17.4.5.1a) is calculated. adhesive anchor systems No tension load applied: $N_{cb} = 0$. Shear load applied, so calculate concrete pryout ($k_{cp} N_{cp}$). adhesive anchor system: $V_{cp} = k_{cp} \text{ MIN } \{N_{cb} ; N_a\}$.  Reference the Variables section of the PROFIS Engineering report for information on: k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic concrete breakout strength in tension

PART 4 SHEAR LOAD / Pryout Failure Mode (Pryout Bond)

Results V_{cpg}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cpg}	17.5.3.1 The nominal pryout strength, ... V_{cpg} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, ... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.5.1 The nominal bond strength in tension..... N_{ag} of a group of adhesive anchors, shall not exceed (b) For a group of adhesive anchors: $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ Summary of ACI 318-14 pryout calculations for adhesive anchors. adhesive anchor systems adhesive anchor system: $V_{cpg} = k_{cp} \text{MIN} \{N_{cbg} ; N_{ag}\}.$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. When designing adhesive anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a group of anchors (V_{cpg}) as the product of the coefficient for pryout strength (k_{cp}) and the smaller of (N_{cbg}) and the nominal bond strength for a group of anchors (N_{ag}). The bond strength parameter (N_{ag}) for pryout failure in shear is calculated per ACI 318-14 Eq. (17.4.5.1b), but predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. Note that (17.5.3.1b) denotes the “concrete pryout strength” parameter “N_{cpg}” to distinguish it from the bond strength parameter “N_{ag}”. For the example illustrated below, four anchors are subjected to a tension load, but all six anchors are subjected to a shear load. A nominal concrete breakout strength (N_{cbg}) and a nominal bond strength (N_{ag}) are calculated for anchors 1,2,3 and 4; but a pryout parameter “N_{cpg}” corresponding to the smaller of N_{cbg} calculated per Eq. (17.4.2.1b), and N_{ag} calculated per Eq. (17.4.5.1b), is calculated for anchors 1,2,3,4,5 and 6. Reference the Variables section of the PROFIS Engineering report for information on: k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for information on: A_{Na}: Area of influence for anchors in tension A_{Na0}: Area of influence for single anchor in tension $\psi_{ec,Na}$: Tension modification factor for eccentricity $\psi_{ed,Na}$: Tension modification factor for edge distance $\psi_{cp,Na}$: Modification factor for splitting N_{ba}: Basic concrete breakout strength in tension

Results ϕ_{concrete}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																							
ϕ_{concrete}	17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (c) (c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength <table><tr><th></th><th>Condition A</th><th>Condition B</th></tr><tr><td>(i) Shear loads</td><td>0.75</td><td>0.70</td></tr><tr><td>.....</td><td></td><td></td></tr></table> Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present and for pullout and pryout strengths. Example: Example of a post-installed adhesive anchor system strength reduction factor (ϕ-factor) corresponding to concrete breakout failure in shear. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="8">Nominal Rod Diameter (in).</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1/4 or #10</th></tr><tr><td>Strength reduction factor for shear, concrete failure modes, Condition B</td><td>ϕ</td><td>-</td><td colspan="8">0.70</td></tr></table>		Condition A	Condition B	(i) Shear loads	0.75	0.70				DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in).								3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1/4 or #10	Strength reduction factor for shear, concrete failure modes, Condition B	ϕ	-	0.70								ACI 318-14 strength design provisions for concrete pryout failure in tension require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{cp} or ϕV_{cpg}). PROFIS Engineering designates the ϕ-factor corresponding to concrete breakout failure "ϕ_{concrete}". Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. ϕ-factors derived from AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor correspond to "Condition B" as defined in ACI 318-14 Section 17.3.3. "Condition A" is not considered for pryout calculations. If Condition A is selected as a design parameter, PROFIS Engineering uses the Condition B ϕ-factor to calculate the design concrete pryout strength. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp} or V_{cpg}: Nominal concrete pryout strength ϕV_{cp} or ϕV_{cpg}: Design concrete pryout strength
	Condition A	Condition B																																							
(i) Shear loads	0.75	0.70																																							
.....																																									
DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in).																																						
			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1/4 or #10																															
Strength reduction factor for shear, concrete failure modes, Condition B	ϕ	-	0.70																																						

Results ϕ_{seismic}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering						
ϕ_{seismic}	17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{sa}]$ corresponds to steel failure (tension) in Table 17.3.1.1] (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided $[\phi N_{cb}]$ or $[\phi N_{cbg}]$ correspond to concrete breakout failure (tension) in Table 17.3.1.1] (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{pn}]$ corresponds to pullout failure (tension) in Table 17.3.1.1] (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ $[\phi N_{sb}]$ or $[\phi N_{sbg}]$ correspond to side-face blowout failure (tension) in Table 17.3.1.1] (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ $[\phi N_a]$ or $[\phi N_{ag}]$ correspond to bond failure (tension) in Table 17.3.1.1] where ϕ is in accordance with 17.3.3. 17.3.3 Strength reduction factor ϕ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength <table> <tr> <th></th><th>Condition A</th><th>Condition B</th></tr> <tr> <td>(i) Shear loads</td><td>0.75</td><td>0.70</td></tr> </table> Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present, and for pullout and pryout strengths PROFIS Engineering calculations for concrete pryout failure in shear when seismic load conditions are being modeled: single anchor: design concrete pryout strength = $\phi_{\text{concrete}} V_{cp}$ anchor group: design concrete pryout strength = $\phi_{\text{concrete}} V_{cpg}$		Condition A	Condition B	(i) Shear loads	0.75	0.70	When designing an anchorage for seismic tension load conditions, ACI 318-14 provisions for non-steel failure modes in tension require calculation of a nominal strength (N_n). The nominal strength is multiplied by two strength reduction factors (ϕ-factors): one ϕ-factor for the failure mode being considered, e.g. concrete breakout failure or bond failure; and one ϕ-factor for seismic tension load conditions. The resulting design strength includes a seismic reduction factor of 0.75: seismic design strength for non-steel failure modes = $(0.75\phi N_n)$. PROFIS Engineering designates the 0.75 seismic tension reduction factor noted in ACI 318-14 Section 17.2.3.4.4 "ϕ_{seismic}". This reduction is only considered with respect to non-steel tension failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors subjected to seismic tension loads. When designing an anchorage for seismic shear load conditions, ACI 318-14 strength design provisions for concrete pryout failure in shear require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}) that is only multiplied by one ϕ-factor to obtain a shear design strength (ϕV_{cp} or ϕV_{cpg}). PROFIS Engineering designates this ϕ-factor "ϕ_{concrete}". The 0.75 seismic strength reduction factor (ϕ_{seismic}) required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cp} or V_{cpg} when the anchorage is being designed for seismic shear load conditions. The PROFIS Engineering report always shows ϕ_{seismic} equal to 1.0 for shear concrete pryout calculations when seismic shear load conditions are being modeled. When calculating the design concrete pryout strength in shear for adhesive anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report corresponds to the "Condition B" ϕ-factor for shear given in the ICC-ESR for the anchor. Per ACI 318-14 Section 17.3.3, Condition A is not considered for pryout strength calculations. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp} or V_{cpg}: Nominal concrete pryout strength in shear ϕV_{cp} or ϕV_{cpg}: Design concrete pryout strength in shear ϕ_{concrete}: Strength reduction factor for shear concrete pryout failure
	Condition A	Condition B						
(i) Shear loads	0.75	0.70						

Results $\phi_{\text{nonductile}}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	When designing an anchorage for seismic tension load conditions, ACI 318-14 provisions for non-steel failure modes in tension require calculation of a nominal strength (N_n). The nominal strength is multiplied by two strength reduction factors (ϕ-factors): one ϕ-factor for the failure mode being considered, e.g. concrete breakout failure or bond failure; and one ϕ-factor for seismic tension load conditions. The resulting design strength includes a seismic reduction factor of 0.75: seismic design strength for non-steel failure modes = $(0.75\phi N_n)$. PROFIS Engineering designates the 0.75 seismic tension reduction factor noted in ACI 318-14 Section 17.2.3.4.4 “ϕ_{seismic}”. This reduction is only considered with respect to non-steel tension failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors subjected to seismic tension loads. When designing an anchorage for seismic shear load conditions, ACI 318-14 strength design provisions for concrete pryout failure in shear require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}) that is only multiplied by one ϕ-factor to obtain a shear design strength (ϕV_{cp} or ϕV_{cpg}). PROFIS Engineering designates this ϕ-factor “ϕ_{concrete}”. The 0.75 seismic strength reduction factor (ϕ_{seismic}) required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cp} or V_{cpg} when the anchorage is being designed for seismic shear load conditions. The parameter “$\phi_{\text{nonductile}}$” is a reduction factor for seismic tension and seismic shear load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor “$\phi_{\text{nonductile}}$”. “$\phi_{\text{nonductile}}$” is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

PART 4 SHEAR LOAD / Pryout Failure Mode (Pryout Bond)

Results ϕV_{cp}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cp}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Single Anchor $\phi V_{cp} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal concrete pryout strength in shear ϕV_{cp}: Design concrete pryout strength in shear $\phi V_{cp} \geq V_{ua}$: Design check for pryout Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

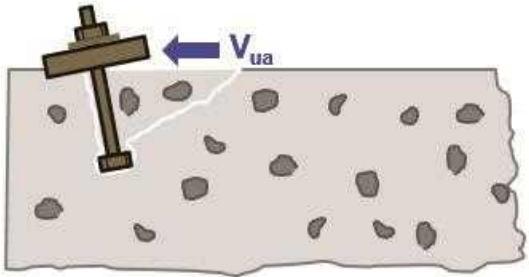
Results ϕV_{cpg}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cpg}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Anchors as a Group $\phi V_{cpg} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: V_{cpg}: Nominal concrete pryout strength in shear ϕV_{cpg}: Design concrete pryout strength in shear $\phi V_{cpg} \geq V_{ua}$: Design check for pryout Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cpg}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: strength reduction factor for seismic shear V_{ua}: factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

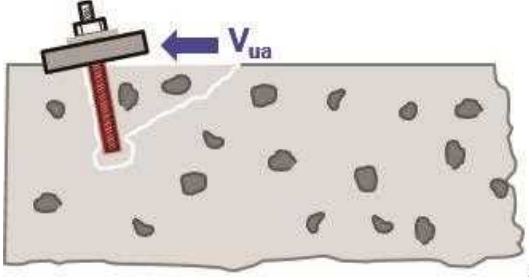
Results V_{ua}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
V_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the shear failure modes considered in ACI 318-14 anchoring-to-concrete provisions Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi V_{sa} \geq V_{ua}$</td><td>$\phi V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi V_{cb} \geq V_{ua}$</td><td></td><td>$\phi V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi V_{cp} \geq V_{ua}$</td><td></td><td>$\phi V_{cpg} \geq V_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi V_{cb} \geq V_{ua}$		$\phi V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi V_{cp} \geq V_{ua}$		$\phi V_{cpg} \geq V_{ua,g}$	ACI 318-14 strength design provisions for concrete pryout failure in shear require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{cp} or ϕV_{cpg}). Design strength is checked against a factored shear load, defined by the parameter "V_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored shear load parameter "V_{ua}". V_{ua} = factored shear force applied to a single anchor or group of anchors (lb) $V_{ua,i}$ = factored shear force applied to most highly stressed anchor in a group of anchors (lb) $V_{ua,g}$ = total factored shear force applied to anchor group (lb) The design concrete pryout strength for a single anchor in shear (ϕV_{cp}) calculated per Section 17.5.3 is checked against the factored shear load acting on the anchor, which is designated "V_{ua}" in Table 17.3.1.1. If $\phi V_{cp} \geq V_{ua}$, the provisions for considering concrete pryout failure in shear have been satisfied per Table 17.3.1.1. The design concrete pryout strength for a group of anchors in shear (ϕV_{cpg}) calculated per Section 17.5.3 is checked against the total factored shear load acting on the anchors that are in shear, which is designated "$V_{ua,g}$" in Table 17.3.1.1. If $\phi V_{cpg} \geq V_{ua,g}$, the provisions for considering concrete pryout failure in shear have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation "V_{ua}" to define the factored shear load being checked against the calculated design concrete pryout strength ϕV_{cp} or ϕV_{cpg}. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting shear loads. The software only performs shear load checks per Table 17.3.1.1 if shear loads have been input via one of the load input functionalities. If a single anchor in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{cp}, and checks this value against either (a) the factored shear load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored shear load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored shear load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the factored shear load determined to be acting on the anchor. If a group of anchors in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{cpg}, and checks this value against either (a) the total factored shear load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored shear load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored shear load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the total factored shear load determined to be acting on the anchor group. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: nominal shear concrete pryout strength for a single anchor V_{cpg}: nominal shear concrete pryout strength an anchor group $\phi_{concrete}$: strength reduction factor for concrete failure modes $\phi_{seismic}$: strength reduction factor for seismic loads $\phi_{nonductile}$: strength reduction factor for non-ductile failure modes
Failure Mode	Single Anchor			Anchor Group																
		Individual anchor in a Group	Anchors as a group																	
Steel strength in shear (17.5.1)	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$																		
Concrete breakout strength in shear (17.5.2)	$\phi V_{cb} \geq V_{ua}$		$\phi V_{cbg} \geq V_{ua,g}$																	
Concrete pryout strength in shear (17.5.3)	$\phi V_{cp} \geq V_{ua}$		$\phi V_{cpg} \geq V_{ua,g}$																	

Equation V_{cp}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cp} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Nc0}} \right) \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \right]$	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. When designing cast-in-place anchors and post-installed mechanical anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a single anchor (V_{cp}) as the product of the coefficient for pryout strength (k_{cp}) and the nominal concrete breakout strength in tension for a single anchor (N_{cb}). ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a single adhesive anchor (V_{cp}) as the product of k_{cp} and the smaller of (N_{cb}) and the nominal bond strength for a single anchor (N_a). The concrete breakout strength parameter (N_{cb}) for pryout failure in shear is calculated per ACI 318-14 Eq. (17.4.2.1a), but predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. Note that (17.5.3.1a) denotes the “concrete pryout strength” parameter “N_{cp}” to distinguish it from the tension concrete breakout strength parameter “N_{cb}”. For the example illustrated below, a single anchor is subjected to only a shear load. No tension load acts on the anchor; therefore, nominal concrete breakout in tension (N_{cb}) is not calculated, but a pryout parameter “N_{cp}” corresponding to N_{cb} calculated per Eq. (17.4.2.1a) is calculated. cast-in anchors and mechanical anchors No tension load applied: $N_{cb} = 0$. Shear load applied, so calculate concrete pryout ($k_{cp} N_{cp}$). cast in anchor: $V_{cp} = k_{cp} N_{cb}$ mechanical anchor: $V_{cp} = k_{cp} N_{cb}$ 

Equation V_{cp} (continued)

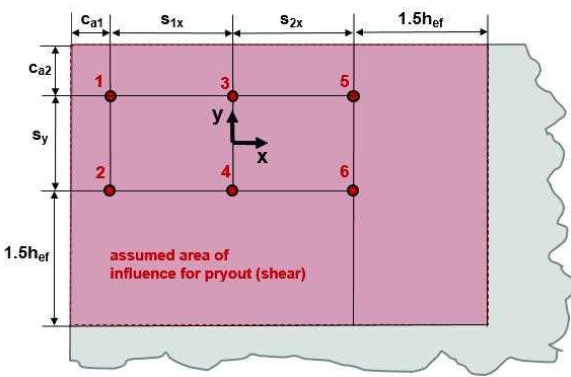
Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cp} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Nc0}} \right) \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \right]$		adhesive anchor systems No tension load applied: $N_{cb} = 0$. Shear load applied, so calculate concrete pryout ($k_{cp} N_{cp}$). adhesive anchor system: $V_{cp} = k_{cp} \text{MIN} \{N_{cb} ; N_a\}$.  Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension

PART 4 SHEAR LOAD / Pryout Failure Mode (Concrete Breakout)

Equation V_{cpg}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cpg} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Nc0}} \right) \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \right]$	17.5.3.1 The nominal pryout strength, ... V_{cpg} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, ... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.5.1 The nominal bond strength in tension..... N_{ag} of a group of adhesive anchors, shall not exceed (b) For a group of adhesive anchors: $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ Summary of ACI 318-14 pryout calculations. cast-in anchors and mechanical anchors cast in anchor: $V_{cpg} = k_{cp} N_{cbg}$ mechanical anchor: $V_{cpg} = k_{cp} N_{cbg}$ adhesive anchor systems adhesive anchor system: $V_{cpg} = k_{cp} \text{MIN} \{N_{cbg} ; N_{ag}\}.$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. When designing cast-in-place anchors and post-installed mechanical anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a group of anchors (V_{cpg}) as the product of the coefficient for pryout strength (k_{cp}) and the nominal concrete breakout strength in tension for a group of anchors (N_{cbg}). ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a group of adhesive anchors (V_{cpg}) as the product of k_{cp} and the smaller of (N_{cbg}) and the nominal bond strength for a group of anchors (N_{ag}). The concrete breakout strength parameter (N_{cbg}) for pryout failure in shear is calculated per ACI 318-14 Eq. (17.4.2.1b), but predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. Note that (17.5.3.1b) denotes the “concrete pryout strength” parameter “N_{cpg}” to distinguish it from the tension concrete breakout strength parameter “N_{cbg}”. For the example illustrated below, four anchors are subjected to a tension load, but all six anchors are subjected to a shear load. Therefore, nominal concrete breakout in tension (N_{cbg}) is calculated for anchors 1,2,3 and 4; but a pryout parameter “N_{cpg}” corresponding to N_{cbg} calculated per Eq. (17.4.2.1b) is calculated for anchors 1,2,3,4,5 and 6.

Equation V_{cpg} (continued)

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_{cpg} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Nc0}} \right) \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \right]$		 Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for information on: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ec,N}$: Tension modification factor for eccentricity $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension

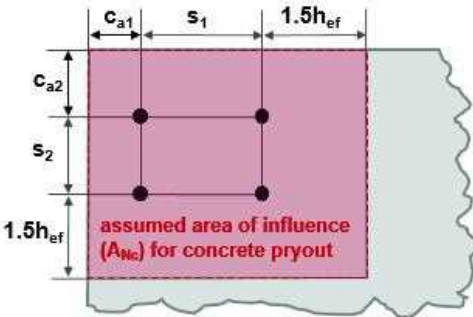
Equation ϕ_{cp}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{cp} \geq V_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Single Anchor $\phi V_{cp} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic shear ϕV_{cp}: Design concrete pryout strength in shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

Equation ϕ_{cpg}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{cpg} \geq V_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Anchors as a Group $\phi V_{cpg} \geq V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cpg}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic shear ϕV_{cpg}: Design concrete pryout strength in shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

Equation A_{Nc}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Nc}	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors..... 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor or N_{cbg} of a group of anchors, shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Nc} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor or a group of anchors creates a prying (i.e. tension) action on the anchor(s). A_{Nc} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Nc} is defined by projected distances from the anchors that are in shear. The maximum projected distance from an anchor that is considered when calculating A_{Nc} is limited to $1.5h_{ef}$, where h_{ef} is the effective embedment depth of the anchor. Therefore, the maximum edge distance parameter used to calculate A_{Nc} equals $1.5h_{ef}$ and the maximum spacing parameter used to calculate A_{Nc} equals $3.0h_{ef}$. The figure below illustrates how A_{Nc} is calculated for pryout when a shear load acts on a group of four anchors with fixed edge distances equal to c_{a1} and c_{a2}, and spacing parameters equal to s_1 and s_2. Note that the maximum edge distance parameter used to calculate A_{Nc} equals $1.5h_{ef}$. Anchors spaced greater than $3.0h_{ef}$ from one another would not be considered to act as a group with respect to that spacing.  $A_{Nc} = (c_{a1} + s_1 + 1.5h_{ef})(c_{a2} + s_2 + 1.5h_{ef})$ where: c_{a1} and c_{a2} are $\leq 1.5h_{ef}$ s_1 and s_2 are $\leq 3.0h_{ef}$ It is important to understand that “A_{Nc}” calculated for concrete breakout failure in tension is not necessarily the same as “A_{Nc}” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Nc}.

Equation A_{Nc0}

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$A_{Nc0} = 9h_{ef}^2$	17.4.2.1 A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance greater than $1.5h_{ef}$. $A_{Nc0} = 9h_{ef}^2 \quad (17.4.2.1c)$ 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor or N_{cbg} of a group of anchors, shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Nc0} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor without the influence of any fixed edges creates a prying (i.e. tension) action on the anchor. A_{Nc0} is calculated with the effective embedment depth of the anchor (h_{ef}) input into the PROFIS Engineering model. The geometry for A_{Nc0} is defined by a projected distance of $1.5h_{ef}$ from the anchor in the x and y directions. The figure below illustrates how A_{Nc0} is calculated. $A_{Nc0} = (1.5h_{ef} + 1.5h_{ef})(1.5h_{ef} + 1.5h_{ef})$$= (9.0h_{ef}^2)$ Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Calculations section of the PROFIS Engineering report for more information on A_{Nc}.

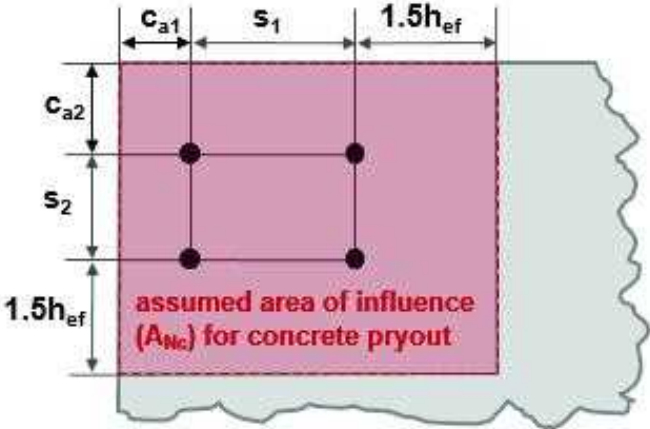
Equation $\psi_{ec,N}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{C_{Na}}\right)}$	17.5.3.1 The nominal pryout strength, ... V_{cpg} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension..... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \leq 1.0 \quad (17.4.5.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	Concrete pryout strength for a group of anchors in shear (V_{cpg}) is calculated per Eq. (17.5.3.1b). The parameter "N_{cpg}" in this equation corresponds to the nominal concrete breakout strength (N_{cbg}), calculated per Eq. (17.4.2.1b), but with respect to concrete pryout failure. It is important to understand that "N_{cbg}" calculated for concrete breakout failure in tension is not necessarily the same as "N_{cbg}" calculated for concrete pryout failure in shear. Reasons for this can include: • The number of anchors in tension is not the same as the number of anchors in shear • The tension load may be eccentric with the anchors in tension but the shear load may not be eccentric with the anchors in shear • The shear load may be eccentric with the anchors in shear but the tension load may not be eccentric with the anchors in tension • Tension and shear eccentricities are not necessarily equal When considering concrete pryout failure, the parameter "$\psi_{ec,N}$" in Eq. (17.4.2.1b) is a modification factor that accounts for shear load eccentricity. Therefore, when calculating the nominal concrete pryout strength in shear using Eq. (17.4.2.1b), the parameter $\psi_{ec,N}$ accounts for a resultant shear load that is eccentric with respect to the centroid of the anchors that are loaded in shear. $\psi_{ec,N}$ is only considered for an anchor group loaded in shear when calculating the nominal concrete pryout strength (V_{cpg}). The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cpg}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".

Equation $\psi_{ec,N}$ (continued)

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{C_{Na}}\right)}$		If shear eccentricity exists in more than one direction, PROFIS Engineering calculates a ψ-modification factor for each direction using Eq. (17.4.2.4). PROFIS Engineering designates the ψ-modification factor for eccentricity in the x-direction “$\psi_{ec1,N}$”, and the ψ-modification factor for eccentricity in the y-direction “$\psi_{ec2,N}$”. Per Section 17.4.2.4, PROFIS Engineering uses the product of these modification factors in Eq. (17.4.2.1b) to calculate the pryout parameter (N_{cpb}) per Eq. (17.5.3.1b) when shear eccentricity exists in both the x and y directions. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for shear eccentricity with respect to the x direction $e_{c2,N}$: Parameter for shear eccentricity with respect to the y direction h_{ef}: Parameter for anchor effective embedment depth Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: $\psi_{ec1,N}$: Modification factor for shear eccentricity with respect to the x direction $\psi_{ec2,N}$: Modification factor for shear eccentricity with respect to the y direction

Equation $\psi_{ed,N}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \leq 1.0$	17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,Na} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right)$ (17.4.2.5b)	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter $\psi_{ed,N}$ is a modification factor that accounts for fixed edge distances less than $1.5h_{ef}$, where h_{ef} corresponds to the effective embedment depth that has been selected for the anchor being modeled in PROFIS Engineering. The illustration below shows how the assumed area of influence with respect to pryout (A_{Nc}) would be defined for an anchoring application being modeled with two fixed edges (c_{a1} and c_{a2}) that are both less than $1.5h_{ef}$, and with c_{a1} being less than c_{a2}. The smallest edge distance (c_{a1}) corresponds to the parameter $c_{a,min}$, and would be used to calculate the modification factor $\psi_{ed,N}$.  $\psi_{ed,N} = 0.7 + 0.3 (c_{a1} / 1.5h_{ef})$ It is important to understand that “$\psi_{ed,N}$” calculated for concrete breakout failure in tension is not necessarily the same as “$\psi_{ed,N}$” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: Parameter for the smallest fixed edge being modeled h_{ef}: Parameter for anchor effective embedment depth Reference the Calculations section of the PROFIS Engineering report for more information on $\psi_{ed,N}$ when calculating concrete pryout strength.

Equation $\psi_{cp,N}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering								
$\psi_{cp,N} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5h_{ef}}{c_{ac}} \right) \leq 1.0$	17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq 1.5c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than 1.5h_{ef}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, including cast-in anchors, $\psi_{cp,N}$ shall be taken as 1.0. 17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors.</td><td>2h_{ef}</td></tr><tr><td>Undercut anchors</td><td>2.5h_{ef}</td></tr><tr><td>Torque-controlled expansion anchors</td><td>4h_{ef}</td></tr><tr><td>Displacement-controlled expansion anchor</td><td>4h_{ef}</td></tr></table>	Adhesive anchors.	2h_{ef}	Undercut anchors	2.5h_{ef}	Torque-controlled expansion anchors	4h_{ef}	Displacement-controlled expansion anchor	4h_{ef}	When calculating the nominal concrete pryout strength in shear (V_{cp} or $V_{cp,N}$), the parameter $\psi_{cp,N}$ is a modification factor that considers splitting failure for a post-installed anchor. Since ACI 318 anchoring-to-concrete provisions do not specifically consider concrete splitting as a failure mode, splitting is addressed through the $\psi_{cp,N}$ modification factor. The parameter $\psi_{cp,N}$ is only considered when designing post-installed mechanical or adhesive anchors installed in uncracked concrete. Splitting failure will typically not occur for cast-in-place anchors; therefore, the parameter $\psi_{cp,N}$ is not considered in PROFIS Engineering when modeling cast-in-place anchors. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\psi_{cp,N}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” $\psi_{cp,N}$ does not need to be calculated if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}, or if cracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2 is used to derive c_{ac} values for mechanical anchors. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR. ACI 318-14 Section 17.7.6 provides c_{ac}-values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the c_{ac}-value that is given in the ICC-ES evaluation report for an anchor to calculate $\psi_{cp,N}$. The value for $\psi_{cp,N}$ that PROFIS Engineering calculates will be limited to MAXIMUM { $c_{a,min}/c_{ac}$: 1.5h_{ef}/c_{ac} } where $c_{a,min}$ is the smallest fixed edge distance being modeled in the application and h_{ef} is the effective embedment depth that has been selected for the anchor being modeled. It is important to understand that “$\psi_{cp,N}$” calculated for concrete breakout failure in tension is not necessarily the same as “$\psi_{cp,N}$” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled c_{ac}: Value derived from testing per AC193/ACI 355.2 or AC308/ACI 355.4 for the anchor being modeled h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter $\psi_{cp,N}$.
Adhesive anchors.	2h_{ef}									
Undercut anchors	2.5h_{ef}									
Torque-controlled expansion anchors	4h_{ef}									
Displacement-controlled expansion anchor	4h_{ef}									

Equation N_b

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5}$	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor or N_{cbg} of a group of anchors, shall not exceed: a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ a) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b shall not exceed $N_b = 16 \lambda_a \sqrt{f'_c h_{ef}}^{5/3} \quad (17.4.2.2b)$	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter "N_b" corresponds to the "basic concrete breakout strength in tension" that is used to calculate a concrete breakout strength (N_{cb} or N_{cbg}). The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The parameter "coefficient for the basic concrete breakout strength in tension" (k_c) defaults to a value of 24 for cast-in-place anchors, corresponding to cracked concrete conditions. PROFIS Engineering always uses a k_c-value of 24 for cast-in-place anchors installed at an effective embedment depth (h_{ef}) less than 11 in. for both cracked and uncracked concrete conditions. When designing cast-in-place anchors in uncracked concrete, the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). The default k_c-value noted for post-installed mechanical anchors and adhesive anchor systems in ACI 318-14 Section 17.4.2.2 equals 17. This section also notes that testing per the ACI test standards ACI 355.2 and ACI 355.4 can be used to derive k_c values for these anchors. k_c values for mechanical anchors can be derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. k_c values for adhesive anchor systems can be derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. These k_c values are specific to either cracked or uncracked concrete conditions; are relevant to the effective embedment depth range for the anchor; and are provided in an ICC-ESR. PROFIS Engineering uses the k_c-value that is given in the ICC-ES evaluation report for a post-installed anchor to calculate N_b. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c: Coefficient for basic concrete breakout strength in tension λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength h_{ef}: Effective embedment depth that has been selected for the anchor being modeled $\psi_{c,N}$: Modification factor for cracked or uncracked concrete conditions Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_b.

PART 4 SHEAR LOAD / Pryout Failure Mode (Concrete Breakout)

Equation $N_b = 16\lambda_a$

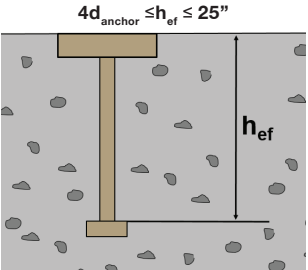
Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$N_b = 16\lambda_a \sqrt{f'_c h_{ef}}^{5/3}$	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_b determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor or N_{cbg} of a group of anchors, shall not exceed: a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ a) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_{ba}, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b shall not exceed $N_b = 16\lambda_a \sqrt{f'_c h_{ef}}^{5/3} \quad (17.4.2.2b)$	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter "N_b" corresponds to the "basic concrete breakout strength in tension" that is used to calculate a concrete breakout strength (N_{cb} or N_{cbg}). ACI 318 anchoring-to-concrete provisions for concrete breakout strength in tension require calculation of various modification factors corresponding to area of influence (A_{Nc}/A_{Nc0}), eccentricity ($\psi_{ec,N}$), edge distance ($\psi_{ed,N}$), cracked or uncracked concrete ($\psi_{c,N}$), and splitting ($\psi_{cp,N}$); and then multiplying these factors by what is termed the "basic concrete breakout strength in tension" (N_b) to obtain a "nominal concrete breakout strength in tension" (N_{cb} or N_{cbg}). The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The general equation for calculating N_b is defined as Eq. (17.4.2.2a) in ACI 318-14. This equation is written as: ACI 318 anchoring-to-concrete provisions include a special case for calculating N_b when designing cast-in-place headed studs and headed bolts installed at an embedment depth within the range $11 \text{ in} \leq h_{ef} \leq 25 \text{ in}$. This case is defined in ACI 318-14 by Eq. (17.4.2.2b). The "coefficient for the basic concrete breakout strength in tension" (k_c) equals 16 in Eq. (17.4.2.2b), and the effective embedment depth (h_{ef}) is raised to the 5/3 power instead of being raised to the 1.5 power per Eq. (17.4.2.2a). The provisions associated with use of Eq. (17.4.2.2b) are only relevant for cast-in-place headed studs and headed bolts installed at an embedment depth within the range $11 \text{ in} \leq h_{ef} \leq 25 \text{ in}$. $k_c = 16$ corresponds to cracked concrete conditions. When designing cast-in-place anchors in uncracked concrete per Eq. (17.4.2.2b); the modification factor $\psi_{c,N}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). PROFIS Engineering calculates N_b per Eq. (17.4.2.2b) when cast-in-place headed studs and headed bolts with an embedment depth $11 \text{ in} \leq h_{ef} \leq 25 \text{ in}$ are being modeled. The commentary R17.4.2.2 notes that concrete breakout calculations for $h_{ef} > 25 \text{ in}$ per Equation (17.4.2.2b) could be unconservative. PROFIS Engineering calculations for concrete breakout strength in tension limit the embedment depth for both cast-in-place and post-installed anchors to a maximum value of 25 in. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c: Coefficient for basic concrete breakout strength in tension λ_a: Lightweight concrete modification factor f'_c: Concrete compressive strength h_{ef}: Effective embedment depth that has been selected for the anchor being modeled $\psi_{c,N}$: Modification factor for cracked or uncracked concrete conditions Reference the Calculations section of the PROFIS Engineering report for more information on the parameter N_b.

PART 4 SHEAR LOAD / Pryout Failure Mode (Concrete Breakout)

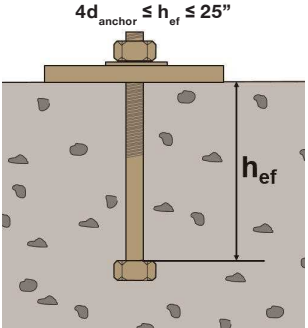
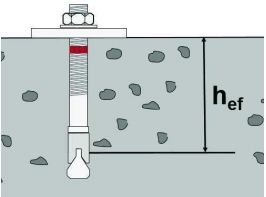
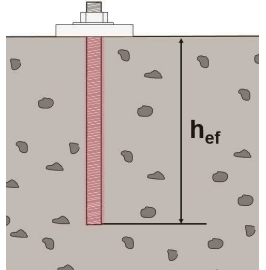
Variables k_{cp}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
k_{cp}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b). In Eq. (17.5.3.1a) and (17.5.3.1b), $k_{cp} = 1.0$ for $h_{ef} < 2.5$ in.; and $k_{cp} = 2.0$ for $h_{ef} \geq 2.5$ in.	The parameter "k_{cp}" is defined in ACI 318-14 as the "coefficient for pryout strength". The commentary R17.5.3.1 states: ".....the pryout shear resistance can be approximated as one to two times the anchor tensile resistance with the lower value appropriate for h_{ef} less than 2.5 in." PROFIS Engineering applies k_{cp} per Section 17.5.3.1 for the cast-in anchors and post-installed anchors in its portfolio.

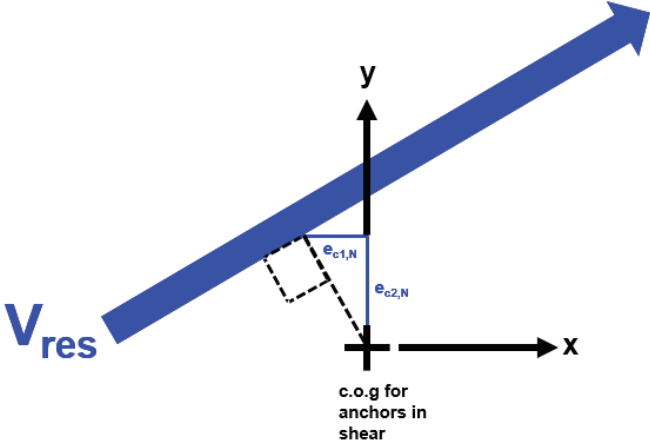
Variables h_{ef}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
h_{ef}	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors..... 17.4.2.1 A_{Nco} is the projected concrete failure area of a single anchor with an edge distance greater than $1.5h_{ef}$. $A_{Nco} = 9h_{ef}^2 \quad (17.4.2.1c)$ 17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \quad (17.4.2.4)$	h_{ef} is defined as the "effective embedment depth of an anchor". This parameter corresponds to the embedded portion of the anchor that is "effective" in transferring tension load from the anchor into the concrete. Excerpted ACI 318-14 anchoring-to-concrete provisions that include h_{ef} for calculating concrete breakout strength in tension are shown to the left. These provisions are also used to calculate concrete pryout strength in shear. It is important to understand that the calculated value for some of the parameters defined in these provisions will be dependent on whether concrete breakout failure in tension is being considered or concrete pryout failure in shear is being considered since the number of anchors in tension may be different from the number of anchors in shear. However, the parameter h_{ef} will not change when used in these provisions to calculate either concrete breakout in tension or concrete pryout in shear. For cast-in-place anchors, PROFIS Engineering permits users to input h_{ef} values ranging between $4d_{anchor}$ and 25". cast-in-place headed studs 

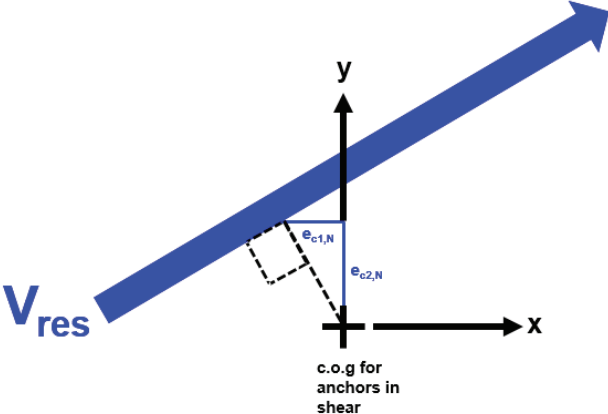
Variables h_{ef} (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
h_{ef}	17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,Na} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right)$ (17.4.2.5b) 17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq 1.5c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}^{1.5}} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c h_{ef}^{5/3}} \quad (17.4.2.2b)$	cast-in-place headed bolts $4d_{\text{anchor}} \leq h_{ef} \leq 25"$  For post-installed mechanical anchors, PROFIS Engineering permits users to input specific h_{ef} values that are relative to a specific diameter as given in the ICC-ES evaluation report for the anchor. post-installed expansion anchor (reference product approval for h_{ef})  For post-installed adhesive anchors, PROFIS Engineering permits users to input a range of h_{ef} values that are relative to a specific diameter as given in the ICC-ES evaluation report for the anchor. post-installed adhesive anchor $h_{ef,min} \leq h_{ef} \leq h_{ef,max}$ (reference product approval for $h_{ef,min}$ and $h_{ef,max}$) 

Variables $e_{c1,N}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c1,N}$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \tag{17.4.2.4}$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	$e_{c1,N}$ is a PROFIS Engineering parameter to define pryout eccentricity with respect to the x direction. The value for $e_{c1,N}$ corresponds the distance in the x direction of a resultant shear load from the centroid of anchors that are loaded in shear. When considering concrete pryout strength in shear, PROFIS Engineering uses $e_{c1,N}$ to calculate the ACI 318 modification factor for eccentricity ($\psi_{ec,N}$), and designates this modification factor $\psi_{ec1,N}$ to indicate eccentricity is being considered in the x direction. PROFIS Engineering pryout calculations for shear eccentricity with respect to the x direction are as follows: • Calculate a resultant shear load acting on the anchors • Calculate the distance in the x direction ($e_{c1,N}$) between this load and the centroid of the anchors loaded in shear • Calculate a modification factor for eccentricity ($\psi_{ec1,N}$) with respect to the x direction If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for pryout eccentricity. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cpb}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter “$e_{c1,N}$” and eccentricity in the y-direction as the parameter “$e_{c2,N}$”.  Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c2,N}$: Parameter for pryout eccentricity with respect to the y direction

Variables $e_{c2,N}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$e_{c2,N}$	17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \tag{17.4.2.4}$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	$e_{c2,N}$ is a PROFIS Engineering parameter to define pryout eccentricity with respect to the y direction. The value for $e_{c2,N}$ corresponds the distance in the y direction of a resultant shear load from the centroid of anchors that are loaded in shear. When considering concrete pryout strength in shear, PROFIS Engineering uses $e_{c2,N}$ to calculate the ACI 318 modification factor for eccentricity ($\psi_{ec,N}$), and designates this modification factor $\psi_{ec2,N}$ to indicate eccentricity is being considered in the y direction. PROFIS Engineering pryout calculations for shear eccentricity with respect to the y direction are as follows: • Calculate a resultant shear load acting on the anchors • Calculate the distance in the y direction ($e_{c2,N}$) between this load and the centroid of the anchors loaded in shear • Calculate a modification factor for eccentricity ($\psi_{ec2,N}$) with respect to the y direction If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates the eccentricity for each direction ($e_{c1,N}$ with respect to the x direction and $e_{c2,N}$ with respect to the y direction), and the $\psi_{ec,N}$ modification factor for each direction ($\psi_{ec1,N}$ for eccentricity with respect to the x direction and $\psi_{ec2,N}$ for eccentricity with respect to the y direction). $\psi_{ec1,N}$ and $\psi_{ec2,N}$ are multiplied together to give a total modification factor for pryout eccentricity. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cpb}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter “$e_{c1,N}$” and eccentricity in the y-direction as the parameter “$e_{c2,N}$”.  Reference the Variables section of the PROFIS Engineering report for more information on: $e_{c1,N}$: Parameter for pryout eccentricity with respect to the x direction

Variables $c_{a,min}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$c_{a,min}$	17.4.2.1 A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors..... 17.4.2.1 A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance greater than $1.5h_{ef}$. $A_{Nc0} = 9h_{ef}^2 \quad (17.4.2.1c)$ 17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as $\text{If } c_{a,min} \geq 1.5h_{ef}, \text{ then } \psi_{ed,N} = 1.0 \quad (17.4.2.5a)$ $\text{If } c_{a,min} < 1.5h_{ef}, \text{ then } \psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right) \quad (17.4.2.5b)$ 17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 $\text{If } c_{a,min} \geq 1.5c_{ac}, \text{ then } \psi_{cp,N} = 1.0 \quad (17.4.2.7a)$ $\text{If } c_{a,min} < c_{ac}, \text{ then } \psi_{cp,N} = \frac{c_{a,min}}{c_{ac}} \quad (17.4.2.7b)$ but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6.	$c_{a,min}$ is defined as the “minimum distance from the center of an anchor shaft to the edge of concrete.” When one or more fixed edges are modeled in PROFIS Engineering, the report will show the smallest fixed edge as “$c_{a,min}$” in the Variables section. Excerpted ACI 318-14 anchoring-to-concrete provisions that include $c_{a,min}$ for calculating concrete breakout strength in tension are shown to the left. These provisions are also used to calculate concrete pryout strength in shear. It is important to understand that the calculated value for some of the parameters defined in these provisions will be dependent on whether concrete breakout failure in tension is being considered or concrete pryout failure in shear is being considered since the number of anchors in tension may be different from the number of anchors in shear. Therefore, the parameter for $c_{a,min}$ used to calculate concrete breakout in tension may be different from the parameter for $c_{a,min}$ used to calculate concrete pryout in shear. Reference the parameters A_{Nc} and A_{Nc0} in the Equations section of the PROFIS Engineering report for more information on the following parameters: c_{a1}: Distance from the center of an anchor shaft to the edge of concrete in one direction (e.g. the x+ direction). For pryout calculations, c_{a1} is the smallest fixed edge distance c_{a2}: Distance from the center of an anchor shaft to the edge of concrete in a direction perpendicular to c_{a1} (e.g. the y+ direction) Reference the parameters $\psi_{ed,N}$ and $\psi_{cp,N}$ in the Equations and Calculations sections of the PROFIS Engineering report for more information on how $c_{a,min}$ is used to calculate these parameters when considering pryout in shear.

Variables $\psi_{c,N}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{c,N}$	17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted: (a) $\psi_{c,N} = 1.25$ for cast-in anchors (b) $\psi_{c,N} = 1.4$ for post-installed anchors, where the value of k_c used in Eq. (17.4.2.2a) is 17 $N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5} \quad (17.4.2.2a)$ Where the value of k_c used in Eq. (17.4.2.2a) is taken from the ACI 355.2 or ACI 355.4 product evaluation report for post-installed anchors shown compliance for use in both cracked and uncracked concrete, the values of k_c and $\psi_{c,N}$, shall be based on the ACI 355.2 or ACI 355.4 product evaluation report. Where the value of k_c used in Eq. (17.4.2.2a) is taken from the ACI 355.2 or ACI 355.4 product evaluation report for post-installed anchors shown compliance for use in uncracked concrete, $\psi_{c,N}$, shall be taken as 1.0. When analysis indicates cracking at service load levels, $\psi_{c,N}$, shall be taken as 1.0 for both cast-in anchors and post-installed anchors. Post-installed anchors shall be shown compliance for use in cracked concrete in accordance with ACI 355.2 or ACI 355.4. The cracking in the concrete shall be controlled by flexural reinforcement distributed in accordance with 24.3.2, or equivalent crack control shall be provided by confining reinforcement.	When calculating concrete pryout strength in shear, $\psi_{c,N}$, is a modification factor for cracked or uncracked concrete conditions. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. Concrete is typically assumed to crack under service load conditions. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing cast-in-place and post-installed anchors, since cracks in the anchor vicinity can result in a reduced ultimate load capacity and increased displacement at ultimate load, compared to uncracked concrete conditions. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions. When a cast-in-place anchor is selected for cracked concrete conditions, PROFIS Engineering sets $\psi_{c,N}$ equal to 1.0 when calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}). If uncracked concrete conditions are selected, PROFIS Engineering sets $\psi_{c,N}$ equal to 1.25. When a post-installed anchor is selected, PROFIS Engineering uses the k_c-value for cracked or uncracked concrete (depending on the condition selected) derived from testing per ACI 355.2/AC193 (mechanical anchor) or ACI 355.4/AC308 (adhesive anchor system) to calculate the basic concrete breakout strength (N_b), which is a parameter used to calculate V_{cp} or V_{cpg}. PROFIS Engineering always sets $\psi_{c,N}$ equal to 1.0 when calculating V_{cp} or V_{cpg} for a post-installed anchor. Reference the Variables section of the PROFIS Engineering report for more information on the coefficient for basic concrete breakout strength (k_c). Reference the Equations and Calculations sections for more information on the basic concrete breakout strength (N_b).

Variables c_{ac}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																													
c_{ac}	17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq 1.5c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than 1.5h_{ef}/c_{ac}, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, including cast-in anchors, $\psi_{cp,N}$ shall be taken as 1.0. 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: Adhesive anchors 2h_{ef} Undercut anchors 2.5h_{ef} Torque-controlled expansion anchors 4h_{ef} Displacement-controlled expansion anchors 4h_{ef} Example: Example of critical edge distance requirements given in a mechanical anchor approval. ICC-ES ECR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="12">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="3">1/2</th><th colspan="3">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td><td></td></tr><tr><td>Min. member thickness</td><td>h_{min}</td><td>in.</td><td>3-1/4</td><td>4</td><td>5</td><td>5</td><td>4</td><td>6</td><td>6</td><td>8</td><td>5</td><td>6</td><td>8</td><td>5-1/2</td><td>6</td><td>8</td><td>8</td></tr><tr><td>Critical edge distance</td><td>c_{ac}</td><td>in.</td><td>6</td><td>4-3/8</td><td>4</td><td>4-1/8</td><td>5-1/2</td><td>4-1/2</td><td>7-1/2</td><td>6</td><td>6-1/2</td><td>8-3/4</td><td>6-3/4</td><td>12</td><td>10</td><td>8</td><td>9</td></tr></table>	Design information	Symbol	Units	Nominal anchor diameter (in.)												3/8			1/2			5/8			3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4		Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	6	8	8	Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12	10	8	9	$\psi_{cp,N}$ is a modification factor that considers splitting failure for a post-installed anchor when calculating the nominal concrete pryout strength in shear (V_{cp} or $V_{cp,g}$). $\psi_{cp,N}$ is only considered when designing post-installed mechanical or adhesive anchors installed in uncracked concrete. Concrete cracks when tensile stresses in the concrete imposed by loads or restraint conditions exceed its tensile strength. ACI 318 anchoring-to-concrete provisions assume cracked concrete as the baseline condition for designing anchors. Uncracked concrete conditions can be assumed if it can be shown that cracking of the concrete at service load levels will not occur over the anchor service life. PROFIS Engineering defaults to cracked concrete conditions. Splitting failure is influenced by the distance of an anchor from a fixed edge “in a region of a concrete member where analysis indicates no cracking at service load levels”. The parameter c_{ac} that is used to calculate $\psi_{cp,N}$ is defined in ACI 318 as the “critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting.” Nominal concrete breakout strength in tension (N_{cb} or $N_{cb,g}$) and nominal bond strength (N_b or $N_{b,g}$) are considered when calculating nominal pryout strength in shear. Calculation of these strengths includes the parameter $\psi_{cp,N}$ when uncracked concrete conditions are assumed. Therefore, the parameter c_{ac} is also relevant to pryout calculations when uncracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2 is used to derive c_{ac} values for mechanical anchors. Values derived from this testing are provided in an ICC-ESR. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} for adhesive anchor systems is calculated using the effective embedment depth (h_{ef}), and characteristic bond stress in uncracked concrete ($\tau_{k,uncr}$). The c_{ac}-values for post-installed anchors noted in ACI 318-14 Section 17.7.6 are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering always uses the c_{ac}-value that is given (mechanical anchor) or calculated (adhesive anchor system) in the ICC-ES evaluation report for the anchor. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter $\psi_{cp,N}$. Reference the Variables section of the PROFIS Engineering report for more information on the parameter h_{ef}. Reference the Variables section for bond strength in the PROFIS Engineering report for more information on the parameter $\tau_{k,uncr}$.
Design information	Symbol				Units	Nominal anchor diameter (in.)																																																																									
		3/8				1/2			5/8			3/4																																																																			
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																			
Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	6	8	8																																																														
Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12	10	8	9																																																														

Variables c_{ac} (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
c_{ac}	Example of critical edge distance requirements given in an adhesive anchor approval. Reference ICC-ESR-3187 Section 4.1.10.2. 4.1.10.2 Threaded Rod, Steel Reinforcing Bars, and Hilti HIS-N and HIS-RN Inserts: The modification factor $\psi_{cp,Na}$ must be determined in accordance with ACI 318-14 17.4.5.5 or ACI 318-11 D.5.5 as applicable, except as noted below. For all cases where $c_{Na}/c_{ac} < 1.0$, $\psi_{cp,Na}$ determined from ACI 318-14 Eq. 17.4.5.5b or ACI 318-11 Eq. D-27, as applicable, need not be taken less than c_{Na}/c_{ac}. For all other cases $\psi_{cp,Na}$ shall be taken as 1.0. The critical edge distance c_{ac} must be calculated according to Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11, in lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6 as applicable. $c_{ac} = h_{ef} \left(\frac{\tau_{k,uncr}}{1160} \right)^{0.4} * \left[3.1 - 0.7 \frac{h}{h_{ef}} \right]$ (Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11) where $\left[\frac{h}{h_{ef}} \right]$ need not be taken as larger than 2.4; and $\tau_{k,uncr}$ is the characteristic bond strength in uncracked concrete, h is the member thickness, and h_{ef} is the embedment depth. $\tau_{k,uncr}$ need not be taken greater than: $\tau_{k,uncr} = \frac{k_{uncr}}{\pi_d} \sqrt{\frac{h_{ef}}{d}} f'_c \quad \text{Eq. (4-1)}$	

Variables k_c

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																						
k_c	17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}}^{1.5} \quad (17.4.2.2a)$ where $k_c = 24$ for cast-in anchors and 17 for post-installed anchors. The value of k_c for post-installed anchors shall be permitted to be increased above 17 based on ACI 355.2 or ACI 355.4 product-specific tests, but shall not exceed 24. $N_b = 16\lambda_a \sqrt{f'_c h_{ef}}^{5/3} \quad (17.4.2.2b)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b, shall not exceed Example: Example of k_c-values given in a mechanical anchor approval. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="2">3/4</th><th colspan="2"></th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Effective factor k_{uncr} for uncracked concrete</td><td></td><td></td><td colspan="10">24</td></tr><tr><td>Effective factor k_{cr} for cracked concrete</td><td></td><td></td><td colspan="10">17</td></tr></table> Example: Example of k_c-values given in an adhesive anchor system approval. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal Rod Diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1-1/4 or #10</th><th></th></tr><tr><td>Effectiveness factor k_{uncr} for cracked concrete</td><td>$k_{c,cr}$</td><td>in-lb</td><td colspan="10">17</td></tr><tr><td>Effectiveness factor k_{uncr} for uncracked concrete</td><td>$k_{c,uncr}$</td><td>in-lb</td><td colspan="10">24</td></tr><tr><td>Minimum Embedment</td><td>$h_{ef,min}$</td><td>in.</td><td>2 3/8</td><td>2 3/4</td><td>3 1/8</td><td>3 1/2</td><td>3 1/2</td><td>4</td><td>4 1/2</td><td>5</td><td></td></tr><tr><td>Maximum Embedment</td><td>$h_{ef,max}$</td><td>in.</td><td>7 1/2</td><td>10</td><td>12.5</td><td>15</td><td>17 1/2</td><td>20</td><td>22 1/2</td><td>25</td><td></td></tr></table>	Design information	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4				Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Effective factor k_{uncr} for uncracked concrete			24										Effective factor k_{cr} for cracked concrete			17										DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)										3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1-1/4 or #10		Effectiveness factor k_{uncr} for cracked concrete	$k_{c,cr}$	in-lb	17										Effectiveness factor k_{uncr} for uncracked concrete	$k_{c,uncr}$	in-lb	24										Minimum Embedment	$h_{ef,min}$	in.	2 3/8	2 3/4	3 1/8	3 1/2	3 1/2	4	4 1/2	5		Maximum Embedment	$h_{ef,max}$	in.	7 1/2	10	12.5	15	17 1/2	20	22 1/2	25		When calculating concrete pryout strength in shear, the parameter “N_b” corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. The parameter “coefficient for the basic concrete breakout strength in tension” (k_c) used to calculate N_b defaults to a value of 24 for cast-in-place anchors, corresponding to cracked concrete conditions. When calculating concrete pryout strength in shear (V_{cp} or V_{cpg}) for cast-in-place anchors installed at an effective embedment depth (h_{ef}) less than 11 in. PROFIS Engineering always uses a k_c-value of 24, for both cracked and uncracked concrete conditions. When designing cast-in-place anchors in uncracked concrete, the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). The default k_c-value of 17 noted for post-installed mechanical anchors and adhesive anchor systems in ACI 318-14 Section 17.4.2.2 is only intended to be used as “guide value” in the absence of k_c values derived from product-specific testing. k_c values for mechanical anchors can be derived from testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. k_c values for adhesive anchor systems can be derived from testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. These k_c values are specific to either cracked or uncracked concrete conditions; are relevant to the effective embedment depth range for the anchor; and are provided in an ICC-ESR. When calculating concrete pryout strength in shear (V_{cp} or V_{cpg}) for a post-installed anchor, PROFIS Engineering uses the k_c-value that is given in the ICC-ES evaluation report to calculate N_b per Eq. (17.4.2.2a). For cast-in-place headed studs and headed bolts installed at an embedment depth range 11 in $\leq h_{ef} \leq 25$ in k_c equals 16 per Eq. (17.4.2.2b). $k_c = 16$ corresponds to cracked concrete conditions. When designing cast-in-place anchors in uncracked concrete per Eq. (17.4.2.2b); the modification factor $\psi_{c,n}$ can be increased from a value of 1.0 (cracked concrete conditions) to a value of 1.25 (uncracked concrete conditions). When calculating concrete pryout strength in shear (V_{cp} or V_{cpg}) for cast-in-place headed studs and headed bolts with an embedment depth 11 in $\leq h_{ef} \leq 25$ in PROFIS Engineering calculates N_b per Eq. (17.4.2.2b). The report will show the k_c-value as 16. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_b. Reference the Variables section of the PROFIS Engineering report for more information on the parameter $\psi_{c,n}$.
Design information	Symbol				Units	Nominal anchor diameter (in.)																																																																																																																																		
		3/8		1/2		5/8		3/4																																																																																																																																
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																																																																												
Effective factor k_{uncr} for uncracked concrete			24																																																																																																																																					
Effective factor k_{cr} for cracked concrete			17																																																																																																																																					
DESIGN INFORMATION	Symbol	Units	Nominal Rod Diameter (in.)																																																																																																																																					
			3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1-1/4 or #10																																																																																																																														
Effectiveness factor k_{uncr} for cracked concrete	$k_{c,cr}$	in-lb	17																																																																																																																																					
Effectiveness factor k_{uncr} for uncracked concrete	$k_{c,uncr}$	in-lb	24																																																																																																																																					
Minimum Embedment	$h_{ef,min}$	in.	2 3/8	2 3/4	3 1/8	3 1/2	3 1/2	4	4 1/2	5																																																																																																																														
Maximum Embedment	$h_{ef,max}$	in.	7 1/2	10	12.5	15	17 1/2	20	22 1/2	25																																																																																																																														

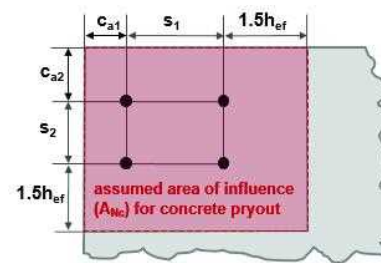
Variables λ_a

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
λ_a	17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure 1.0 λ Expansion and adhesive anchor concrete failure. 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 19.2.4 Lightweight concrete 19.2.4.1 To account for the properties of lightweight concrete, a modification factor λ is used as a multiplier of $\sqrt{f'_c}$ in all applicable provisions of this Code. 19.2.4.2 The value of λ shall be based on the composition of the aggregate in the concrete mixture in accordance with Table 19.2.4.2 or as permitted in 19.2.4.3. Table 19.2.4.2 — Modification factor λ^{(1) (2)} <table> <tr> <th>Concrete</th><th>Composition of Aggregates</th><th>λ</th></tr> <tr> <td>All-lightweight</td><td>Fine: ASTM C330 Coarse: ASTM C330</td><td>0.75</td></tr> <tr> <td>Lightweight, fine blend</td><td>Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330</td><td>0.75 to 0.85⁽¹⁾</td></tr> <tr> <td>Sand-lightweight</td><td>Fine: ASTM C33 Coarse: ASTM C330</td><td>0.85</td></tr> <tr> <td>Sand-lightweight, coarse blend</td><td>Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33</td><td>0.85 to 1⁽²⁾</td></tr> <tr> <td>Normal weight</td><td>Fine: ASTM C33 Coarse: ASTM C33</td><td>1</td></tr> </table> 1 Linear interpolation of 0.75 to 0.85 is permitted based on the absolute volume of normal weight fine friction aggregate as a fraction of the total absolute volume of fine aggregate. 2 Linear interpolation of 0.85 to 1 is permitted based on the absolute volume of normal weight coarse friction aggregate as a fraction of the total absolute volume of coarse aggregate. 19.2.4.3 If the measured average splitting tensile strength of lightweight concrete, f_{ct}, is used to calculate λ, laboratory tests shall be conducted in accordance with ASTM C330 to establish the value of f_{ct} and the corresponding value of f_{cm} and λ shall be calculated by: $\lambda = \frac{f_{ct}^{1.5}}{6.7 / f_{cm}} \leq 1.0 \quad (19.2.4.3)$ The concrete mixture tested in order to calculate λ shall be representative of that to be used in the Work. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b, shall not exceed $N_b = 16 \lambda_a \sqrt{f'_c} h_{ef}^{5/3} \quad (17.4.2.2b)$	Concrete	Composition of Aggregates	λ	All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75	Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾	Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85	Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ⁽²⁾	Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1	When calculating nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), λ_a is a modification factor for lightweight concrete that is used to calculate the parameter “N_b” per Eq. (17.4.2.2a) or Eq. (17.4.2.2b). Generally speaking, ACI 318 applies a multiplier to the parameter $\sqrt{f'_c}$ to “account for the properties of lightweight concrete”, and designates this parameter “λ”. The parameter “λ_a” is a modification of “λ” that specifically “accounts for the properties of lightweight concrete” with respect to anchoring-to-concrete calculations, hence the subscript “a” in “λ_a”. Per Section 17.2.6, the modification factor λ, determined per the provisions of Section 19.2.4, is multiplied by an additional factor that is specific to the type of anchor being used, to obtain the parameter λ_a. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. λ_a provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ES evaluation report ICC-ESR for the anchor. For post-installed anchor design, PROFIS Engineering uses a λ_a-value as referenced in the ICC-ESR provisions for the anchor. These ICC-ESR provisions typically correspond to the ACI 318 provisions for λ_a. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. Per ACI 318 provisions for determining λ_a, when designing cast-in-place anchors and post-installed undercut anchors, PROFIS Engineering uses the λ-value that has been input, for the λ_a-value to calculate N_b. When designing post-installed expansion and adhesive anchors, PROFIS Engineering multiplies the λ-value that has been input by a factor of 0.8 (expansion and adhesive anchor concrete failure) or 0.6 (adhesive anchor bond failure), for the λ_a-value to calculate N_b. Therefore, the PROFIS Engineering λ_a-value for calculating N_b, when designing cast-in-place and undercut anchors, will equal the λ-value that has been input. Likewise, the PROFIS Engineering λ_a-value for calculating N_b, when designing expansion and adhesive anchors, will equal 0.8λ since the parameter N_b is relevant to concrete failure. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_b.
Concrete	Composition of Aggregates	λ																		
All-lightweight	Fine: ASTM C330 Coarse: ASTM C330	0.75																		
Lightweight, fine blend	Fine: Combination of ASTM C330 and 33 Coarse: ASTM C330	0.75 to 0.85 ⁽¹⁾																		
Sand-lightweight	Fine: ASTM C33 Coarse: ASTM C330	0.85																		
Sand-lightweight, coarse blend	Fine: ASTM C33 Coarse: Combination of ASTM C330 and C33	0.85 to 1 ⁽²⁾																		
Normal weight	Fine: ASTM C33 Coarse: ASTM C33	1																		

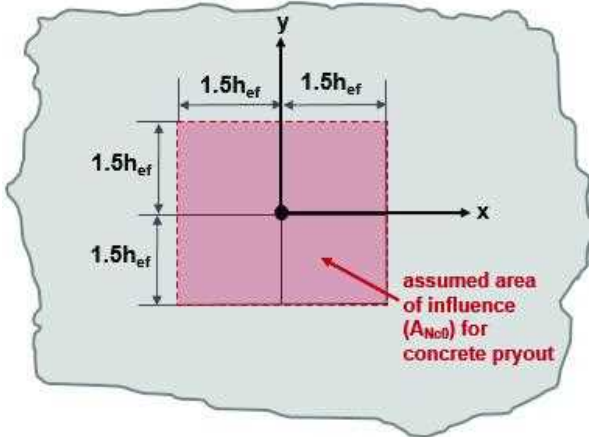
Variables f'_c

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
f'_c	17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors, and 8000 psi for post-installed anchors. Testing is required for post-installed anchors when used in concrete with f'_c greater than 8000 psi. 17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5} \quad (17.4.2.2a)$ where $k_c = 24$ for cast-in anchors and 17 for post-installed anchors. The value of k_c for post-installed anchors shall be permitted to be increased above 17 based on ACI 355.2 or ACI 355.4 product-specific tests, but shall not exceed 24. Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b, shall not exceed $N_b = 16\lambda_a \sqrt{f'_c} h_{ef}^{5/3} \quad (17.4.2.2b)$	When calculating nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), f'_c is a parameter used to define concrete compressive strength. This parameter is used to calculate the parameter "N_b", which is used to calculate a concrete breakout strength (N_{cb} or N_{cbsg}). Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. f'_c provisions for a specific post-installed anchor are derived from this testing and will be given in the ICC-ESR for the anchor. PROFIS Engineering uses these f'_c provisions for post-installed anchor design. The post-installed anchor portfolio in PROFIS Engineering is limited to installation in concrete having a specified compressive strength between 2500 psi and 8500 psi, and design using an f'_c-value less than or equal to 8000 psi. Reference the ICC-ESR for f'_c information specific to a post-installed anchor. PROFIS Engineering users can input an f'_c-value within the range 2500 psi $\leq f'_c \leq 8500$ psi for post-installed anchor design. The maximum f'_c-value for calculations will be limited to 8000 psi. PROFIS Engineering users can input an f'_c-value within the range 2500 psi $\leq f'_c \leq 10,000$ psi for cast-in-place anchor design. The maximum f'_c-value for calculations will be limited to 10,000 psi. Reference the Equations and Calculations sections of the PROFIS Engineering report for more information on the parameter N_b.

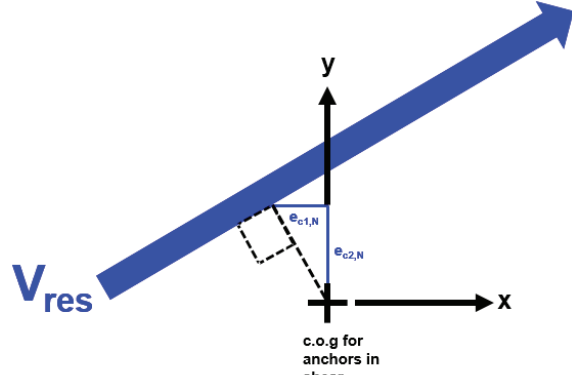
Calculations A_{Nc}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Nc}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor or N_{cbg} of a group of anchors, shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors. A_{Nc} shall not exceed nA_{Nc0}, where n is the number of anchors in the group that resist tension. A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance equal to or greater than $1.5h_{ef}$ $A_{Nc0} = 9h_{ef}^2 \quad (17.4.2.1c)$	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Nc} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor or a group of anchors creates a prying (i.e. tension) action on the anchor(s). A_{Nc} is calculated with the edge conditions and anchor spacing that have been input into the PROFIS Engineering model. The geometry for A_{Nc} is defined by projected distances from the anchors that are in shear. The maximum projected distance from an anchor that is considered when calculating A_{Nc} is limited to $1.5h_{ef}$, where h_{ef} is the effective embedment depth of the anchor. Therefore, the maximum edge distance parameter used to calculate A_{Nc} equals $1.5h_{ef}$ and the maximum spacing parameter used to calculate A_{Nc} equals $3.0h_{ef}$. Using these limits for edge distance and spacing, and defining the parameter A_{Nc0} per Eq. (17.4.2.1c), the value for A_{Nc} will never be greater than nA_{Nc0}, where n corresponds to the number of anchors in shear. This limit is described below. The figure below illustrates how A_{Nc} is calculated for pryout when a shear load acts on a group of four anchors with fixed edge distances equal to c_{a1} and c_{a2}, and spacing parameters equal to s_1 and s_2. Note that the maximum edge distance parameter used to calculate A_{Nc} equals $1.5h_{ef}$. Anchors spaced greater than $3.0h_{ef}$ from one another would not be considered to act as a group with respect to that spacing.  $A_{Nc} = (c_{a1} + s_1 + 1.5h_{ef})(c_{a2} + s_2 + 1.5h_{ef})$ where: c_{a1} and c_{a2} are $\leq 1.5h_{ef}$ s_1 and s_2 are $\leq 3.0h_{ef}$ For the example above, if $c_{a1} = c_{a2} = 1.5h_{ef}$ and $s_1 = s_2 = 3.0h_{ef}$, then A_{Nc} would equal $(1.5h_{ef} + 3.0h_{ef} + 1.5h_{ef})(1.5h_{ef} + 3.0h_{ef} + 1.5h_{ef}) = 36h_{ef}^2$. The parameter A_{Nc}/A_{Nc0} would equal $36h_{ef}^2/9h_{ef}^2 = 4$. Therefore, since the maximum edge distance parameter ($1.5h_{ef}$) and maximum spacing parameter ($3.0h_{ef}$) have been assumed, A_{Nc} equals nA_{Nc0}, where $n = 4$ corresponds to the number of anchors in the group that resist shear. It is important to understand that “A_{Nc}” calculated for concrete breakout failure in tension is not necessarily the same as “A_{Nc}” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. Reference the Variables section of the PROFIS Engineering report for more information on h_{ef}. Reference the Equations section of the PROFIS Engineering report for more information on A_{Nc}.

Calculations A_{Nc0}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
A_{Nc0}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor or V_{cpg} for a group of anchors, shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a). (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b). 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor or N_{cbg} of a group of anchors, shall not exceed: a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,Na} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ a) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ A_{Nc} is the projected concrete failure area of a single anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward $1.5h_{ef}$ from the centerlines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors. A_{Nc} shall not exceed nA_{Nc0}, where n is the number of anchors in the group that resist tension. A_{Nc0} is the projected concrete failure area of a single anchor with an edge distance equal to or greater than $1.5h_{ef}$. $A_{Nc0} = 9h_{ef}^2 \quad (17.4.2.1c)$	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter A_{Nc0} is a modification factor that accounts for the area of influence assumed to develop in concrete when a shear load applied to a single anchor without the influence of any fixed edges creates a prying (i.e. tension) action on the anchor. A_{Nc0} is calculated with the effective embedment depth of the anchor (h_{ef}) input into the PROFIS Engineering model. The geometry for A_{Nc0} is defined by a projected distance of $1.5h_{ef}$ from the anchor in the x and y directions. The figure below illustrates how A_{Nc0} is calculated.  $A_{Nc0} = (1.5h_{ef} + 1.5h_{ef})(1.5h_{ef} + 1.5h_{ef}) = (9.0h_{ef})^2$ For cast-in-place anchors, PROFIS Engineering permits users to input h_{ef} values ranging between $4d_{anchor}$ and 25". Cast-in anchors: $4d_{anchor} \leq h_{ef} \leq 25"$. For post-installed mechanical anchors, PROFIS Engineering permits users to input specific h_{ef} values that are relative to a specific diameter as given in the ICC-ES evaluation report for the anchor. Post-installed mechanical anchors: reference product approval. For post-installed adhesive anchors, PROFIS Engineering permits users to input a range of h_{ef} values that are relative to a specific diameter as given in the ICC-ES evaluation report for the anchor. Post-installed adhesive anchors: $h_{ef,min} \leq h_{ef} \leq h_{ef,max}$. Reference the product approval for $h_{ef,min}$ and $h_{ef,max}$ values. Reference the Variables section of the PROFIS Engineering report for more information on h_e. Reference the Equations section of the PROFIS Engineering report for more information on A_{Nc}.

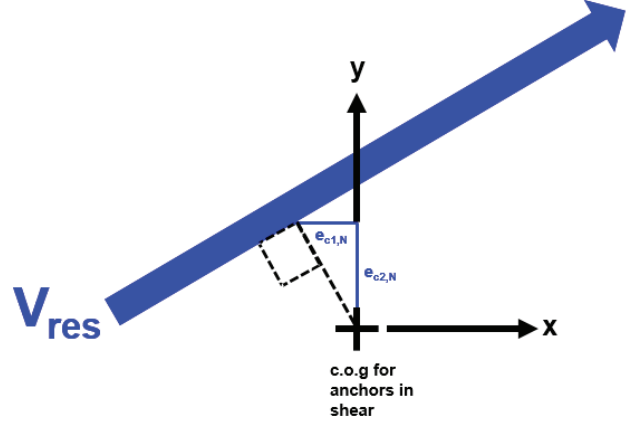
Calculations $\psi_{ec1,N}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,N}$	17.5.3.1 The nominal pryout strength, ... V_{cpg} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cpg} = k_{cp} N_{cpg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cpg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cpg} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension..... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	Concrete pryout strength for a group of anchors in shear (V_{cpg}) is calculated per Eq. (17.5.3.1b). The parameter "N_{cpg}" in this equation corresponds to the nominal concrete breakout strength (N_{cbg}), calculated per Eq. (17.4.2.1b), but with respect to concrete pryout failure. The parameter "$\psi_{ec,N}$" in Eq. (17.4.2.1b) is a modification factor that accounts for a resultant shear load that is eccentric with respect to the centroid of the anchors that are loaded in shear. $\psi_{ec,N}$ is only considered for an anchor group loaded in shear when calculating V_{cpg}. When shear load acting on a group of anchors is eccentric with respect to the x direction, PROFIS Engineering calculates "$\psi_{ec,N}$" per Eq. (17.4.2.4) and designates this parameter "$\psi_{ec1,N}$". PROFIS Engineering designates the eccentricity parameter e'_N in Eq. (17.4.2.4) "$e_{c1,N}$" to likewise indicate that the software is considering eccentricity with respect to the x direction. If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates "$\psi_{ec,N}$" for both directions. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cpg}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".  PROFIS Engineering calculates "$\psi_{ec,N}$" for both directions. $\psi_{ec1,N} = \frac{1}{\left(1 + \frac{2e_{c1,N}}{3h_{ef}}\right)} \quad \psi_{ec2,N} = \frac{1}{\left(1 + \frac{2e_{c2,N}}{3h_{ef}}\right)}$ For this example, the value for "$\psi_{ec,N}$" used in Eq. (17.4.2.1b) equals the product of $\psi_{ec1,N}$ and $\psi_{ec2,N}$: $\psi_{ec,N} = (\psi_{ec1,N})(\psi_{ec2,N})$.

Calculations $\psi_{ec1,N}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec1,N}$		Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec,N}$: Modification factor for shear eccentricity Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for shear eccentricity with respect to the x direction $e_{c2,N}$: Parameter for shear eccentricity with respect to the y direction h_{ef}: Parameter for anchor effective embedment depth Reference the Calculations section of the PROFIS Engineering report for more information on: $\psi_{ec2,N}$: Modification factor for shear eccentricity with respect to the y direction

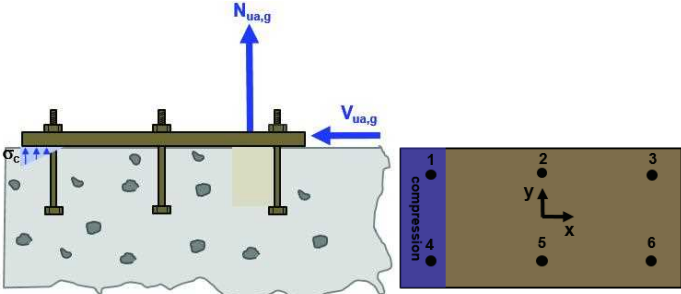
Calculations $\psi_{ec2,N}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,N}$	17.5.3.1 The nominal pryout strength, ... V_{cp} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cp} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension..... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.2.4 The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$ shall be calculated as $\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \quad (17.4.2.4)$ but $\psi_{ec,N}$ shall not be taken greater than 1.0. If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (17.4.2.4) and for the calculation of N_{cbg} according to Eq. (17.4.2.1b). In the case where eccentric loading exists about two axes, the modification factor, $\psi_{ec,N}$, shall be calculated for each axis individually and the product of these factors used as $\psi_{ec,N}$ in Eq. (17.4.2.1b).	Concrete pryout strength for a group of anchors in shear (V_{cp}) is calculated per Eq. (17.5.3.1b). The parameter "N_{cp}" in this equation corresponds to the nominal concrete breakout strength (N_{cbg}), calculated per Eq. (17.4.2.1b), but with respect to concrete pryout failure. The parameter "$\psi_{ec,N}$" in Eq. (17.4.2.1b) is a modification factor that accounts for a resultant shear load that is eccentric with respect to the centroid of the anchors that are loaded in shear. $\psi_{ec,N}$ is only considered for an anchor group loaded in shear when calculating V_{cp}. When shear load acting on a group of anchors is eccentric with respect to the y direction, PROFIS Engineering calculates "$\psi_{ec,N}$" per Eq. (17.4.2.4) and designates this parameter "$\psi_{ec2,N}$". PROFIS Engineering designates the eccentricity parameter e'_N in Eq. (17.4.2.4) "$e_{c2,N}$" to likewise indicate that the software is considering eccentricity with respect to the y direction. If the resultant shear load acting on the anchorage is eccentric with respect to both the x and y directions; PROFIS Engineering calculates "$\psi_{ec,N}$" for both directions. The illustration below shows how PROFIS Engineering considers shear eccentricity when calculating V_{cp}. The resultant shear load (V_{res}) is eccentric in both the x direction and y direction with respect to the centroid of the anchors that are in shear. PROFIS Engineering defines the eccentricity of the shear load in the x-direction as the parameter "$e_{c1,N}$" and eccentricity in the y-direction as the parameter "$e_{c2,N}$".  PROFIS Engineering calculates "$\psi_{ec,N}$" for both directions. $\psi_{ec1,N} = \frac{1}{\left(1 + \frac{2e_{c1,N}}{3h_{ef}}\right)} \quad \psi_{ec2,N} = \frac{1}{\left(1 + \frac{2e_{c2,N}}{3h_{ef}}\right)}$ For this example, the value for "$\psi_{ec,N}$" used in Eq. (17.4.2.1b) equals the product of $\psi_{ec1,N}$ and $\psi_{ec2,N}$: $\psi_{ec,N} = (\psi_{ec1,N})(\psi_{ec2,N})$.

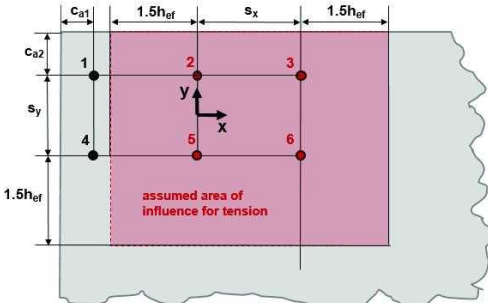
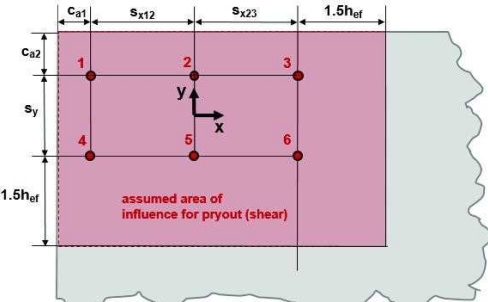
Calculations $\psi_{ec2,N}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ec2,N}$		Reference the Equations section of the PROFIS Engineering report for more information on: $\psi_{ec,N}$: Modification factor for shear eccentricity Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $e_{c1,N}$: Parameter for shear eccentricity with respect to the x direction $e_{c2,N}$: Parameter for shear eccentricity with respect to the y direction h_{ef}: Parameter for anchor effective embedment depth. Reference the Calculations section of the PROFIS Engineering report for more information on: $\psi_{ec1,N}$: Modification factor for shear eccentricity with respect to the x direction

Calculations $\psi_{ed,N}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,N}$	17.4.2.5 The modification factor for edge effects for single anchors or anchor groups loaded in tension, $\psi_{ed,N}$, shall be calculated as If $c_{a,min} \geq 1.5h_{ef}$, then $\psi_{ed,Na} = 1.0$ (17.4.2.5a) If $c_{a,min} < 1.5h_{ef}$, then $\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}} \right)$ (17.4.2.5b)	When calculating the nominal concrete pryout strength in shear (V_{cp} or V_{cpg}), the parameter $\psi_{ed,N}$ is a modification factor that accounts for fixed edge distances less than $1.5h_{ef}$, where h_{ef} corresponds to the effective embedment depth that has been selected for the anchor being modeled in PROFIS Engineering. It is important to understand that “$\psi_{ed,N}$” calculated for concrete breakout failure in tension is not necessarily the same as “$\psi_{ed,N}$” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. In the illustration below, a fixture is being attached with six anchors, which are numbered 1-6. Anchors 2, 3, 5 and 6 are subjected to a tension load, but all six anchors are subjected to a shear load. The edge distance c_{a1} is less than the edge distance c_{a2}, and both edge distances are less than $1.5h_{ef}$.  Since anchors 1 and 4 are in compression, the fixed edge distance in the -x direction from anchors 2 and 5 that is relevant to concrete breakout in tension calculations equals c_{a1} + the spacing between anchors 1 and 2 (s_{x12}). Assuming $c_{a1} + s_{x12}$ is greater than $1.5h_{ef}$, the only fixed edge distance that is considered for $\psi_{ed,N}$ when calculating concrete breakout in tension is the distance in the +y direction (c_{a2}). $\psi_{ed,N} = 0.7 + 0.3 (c_{a1} / 1.5h_{ef})$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: Parameter for the smallest fixed edge being modeled h_{ef}: Parameter for anchor effective embedment depth Reference the Equations section of the PROFIS Engineering report for more information on $\psi_{ed,N}$ when calculating concrete pryout strength.

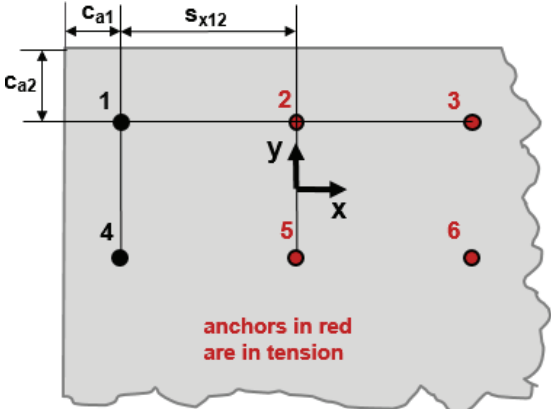
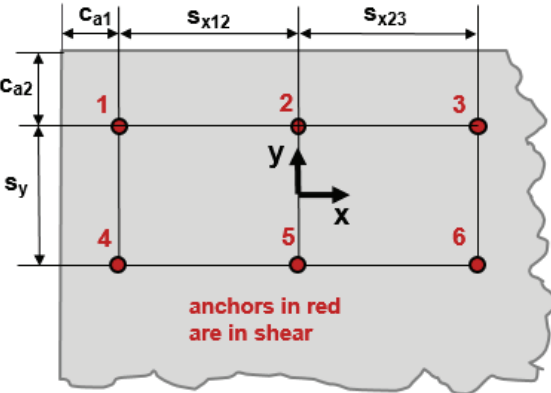
Calculations $\psi_{ed,N}$ (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{ed,N}$		$\psi_{ed,N}$ would be calculated for concrete breakout in tension as follows: $\psi_{ed,N} = 0.7 + 0.3 (c_{a2} / 1.5h_{ef})$  All six anchors are in shear, so both c_{a1} and c_{a2} (which are less than $1.5h_{ef}$) are considered for $\psi_{ed,N}$ when calculating concrete pryout in shear. Since c_{a1} is less than c_{a2}, $\psi_{ed,N}$ would be calculated for concrete pryout in shear using c_{a1} as follows:  $\psi_{ed,N} = 0.7 + 0.3 (c_{a1} / 1.5h_{ef})$ Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: Parameter for the smallest fixed edge being modeled h_{ef}: Parameter for anchor effective embedment depth Reference the Equations section of the PROFIS Engineering report for more information on $\psi_{ed,N}$ when calculating concrete pryout strength.

Calculations $\psi_{cp,N}$

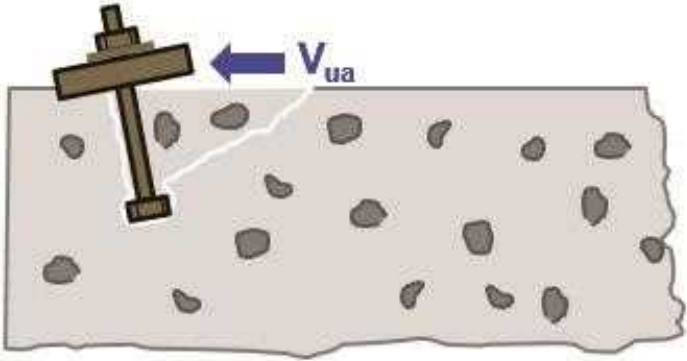
Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																		
$\psi_{cp,N}$	17.4.2.7 The modification factor for post-installed anchors designed for uncracked concrete in accordance with 17.4.2.6 without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be calculated as follows using the critical distance c_{ac} as defined in 17.7.6 If $c_{a,min} \geq 1.5c_{ac}$, then $\psi_{cp,N} = 1.0$ (17.4.2.7a) If $c_{a,min} < c_{ac}$, then $\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}}$ (17.4.2.7b) but $\psi_{cp,N}$ determined from Eq. (17.4.2.7b) shall not be taken less than $1.5h_{ef}/c_{ac}$, where the critical distance c_{ac} is defined in 17.7.6. For all other cases, including cast-in anchors, $\psi_{cp,N}$ shall be taken as 1.0. 17.4.2.6 For anchors located in a region of a concrete member where analysis indicates no cracking at service load levels..... 17.7.6 Unless determined from tension tests in accordance with ACI 355.2 or ACI 355.4, the critical edge distance c_{ac} shall not be taken less than: <table><tr><td>Adhesive anchors.....</td><td>$2h_{ef}$</td></tr><tr><td>Undercut anchors.....</td><td>$2.5h_{ef}$</td></tr><tr><td>Torque-controlled expansion anchors.....</td><td>$4h_{ef}$</td></tr><tr><td>Displacement-controlled expansion anchor.....</td><td>$4h_{ef}$</td></tr></table> Example: Example of critical edge distance requirements given in a mechanical anchor approval. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="12">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="3">1/2</th><th colspan="3">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td><td></td><td></td></tr><tr><td>Min. member thickness</td><td>h_{min}</td><td>in.</td><td>3-1/4</td><td>4</td><td>5</td><td>5</td><td>4</td><td>6</td><td>6</td><td>8</td><td>5</td><td>6</td><td>8</td><td>5-1/2</td><td>6</td></tr><tr><td>Critical edge distance</td><td>c_{ac}</td><td>in.</td><td>6</td><td>4-3/8</td><td>4</td><td>4-1/8</td><td>5-1/2</td><td>4-1/2</td><td>7-1/2</td><td>6</td><td>6-1/2</td><td>8-3/4</td><td>6-3/4</td><td>12</td><td>10</td></tr></table> Example: Example of critical edge distance requirements given in an adhesive anchor approval. Reference ICC-ESR-3187 Section 4.1.10.2.	Adhesive anchors.....	$2h_{ef}$	Undercut anchors.....	$2.5h_{ef}$	Torque-controlled expansion anchors.....	$4h_{ef}$	Displacement-controlled expansion anchor.....	$4h_{ef}$	Design information	Symbol	Units	Nominal anchor diameter (in.)												3/8			1/2			5/8			3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4			Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	6	Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12	10	The parameter $\psi_{cp,N}$ is only considered when designing post-installed anchors in uncracked concrete. $\psi_{cp,N}$ does not need to be calculated if the smallest fixed edge distance ($c_{a,min}$) is greater than or equal to c_{ac}, or if cracked concrete conditions are assumed. Testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2 is used to derive c_{ac} values for mechanical anchors. Testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4 is used to derive c_{ac} values for adhesive anchor systems. c_{ac} values derived from this testing are provided in an ICC-ESR. ACI 318-14 Section 17.7.6 provides c_{ac}-values for post-installed anchors; however, these values are only intended to be used as “guide values” in the absence of c_{ac} values derived from product-specific testing. PROFIS Engineering uses the c_{ac}-value that is given in the ICC-ES evaluation report for an anchor to calculate $\psi_{cp,N}$. The value for $\psi_{cp,N}$ that PROFIS Engineering calculates will be limited to MAXIMUM $\{c_{a,min}/c_{ac} : 1.5h_{ef}/c_{ac}\}$, where $c_{a,min}$ is the smallest fixed edge distance being modeled in the application and h_{ef} is the effective embedment depth that has been selected for the anchor. “$\psi_{cp,N}$” calculated for concrete breakout failure in tension is not necessarily the same as “$\psi_{cp,N}$” calculated for concrete pryout failure in shear since the number of anchors in tension may not be the same as the number of anchors in shear. When calculating concrete breakout in tension, values for c_{ac} should be checked against fixed edge distances relevant to anchors in tension. When calculating concrete pryout in shear, values for c_{ac} should be checked against fixed edge distances relevant to anchors in shear. Consider: 4-anchors in tension and 6-anchors in shear.
Adhesive anchors.....	$2h_{ef}$																																																																																			
Undercut anchors.....	$2.5h_{ef}$																																																																																			
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Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																								
Min. member thickness	h_{min}	in.	3-1/4	4	5	5	4	6	6	8	5	6	8	5-1/2	6																																																																					
Critical edge distance	c_{ac}	in.	6	4-3/8	4	4-1/8	5-1/2	4-1/2	7-1/2	6	6-1/2	8-3/4	6-3/4	12	10																																																																					

Calculations $\psi_{cp,N}$ (continued)

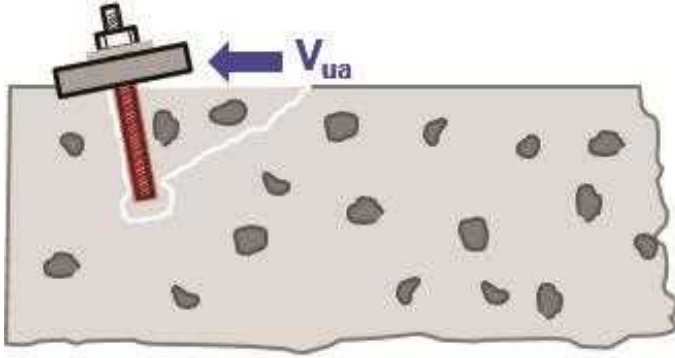
Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\psi_{cp,N}$	4.1.10.2 Threaded Rod, Steel Reinforcing Bars, and Hilti HIS-N and HIS-RN Inserts: The modification factor $\psi_{cp,Na}$ must be determined in accordance with ACI 318-14 17.4.5.5 or ACI 318-11 D.5.5 as applicable, except as noted below. For all cases where $c_{Na}/c_{ac} < 1.0$, $\psi_{cp,Na}$ determined from ACI 318-14 Eq. 17.4.5.5b or ACI 318-11 Eq. D-27, as applicable, need not be taken less than c_{Na}/c_{ac}. For all other cases $\psi_{cp,Na}$ shall be taken as 1.0. The critical edge distance c_{ac} must be calculated according to Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11, in lieu of ACI 318-14 17.7.6 or ACI 318-11 D.8.6 as applicable. $c_{ac} = h_{ef} \left(\frac{\tau_{k,uncr}}{1160} \right)^{0.4} * \left[3.1 - 0.7 \frac{h}{h_{ef}} \right]$ (Eq. 17.4.5.5c for ACI 318-14 or Eq. D-27a for ACI 318-11) where $\left[\frac{h}{h_{ef}} \right]$ need not be taken as larger than 2.4; and $\tau_{k,uncr}$ is the characteristic bond strength in uncracked concrete, h is the member thickness, and h_{ef} is the embedment depth. $\tau_{k,uncr}$ need not be taken greater than: $\tau_{k,uncr} = \frac{k_{uncr}}{\pi d} \sqrt{h_{ef} f'_c} \quad \text{Eq. (4-1)}$	Concrete breakout calculations in tension: $c_{a,min} = \text{MIN}\{c_{a1} + s_{x12}; c_{a2}\}$. Check MAXIMUM $\{c_{a,min}/c_{ac} : 1.5h_{ef}/c_{ac}\}$.  Concrete breakout calculations in shear: $c_{a,min} = \text{MIN}\{c_{a1} : c_{a2}\}$. Check MAXIMUM $\{c_{a,min}/c_{ac} : 1.5h_{ef}/c_{ac}\}$.  Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: $c_{a,min}$: The smallest fixed edge distance being modeled c_{ac}: Value derived from testing per AC193/ACI 355.2 or AC308/ACI 355.4 for the anchor being modeled h_{ef}: Effective embedment depth that has been selected for the anchor being modeled Reference the Calculations section of the PROFIS Engineering report for more information on the parameter $\psi_{cp,N}$.

Calculations N_b

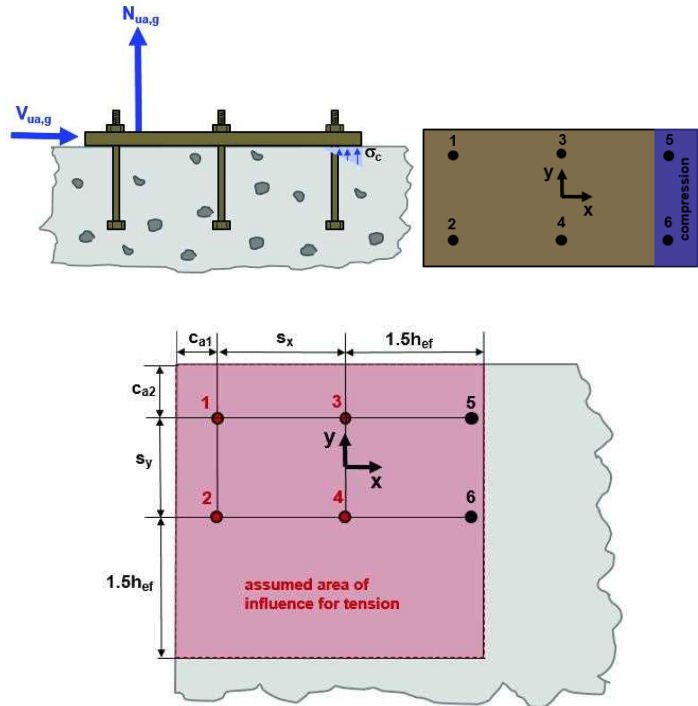
Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																		
N_b	17.4.2.2 The basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b, shall not exceed $N_{ba} = k_c \lambda_a \sqrt{f'_c h_{ef}^{1.5}} \quad (17.4.2.2a)$ Alternatively, for cast-in headed studs and headed bolts with 11 in. $\leq h_{ef} \leq 25$ in., N_b shall not exceed $N_b = 16\lambda_a \sqrt{f'_c h_{ef}^{5/3}} \quad (17.4.2.2b)$ Example: Example of k_c-values given in a mechanical anchor approval. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Effectiveness factor k_{uncr} for uncracked concrete</td><td></td><td></td><td colspan="10">24</td></tr><tr><td>Effectiveness factor k_{uncr} for cracked concrete</td><td></td><td></td><td colspan="10">17</td></tr></table> Example: Example of k_c-values given in an adhesive anchor system approval. ICC-ESR-3187 Table 12 <table><tr><th rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th>3/8 or #3</th><th>1/2 or #4</th><th>5/8 or #5</th><th>3/4 or #6</th><th>7/8 or #7</th><th>1 or #8</th><th>#9</th><th>1-1/4 or #10</th></tr><tr><td>Effectiveness factor k_{uncr} for cracked concrete</td><td>$k_{c,cr}$</td><td>in-lb</td><td colspan="10">17</td></tr><tr><td>Effectiveness factor for uncracked concrete</td><td>$k_{c,uncr}$</td><td>in-lb</td><td colspan="10">24</td></tr><tr><td>Minimum embedment</td><td>$h_{ef,min}$</td><td>in.</td><td>2-3/8</td><td>2-3/4</td><td>3-1/8</td><td>3-1/2</td><td>3-1/2</td><td>4</td><td>4-1/2</td><td>5</td></tr><tr><td>Maximum embedment</td><td>$h_{ef,max}$</td><td>in.</td><td>7-1/2</td><td>10</td><td>12-1/2</td><td>15</td><td>17-1/2</td><td>20</td><td>22-1/2</td><td>25</td></tr></table> 17.2.6 Modification factor λ_a for lightweight concrete shall be taken as: Cast-in and undercut anchor concrete failure 1.0 λ Expansion and adhesive anchor concrete failure. 0.8 λ Adhesive anchor bond failure per Eq. (17.4.5.2) 0.6 λ where λ is determined in accordance with 19.2.4. It shall be permitted to use an alternative value of λ_a where tests have been performed and evaluated in accordance with ACI 355.2 or ACI 355.4. 17.2.7 The values of f'_c used for calculation purposes in this chapter shall not exceed 10,000 psi for cast-in anchors, and 8000 psi for post-installed anchors. Testing is required for post-installed anchors when used in concrete with f'_c greater than 8000 psi.	Design information	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Effectiveness factor k_{uncr} for uncracked concrete			24										Effectiveness factor k_{uncr} for cracked concrete			17										DESIGN INFORMATION	Symbol	Units	Nominal anchor diameter (in.)										3/8 or #3	1/2 or #4	5/8 or #5	3/4 or #6	7/8 or #7	1 or #8	#9	1-1/4 or #10	Effectiveness factor k_{uncr} for cracked concrete	$k_{c,cr}$	in-lb	17										Effectiveness factor for uncracked concrete	$k_{c,uncr}$	in-lb	24										Minimum embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5	Maximum embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25	The parameter N_b corresponds to a calculated concrete breakout strength for a single anchor without any fixed edge or spacing influences. PROFIS Engineering uses $k_c = 24$ to calculate N_b for cast-in anchors installed at an effective embedment depth (h_{ef}) less than 11", and $k_c = 16$ to calculate N_b for cast-in anchors installed at an effective embedment depth 11" $\leq h_{ef} \leq 25$". PROFIS Engineering uses the k_c-value given in the ICC-ES evaluation report for an anchor to calculate N_b for post-installed anchors. PROFIS Engineering users can input a λ-value based on the properties of the lightweight concrete being used in the application. Any λ-value between 0.75 and 1.0 can be input. PROFIS Engineering uses the provisions of ACI 318-14 Section 17.2.6 to calculate λ_a. PROFIS Engineering users can input an f'_c-value within the range 2500 psi $\leq f'_c \leq 8500$ psi for post-installed anchor design. The maximum f'_c-value for post-installed anchor calculations will be limited to 8000 psi. PROFIS Engineering users can input an f'_c-value within the range 2500 psi $\leq f'_c \leq 10,000$ psi for cast-in anchor design. The maximum f'_c-value for cast-in anchor calculations will also equal 10,000 psi. PROFIS Engineering permits users to input an effective embedment depth (h_{ef}) value ranging between 4d_{anchor} and 25" for cast-in anchors. For post-installed mechanical anchors, PROFIS Engineering permits users to input a specific h_{ef} value that given in the ICC-ES evaluation report for the anchor. For post-installed adhesive anchors, PROFIS Engineering permits users to input an h_{ef} value in the range $h_{ef,min} \leq h_{ef} \leq h_{ef,max}$. Reference the product approval for $h_{ef,min}$ and $h_{ef,max}$ values. Reference the Variables section of the PROFIS Engineering report for more information on the following parameters: k_c : Coefficient for basic concrete breakout strength in tension λ_a : Lightweight concrete modification factor f'_c : Concrete compressive strength h_{ef} : Effective embedment depth $\psi_{c,N}$: Modification factor for cracked or uncracked concrete conditions Reference the Equations section of the PROFIS Engineering report for more information on the parameter N_b.
Design information	Symbol				Units	Nominal anchor diameter (in.)																																																																																																																														
		3/8		1/2		5/8		3/4																																																																																																																												
Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4																																																																																																																								
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Effectiveness factor k_{uncr} for cracked concrete	$k_{c,cr}$	in-lb	17																																																																																																																																	
Effectiveness factor for uncracked concrete	$k_{c,uncr}$	in-lb	24																																																																																																																																	
Minimum embedment	$h_{ef,min}$	in.	2-3/8	2-3/4	3-1/8	3-1/2	3-1/2	4	4-1/2	5																																																																																																																										
Maximum embedment	$h_{ef,max}$	in.	7-1/2	10	12-1/2	15	17-1/2	20	22-1/2	25																																																																																																																										

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cp}	17.5.3.1 The nominal pryout strength, V_{cp} for a single anchor shall not exceed: (a) For a single anchor $V_{cp} = k_{cp} N_{cp} \quad (17.5.3.1a)$ For cast-in, expansion, and undercut anchors, N_{cp} shall be taken as N_{cb} determined from Eq. (17.4.2.1a), and for adhesive anchors, N_{cp} shall be the lesser of N_a determined from Eq. (17.4.5.1a) and N_{cb} determined from Eq. (17.4.2.1a) 17.4.2.1 The nominal concrete breakout strength in tension, N_{cb} of a single anchor shall not exceed: (a) For a single anchor $N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1a)$ 17.4.5.1 The nominal bond strength in tension, N_a of a single adhesive anchor shall not exceed: (a) For a single adhesive anchor $N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1a)$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. When designing cast-in-place anchors and post-installed mechanical anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a single anchor (V_{cp}) as the product of the coefficient for pryout strength (k_{cp}) and the nominal concrete breakout strength in tension for a single anchor (N_{cp}). ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a single adhesive anchor (V_{cp}) as the product of k_{cp} and the smaller of (N_{cb}) and the nominal bond strength for a single anchor (N_a). The concrete breakout strength parameter (N_{cb}) for pryout failure in shear is calculated per ACI 318-14 Eq. (17.4.2.1a), but predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. Note that (17.5.3.1a) denotes the “concrete pryout strength” parameter “N_{cp}” to distinguish it from the tension concrete breakout strength parameter “N_{cb}”. For the example illustrated below, a single anchor is subjected to only a shear load. No tension load acts on the anchor; therefore, nominal concrete breakout in tension (N_{cb}) is not calculated, but a pryout parameter “N_{cp}” corresponding to N_{cb} calculated per Eq. (17.4.2.1a) is calculated. cast-in anchors and mechanical anchors No tension load applied: $N_{cb} = 0$. Shear load applied, so calculate concrete pryout ($k_{cp} N_{cp}$). cast in anchor: $V_{cp} = k_{cp} N_{cb}$ mechanical anchor: $V_{cp} = k_{cp} N_{cb}$  The diagram shows a cross-section of a concrete slab with several aggregate stones. A single anchor is embedded in the concrete. A horizontal blue arrow labeled V_{ua} points to the left, representing the shear load applied to the anchor. The anchor is shown as a metal rod with a nut and washer on top. A diagonal crack is visible in the concrete, extending from the base of the anchor towards the right, indicating a potential failure mode.

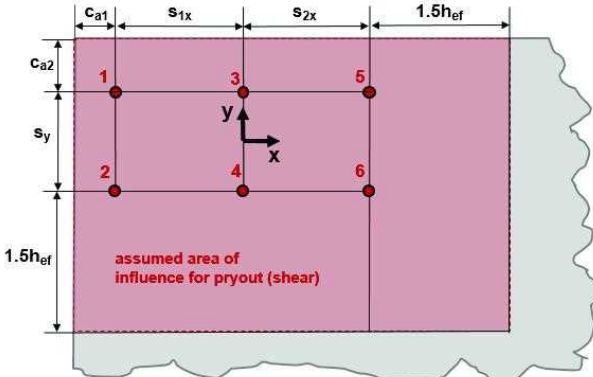
Results V_{cp} (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cp}		adhesive anchor systems No tension load applied: $N_{cb} = 0$. Shear load applied, so calculate concrete pryout ($k_{cp} N_{cp}$). adhesive anchor system: $V_{cp} = k_{cp} \text{MIN}\{N_{cb} ; N_a\}$.  Reference the Variables section of the PROFIS Engineering report for information on: $\psi_{c,N}$: Modification factor for cracked concrete k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for more information on the following parameters: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\psi_{ed,N}$: Tension modification factor for edge distance $\psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension

Results V_{cpg}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cpg}	17.5.3.1 The nominal pryout strength, ... V_{cpg} for a group of anchors, shall not exceed: (b) For a group of anchors $V_{cpg} = k_{cp} N_{cbg} \quad (17.5.3.1b)$ For cast-in, expansion, and undercut anchors, N_{cbg} shall be taken as N_{cbg} determined from Eq. (17.4.2.1b), and for adhesive anchors, N_{cp} shall be the lesser of N_{ag} determined from Eq. (17.4.5.1b) and N_{cbg} determined from Eq. (17.4.2.1b) 17.4.2.1 The nominal concrete breakout strength in tension, ... N_{cbg} of a group of anchors, shall not exceed: (b) For a group of anchors $N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \quad (17.4.2.1b)$ 17.4.5.1 The nominal bond strength in tension..... N_{ag} of a group of adhesive anchors, shall not exceed (b) For a group of adhesive anchors: $N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$ Summary of ACI 318-14 pryout calculations. cast-in anchors and mechanical anchors cast in anchor: $V_{cpg} = k_{cp} N_{cbg}$ mechanical anchor: $V_{cpg} = k_{cp} N_{cbg}$ adhesive anchor systems adhesive anchor system: $V_{cpg} = k_{cp} \text{MIN} \{N_{cbg}; N_{ag}\}.$	Concrete pryout is a shear failure mode that is calculated for cast-in-place anchors and post-installed anchors. When designing cast-in-place anchors and post-installed mechanical anchors, ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a group of anchors (V_{cpg}) as the product of the coefficient for pryout strength (k_{cp}) and the nominal concrete breakout strength in tension for a group of anchors (N_{cbg}). ACI 318-14 Section 17.5.3.1 defines the nominal pryout strength for a group of adhesive anchors (V_{cpg}) as the product of k_{cp} and the smaller of (N_{cbg}) and the nominal bond strength for a group of anchors (N_{ag}). The concrete breakout strength parameter (N_{cbg}) for pryout failure in shear is calculated per ACI 318-14 Eq. (17.4.2.1b), but predicated on the number of anchors subjected to shear load, which may be different than the number of anchors subjected to tension load. Note that (17.5.3.1b) denotes the “concrete pryout strength” parameter “N_{cp}” to distinguish it from the tension concrete breakout strength parameter “N_{cbg}”. For the example illustrated below, four anchors are subjected to a tension load, but all six anchors are subjected to a shear load. Therefore, nominal concrete breakout in tension (N_{cbg}) is calculated for anchors 1,2,3 and 4; but a pryout parameter “N_{cp}” corresponding to N_{cbg} calculated per Eq. (17.4.2.1a) is calculated for anchors 1,2,3,4,5 and 6. 

Results V_{cpg} (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_{cpg}		 Reference the Variables section of the PROFIS Engineering report for information on: $\Psi_{c,N}$: Modification factor for cracked concrete k_{cp}: Coefficient for pryout strength Reference the Calculations section of the PROFIS Engineering report for information on: A_{Nc}: Area of influence for anchors in tension A_{Nc0}: Area of influence for single anchor in tension $\Psi_{ec,N}$: Tension modification factor for eccentricity $\Psi_{ed,N}$: Tension modification factor for edge distance $\Psi_{cp,N}$: Modification factor for splitting N_b: Basic concrete breakout strength in tension

Results ϕ_{seismic}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering						
ϕ_{seismic}	17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors ϕN_{sa} corresponds to steel failure (tension) in Table 17.3.1.1] (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided $[\phi N_{cb}$ or $\phi N1$ correspond to concrete breakout failure (tension) in Table 17.3.1.1] (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors $[\phi N_{pn}$ corresponds to pullout failure (tension) in Table 17.3.1.1] (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ $[\phi N_{sb}$ or ϕN_{sbg} correspond to side-face blowout failure (tension) in Table 17.3.1.1] (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ ϕN_a or ϕN_{ag} correspond to bond failure (tension) in Table 17.3.1.1] where ϕ is in accordance with 17.3.3. 17.3.3 Strength reduction factor ϕ-for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (c) Anchor governed by concrete breakout, side-face blowout, pullout, or pryout strength <table> <tr> <th></th><th>Condition A</th><th>Condition B</th></tr> <tr> <td>(i) Shear loads</td><td>0.75</td><td>0.70</td></tr> </table> Condition A applies where supplementary reinforcement is present except for pullout and pryout strengths. Condition B applies where supplementary reinforcement is not present, and for pullout and pryout strengths. PROFIS Engineering calculations for concrete breakout failure in tension when seismic load conditions are being modeled: single anchor: design concrete breakout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{cb}$. anchor group: design concrete breakout strength = $\phi_{\text{seismic}} \phi_{\text{concrete}} N_{cbg}$. PROFIS Engineering calculations for concrete pryout failure in shear when seismic load conditions are being modeled: single anchor: design concrete pryout strength = $\phi_{\text{concrete}} V_{cp}$. anchor group: design concrete pryout strength = $\phi_{\text{concrete}} V_{cpg}$.		Condition A	Condition B	(i) Shear loads	0.75	0.70	When designing an anchorage for seismic tension load conditions, ACI 318-14 provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by two strength reduction factors (ϕ-factors): one ϕ-factor for concrete breakout failure in tension, and one ϕ-factor for seismic tension load conditions, to obtain a design strength ($0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$). PROFIS Engineering designates the 0.75 seismic tension reduction factor noted in ACI 318-14 Section 17.2.3.4.4 "ϕ_{seismic}". This reduction is only considered with respect to non-steel tension failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors subjected to seismic tension loads. When designing an anchorage for seismic shear load conditions, ACI 318-14 strength design provisions for concrete pryout failure in shear require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}) that is only multiplied by one ϕ-factor to obtain a shear design strength (ϕV_{cp} or ϕV_{cpg}). PROFIS Engineering designates this ϕ-factor "ϕ_{concrete}". The 0.75 seismic strength reduction factor (ϕ_{seismic}) required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cp} or V_{cpg} when the anchorage is being designed for seismic shear load conditions. The PROFIS Engineering report always shows ϕ_{seismic} equal to 1.0 for shear concrete pryout calculations when seismic shear load conditions are being modeled. When calculating the design concrete pryout strength in shear for cast-in-place anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report is taken from Section 17.3.3(c)(i). When calculating the design concrete pryout strength in shear for post-installed anchors, the parameter "ϕ_{concrete}" in the PROFIS Engineering report corresponds to the "Condition B" ϕ-factor for shear given in the ICC-ESR for the anchor. Per ACI 318-14 Section 17.3.3, Condition A is not considered for pryout strength calculations. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp} or V_{cpg}: Nominal concrete pryout strength in shear ϕV_{cp} or ϕV_{cpg}: Design concrete pryout strength in shear ϕ_{concrete}: Strength reduction factor for shear concrete pryout failure
	Condition A	Condition B						
(i) Shear loads	0.75	0.70						

Results $\phi_{\text{nonductile}}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.4.4 17.2.3.4.4 The anchor design tensile strength for resisting earthquake forces shall be determined from consideration of (a) through (e) for the failure modes given in Table 17.3.1.1 assuming the concrete is cracked unless it can be demonstrated that the concrete remains uncracked: (a) ϕN_{sa} for a single anchor or for the most highly stressed individual anchor in a group of anchors (b) $0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$ except that N_{cb} or N_{cbg} need not be calculated where anchor reinforcement satisfying 17.4.2.9 is provided (c) $0.75\phi N_{pn}$ for a single anchor or for the most highly stressed individual anchor in a group of anchors (d) $0.75\phi N_{sb}$ or $0.75\phi N_{sbg}$ (e) $0.75\phi N_a$ or $0.75\phi N_{ag}$ where ϕ is in accordance with 17.3.3. ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	When designing an anchorage for seismic tension load conditions, ACI 318-14 provisions for concrete breakout failure in tension require calculation of a nominal concrete breakout strength (N_{cb} or N_{cbg}). The nominal strength is multiplied by two strength reduction factors (ϕ-factors): one ϕ-factor for concrete breakout failure in tension, and one ϕ-factor for seismic tension load conditions, to obtain a design strength ($0.75\phi N_{cb}$ or $0.75\phi N_{cbg}$). PROFIS Engineering designates the 0.75 seismic tension reduction factor noted in ACI 318-14 Section 17.2.3.4.4 “ϕ_{seismic}”. This reduction is only considered with respect to non-steel tension failure modes when calculating tension design strengths for both cast-in-place and post-installed anchors subjected to seismic tension loads. When designing an anchorage for seismic shear load conditions, ACI 318-14 strength design provisions for concrete pryout failure in shear require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}) that is only multiplied by one ϕ-factor to obtain a shear design strength (ϕV_{cp} or ϕV_{cpg}). PROFIS Engineering designates this ϕ-factor “ϕ_{concrete}”. The 0.75 seismic strength reduction factor (ϕ_{seismic}) required per Section 17.2.3.4.4 is only relevant to tension calculations, and is therefore not applied to V_{cp} or V_{cpg} when the anchorage is being designed for seismic shear load conditions. The parameter “$\phi_{\text{nonductile}}$” is a reduction factor for seismic tension and seismic shear load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor “$\phi_{\text{nonductile}}$”. “$\phi_{\text{nonductile}}$” is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

Results ϕV_{cp}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cp}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Single Anchor $\phi V_{cp} > V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal concrete pryout strength in shear ϕV_{cp}: Design concrete pryout strength in shear $\phi V_{cp} \geq V_{ua}$: Design check for pryout Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: Strength reduction factor for seismic shear V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

Results ϕV_{cpg}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_{cpg}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 Failure Mode Concrete Pryout Strength in Shear Anchors as a Group $\phi V_{cpg} > V_{ua}$	ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). Reference the Equations section of the PROFIS Engineering report for more information on the following parameters: V_{cpg}: Nominal concrete pryout strength in shear ϕV_{cpg}: Design concrete pryout strength in shear $\phi V_{cpg} \geq V_{ua}$: Design check for pryout Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cpg}: Nominal concrete pryout strength in shear $\phi_{concrete}$: Strength reduction factor for concrete failure $\phi_{seismic}$: strength reduction factor for seismic shear V_{ua}: factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

Results V_{ua}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
V_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the shear failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi V_{sa} \geq V_{ua}$</td><td>$\phi V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi V_{cb} \geq V_{ua}$</td><td></td><td>$\phi V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi V_{cp} \geq V_{ua}$</td><td></td><td>$\phi V_{cpg} \geq V_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi V_{cb} \geq V_{ua}$		$\phi V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi V_{cp} \geq V_{ua}$		$\phi V_{cpg} \geq V_{ua,g}$	ACI 318-14 strength design provisions for concrete pryout failure in shear require calculation of a nominal concrete pryout strength (V_{cp} or V_{cpg}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{cp} or ϕV_{cpg}). Design strength is checked against a factored shear load, defined by the parameter "V_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored shear load parameter "V_{ua}". • V_{ua} = factored shear force applied to a single anchor or group of anchors (lb) • $V_{ua,i}$ = factored shear force applied to most highly stressed anchor in a group of anchors (lb) • $V_{ua,g}$ = total factored shear force applied to anchor group (lb) The design concrete pryout strength for a single anchor in shear (ϕV_{cp}) calculated per Section 17.5.3 is checked against the factored shear load acting on the anchor, which is designated "V_{ua}" in Table 17.3.1.1. If $\phi V_{cp} \geq V_{ua}$, the provisions for considering concrete pryout failure in shear have been satisfied per Table 17.3.1.1. The design concrete pryout strength for a group of anchors in shear (ϕV_{cpg}) calculated per Section 17.5.3 is checked against the total factored shear load acting on the anchors that are in shear, which is designated "$V_{ua,g}$" in Table 17.3.1.1. If $\phi V_{cpg} \geq V_{ua,g}$, the provisions for considering concrete pryout failure in shear have been satisfied per Table 17.3.1.1. The PROFIS Engineering report uses the generic designation "V_{ua}" to define the factored shear load being checked against the calculated design concrete pryout strength ϕV_{cp} or ϕV_{cpg}. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting shear loads. The software only performs shear load checks per Table 17.3.1.1 if shear loads have been input via one of the load input functionalities. If a single anchor in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{cp}, and checks this value against either (a) the factored shear load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored shear load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored shear load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the factored shear load determined to be acting on the anchor. If a group of anchors in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{cpg}, and checks this value against either (a) the total factored shear load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored shear load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored shear load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the total factored shear load determined to be acting on the anchor group. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{cp}: Nominal shear concrete pryout strength for a single anchor V_{cpg}: Nominal shear concrete pryout strength an anchor group $\phi_{concrete}$: Strength reduction factor for concrete failure modes $\phi_{seismic}$: Strength reduction factor for seismic loads $\phi_{nonductile}$: Strength reduction factor for non-ductile failure modes
Failure Mode	Single Anchor			Anchor Group																
		Individual anchor in a Group	Anchors as a group																	
Steel strength in shear (17.5.1)	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$																		
Concrete breakout strength in shear (17.5.2)	$\phi V_{cb} \geq V_{ua}$		$\phi V_{cbg} \geq V_{ua,g}$																	
Concrete pryout strength in shear (17.5.3)	$\phi V_{cp} \geq V_{ua}$		$\phi V_{cpg} \geq V_{ua,g}$																	

Equation $V_{sa} = A_{se,V} f_{uta}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																													
$V_{sa} = A_{se,V} f_{uta}$	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (a) For cast-in headed stud anchor $V_{sa} = A_{se,V} f_{uta} \quad (17.5.1.2a)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of $1.9f_{ya}$ and 125,000 psi. PROFIS Engineering AWS D1.1 headed stud portfolio parameters for calculating V_{sa}. <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>ANCHOR DIAMETER (d_a) (in)</th><th>TENSILE STRENGTH (f_{uta}) (ksi)</th><th>YIELD STRENGTH (f_{ua}) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AWS D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td rowspan="4"></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	ANCHOR DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ua}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	AWS D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307	B	0.750	65	51	0.442	B	0.875	65	51	0.601	ACI 318-14 Chapter 2 defines the parameter V_{sa} as follows: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. For cast-in headed studs, PROFIS Engineering calculates V_{sa} using Equation (17.5.1.2a). The PROFIS Engineering cast-in headed stud portfolio is as follows: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) The table to the left shows the parameters used by PROFIS Engineering to calculate V_{sa} for the headed stud portfolio. Reference the Calculations and Results section of the report for more information on V_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,V}$ and f_{uta}.
MATERIAL SPECIFICATION	GRADE OR TYPE	ANCHOR DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{uta}) (ksi)	YIELD STRENGTH (f _{ua}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																									
AWS D1.1	B	0.500	65	51	0.196																										
	B	0.625	65	51	0.307																										
	B	0.750	65	51	0.442																										
	B	0.875	65	51	0.601																										

Equation headed bolt $V_{sa} = 0.6 A_{se,V} f_{uta}$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																
headed bolt $V_{sa} = 0.6 A_{se,V} f_{uta}$	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. PROFIS Engineering headed bolt portfolio parameters for calculating V_{sa}. <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_b) (in)</th><th>TENSILE STRENGTH (f_{ts}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_e) (in²)</th></tr><tr><td rowspan="11">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="11">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td>55</td><td>2.000</td><td>75</td><td>55</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="11">ASTM F 1554</td><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _b) (in)	TENSILE STRENGTH (f _{ts}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _e) (in ²)	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	55	2.000	75	55	3.142	2.500	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900	105	2.000	125	105	3.142	2.500	ACI 318-14 Chapter 2 defines the parameter V_{sa} as follows: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. For cast-in headed bolts, PROFIS Engineering calculates V_{sa} using Equation (17.5.1.2b). The PROFIS Engineering cast-in headed bolt portfolio is as follows: • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1-1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1-1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1-1/2” nominal diameter) The table to the left shows the parameters used by PROFIS Engineering to calculate V_{sa} for the headed bolt portfolio. Reference the Calculations and Results section of the report for more information on V_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,V}$ and f_{uta}.
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _b) (in)	TENSILE STRENGTH (f _{ts}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _e) (in ²)																																																																																																																																																																																																												
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Equation post-Installed anchor $V_{sa} = 0.6 A_{se,V} f_{uta}$

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post-Installed anchor V_{sa} = ESRvalue	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. (c) For post-installed anchors where sleeves extend through the shear plane, V_{sa} shall be based on the results of tests performed and evaluated according to ACI 355.2. Alternatively, Eq. (17.5.1.2b) shall be permitted to be used. Excerpt from a mechanical anchor ICC-ESR showing V_{sa} and $V_{sa,eq}$ values. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Steel strength in shear</td><td>V_{sa}</td><td>lb</td><td>2180</td><td colspan="2">3595</td><td colspan="2">5495</td><td colspan="2">8090</td><td colspan="3">13,675</td></tr><tr><td>Steel strength in shear, seismic</td><td>$V_{sa,eq}$</td><td>lb</td><td>2180</td><td colspan="2">2255</td><td colspan="2">5495</td><td colspan="2">7600</td><td colspan="3">11,475</td></tr></table> Excerpt from an adhesive anchor ICC-ESR showing parameters for V_{sa}. ICC-ESR-3814 Table 6A <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td rowspan="2">ASTM F1554 Gr. 36</td><td>Nominal strength as governed by steel strength</td><td>V_{sa}</td><td>lb</td><td>-</td><td>4940</td><td>7865</td><td>11,640</td><td>16,070</td><td>21,080</td><td>33,725</td></tr><tr><td>Reduction factor, seismic shear</td><td>$\alpha_{V,seis}$</td><td>-</td><td colspan="7">0.60</td></tr></table>	Design information	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Steel strength in shear	V_{sa}	lb	2180	3595		5495		8090		13,675			Steel strength in shear, seismic	$V_{sa,eq}$	lb	2180	2255		5495		7600		11,475			DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	ASTM F1554 Gr. 36	Nominal strength as governed by steel strength	V_{sa}	lb	-	4940	7865	11,640	16,070	21,080	33,725	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.60							ACI 318-14 Chapter 2 defines the parameter V_{sa} as: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. Post-installed mechanical anchors can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2. Data derived from this testing is given in an ICC-ESR. Pre-calculated V_{sa}-values derived from AC193/ACI 355.2 testing are given in mechanical anchor ICC-ESR design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Mechanical anchor ESR-values are specific to static (V_{sa}) or seismic ($V_{sa,eq}$) load conditions. In lieu of Equation (17.5.1.2b), the Equations section of the PROFIS Engineering report for a mechanical anchor references “V_{sa} = ESR value” for static load conditions and “$V_{sa,eq}$ = ESR value” for seismic load conditions”. Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for V_{sa} are given in the ICC-ESR steel design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Adhesive anchor ICC-ESR V_{sa}-values are specific to static load conditions. An additional reduction factor designated “$\alpha_{V,seis}$” is applied to the V_{sa}-value when calculating nominal steel strength in shear for seismic load conditions. $\alpha_{V,seis}$-values are derived from AC308/ACI 355.4 testing, and will be given in the ICC-ESR steel design tables. In lieu of Equation (17.5.1.2b), the Equations section of the PROFIS Engineering report for an adhesive anchor system references “V_{sa} = ICC-ESR value” when modeling static load conditions and “$V_{sa,eq}$ = ICC-ESR value” when modeling seismic load conditions, where $V_{sa,eq} = \alpha_{V,seis} V_{sa}$. One exception to this nomenclature is with respect to the HIT-HY 200 adhesive system. The Equations section of the PROFIS Engineering report for HIT-HY 200 steel strength parameters references “$V_{sa} = (0.6 A_{se,V} f_{uta})$” when modeling static load conditions and “$V_{sa} = \alpha_{V,seis} (0.6 A_{se,V} f_{uta})$” when modeling seismic load conditions, where (0.6 $A_{se,V} f_{uta}$) corresponds to the V_{sa}-value given in the ICC-ESR steel design tables. Anchor elements in the PROFIS Engineering adhesive anchor portfolio are as follows: • Threaded rods • Reinforcing bars • Internally threaded inserts • HIT-Z and HIT-Z-R threaded rods (HIT-HY 200 only) Reference the adhesive anchor system ICC-ESR for V_{sa} values specific to an anchor element. Reference the Calculations and Results section of the report for more information on V_{sa} and $V_{sa,eq}$. Reference the Variables section of the report for more information on the parameters $A_{se,V}$ and f_{uta}.
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Equation HIT-HY 200 adhesive $V_{sa} = (0.6 A_{se,V} f_{uta})$

Equation	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																											
HIT-HY 200 adhesive $V_{sa} = (0.6 A_{se,V} f_{uta})$	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. (c) For post-installed anchors where sleeves extend through the shear plane, V_{sa} shall be based on the results of tests performed and evaluated according to ACI 355.2. Alternatively, Eq. (17.5.1.2b) shall be permitted to be used. Excerpt from ICC-ESR-3187 Table 7 showing V_{sa} and $\alpha_{V,seis}$ values for HIT-Z threaded rods. ICC-ESR-3187 Table 7 <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="4">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th></tr><tr><td rowspan="2">CARBON STEEL</td><td>Nominal strength as governed by steel strength</td><td>V_{sa}</td><td>lb</td><td>3215</td><td>5886</td><td>9375</td><td>13,848</td></tr><tr><td>Reduction factor, seismic shear</td><td>$\alpha_{V,seis}$</td><td>-</td><td colspan="4">0.65</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)				3/8	1/2	5/8	3/4	CARBON STEEL	Nominal strength as governed by steel strength	V_{sa}	lb	3215	5886	9375	13,848	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.65				ACI 318-14 Chapter 2 defines the parameter V_{sa} as: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. The Hilti HIT-HY 200 adhesive system has been qualified for recognition under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in the ICC-ESR-3187. HIT-HY 200 can be used with the following anchor elements: • Threaded rods • Reinforcing bars • Internally threaded inserts • HIT-Z and HIT-Z-R threaded rods Pre-calculated values for V_{sa} are given in the ICC-ESR steel design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Adhesive anchor ICC-ESR V_{sa}-values are specific to static load conditions. An additional reduction factor designated “$\alpha_{V,seis}$” is applied to the V_{sa}-value when calculating nominal steel strength in shear for seismic load conditions. $\alpha_{V,seis}$-values are derived from AC308/ACI 355.4 testing, and will be given in the ICC-ESR steel design tables. The Equations section of the PROFIS Engineering report for HIT-HY 200 steel strength parameters references “$V_{sa} = (0.6 A_{se,V} f_{uta})$” when modeling static load conditions and “$V_{sa} = \alpha_{V,seis} (0.6 A_{se,V} f_{uta})$” when modeling seismic load conditions, where $(0.6 A_{se,V} f_{uta})$ corresponds to the V_{sa}-value given in ICC-ESR-3187 steel design tables. Reference the Calculations and Results section of the report for more information on V_{sa} and $V_{sa,eq}$. Reference the Variables section of the report for more information on the parameters $A_{se,V}$ and f_{uta}.
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Equation HIT-Z/R threaded rods $V_{sa} = \alpha_{V,seis} (0.6 A_{se,V} f_{uta})$

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Equation $\phi V_{\text{steel}} \geq V_{\text{ua}}$

Equation	318-14 Chapter 17 Provision		Comments for PROFIS Engineering
$\phi V_{steel} \geq V_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading.		ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). The parameter “design strength” is defined as the product of a “nominal strength” (V_N) and one or more strength reduction factors (ϕ -factors). If $\phi V_N \geq V_{ua}$ for all relevant shear failure modes, the ACI 318-14 shear provisions are satisfied.
Table 17.3.1.1 Failure Mode Steel Strength in Shear	Single Anchor $\phi V_{sa} \geq V_{ua}$	Individual Anchor in a Group $\phi V_{sa} \geq V_{ua,i}$	Nominal steel strength in shear (V_{sa}) is always calculated for a single anchor when designing with the provisions of ACI 318-14. If an application consists of a group of anchors in shear, V_{sa} is calculated for a single anchor, and the design strength is checked against the highest loaded anchor in shear.
			PROFIS Engineering designates the strength reduction factor for steel failure ϕ_{steel} . ACI 318-08 anchoring-to-concrete provisions include an additional seismic reduction factor that is used to calculate anchor design strengths corresponding to brittle failure modes. Anchor elements can be defined in ACI 318 as “ductile” or “brittle” steel elements. Steel failure for a brittle steel anchor element is a “brittle”, i.e. “nonductile” failure mode; therefore, design steel strength calculated for a brittle steel anchor element using ACI 318-08 seismic provisions includes an additional strength reduction factor. PROFIS Engineering designates this seismic reduction factor “ $\phi_{nonductile}$ ”, and shows it in the results section of the report. Since $\phi_{nonductile}$ is only relevant to seismic calculations with ACI 318-08 provisions, PROFIS Engineering always shows the parameter “ $\phi_{nonductile}$ ” equal to 1.0 in the Results section of reports for ACI 318-14 provisions.
			When modeling an anchor element subject to shear loads using ACI 318-14 provisions, PROFIS Engineering calculates design steel strength for static load conditions as “ $\phi_{steel} V_{sa}$ ”, and the design steel strength for seismic load conditions as “ $\phi_{steel} V_{sa,eq}$ ”. Reference the Calculations and Results section of the PROFIS Engineering report for information on: V_{sa} : Nominal (static) steel strength in shear $V_{sa,eq}$: Nominal (seismic) steel strength in shear
			Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{steel} : Strength reduction factor for steel failure ϕV_s : Design (static) steel strength in shear $\phi V_{sa,eq}$: Design (seismic) steel strength in shear V_{ua} : Factored load acting on anchors in shear
			A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.

PART 4 SHEAR LOAD / Steel Failure Mode

Variables f_{uta}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																																						
f_{uta}	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (a) For cast-in headed stud anchor $V_{sa} = A_{se,V} f_{uta} \quad (17.5.1.2a)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. (c) For post-installed anchors where sleeves extend through the shear plane, V_{sa} shall be based on the results of tests performed and evaluated according to ACI 355.2. Alternatively, Eq. (17.5.1.2b) shall be permitted to be used. PROFIS Engineering cast-in anchor portfolio values for $A_{se,V}$ and f_{uta}: <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_s) (in)</th><th>TENSILE STRENGTH(f_{ut}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AWS D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td rowspan="4"></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td>55</td><td>2.000</td><td>75</td><td>55</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH(f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	AWS D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307	B	0.750	65	51	0.442	B	0.875	65	51	0.601	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	ASTM F 1554	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	55	2.000	75	55	3.142	2.500	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900	105	2.000	125	105	3.142	2.500	ACI 318-14 Equation 17.5.1.2 includes the parameter f_{uta} to calculate the nominal steel strength in shear (V_{sa}). ACI 318-14 Chapter 2 defines f_{uta} as the “specified tensile strength of anchor steel”. ICC-ESR for post-installed anchors include values for the “minimum specified ultimate strength”. Unlike reinforced concrete design, which uses bar yield strength (f_y) for shear calculations; ACI 318 anchoring-to-concrete provisions use the ultimate tensile strength of an anchor element (f_{uta}) to calculate the nominal steel strength in shear (V_{sa}). The ACI 318-14 commentary R17.5.1.2 notes: “The nominal shear strength of anchors is best represented as a function of f_{uta} rather than f_y because the large majority of anchor materials do not exhibit a well-defined yield point”. The PROFIS Engineering cast-in-place anchor portfolio includes the following anchors: • AWS D1.1 Type B headed studs (1/2” – 7/8” nominal diameter) • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) The table to the left shows the f_y and f_{uta} values for the PROFIS Engineering cast-in-place anchor portfolio. PROFIS Engineering uses the f_{uta} values to calculate V_{sa} per Section 17.5.1.2. Post-installed anchor ICC-ESR include pre-calculated values for the nominal static shear steel strength of an anchor element (V_{sa}), and nominal seismic shear steel strength of an anchor element ($V_{sa,eq}$). $A_{se,V}$ and f_{uta} values may also be given in the ICC-ESR; however, PROFIS Engineering uses the pre-calculated V_{sa} and $V_{sa,eq}$ values instead of calculating nominal steel strength in shear per Section 17.5.1.2. Reference the Calculations and Results section of the PROFIS Engineering report for more information on: V_{sa}: Nominal (static) steel strength in shear $V_{sa,eq}$: Nominal (seismic) steel strength in shear Reference the Variables section of the PROFIS Engineering report for more information on: $A_{se,V}$: Tensile stress area of an anchor element
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH(f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																																																																																																		
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	55	0.875	75	55	0.601	0.462																																																																																																																																																																																																																																		
	55	1.000	75	55	0.785	0.606																																																																																																																																																																																																																																		
	55	1.125	75	55	0.994	0.763																																																																																																																																																																																																																																		
	55	1.250	75	55	1.227	0.969																																																																																																																																																																																																																																		
	55	1.375	75	55	1.485	1.160																																																																																																																																																																																																																																		
	55	1.500	75	55	1.767	1.410																																																																																																																																																																																																																																		
	55	1.750	75	55	2.405	1.900																																																																																																																																																																																																																																		
	55	2.000	75	55	3.142	2.500																																																																																																																																																																																																																																		
	ASTM F 1554	105	0.500	125	105	0.196	0.142																																																																																																																																																																																																																																	
105		0.625	125	105	0.307	0.226																																																																																																																																																																																																																																		
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Variables $\alpha_{V,seis}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																							
$\alpha_{V,seis}$	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (a) For cast-in headed stud anchor $V_{sa} = A_{se,V} f_{uta} \quad (17.5.1.2a)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y and 125,000 psi. (c) For post-installed anchors where sleeves extend through the shear plane, V_{sa} shall be based on the results of tests performed and evaluated according to ACI 355.2. Alternatively, Eq. (17.5.1.2b) shall be permitted to be used Excerpts from an adhesive anchor ICC-ESR referencing the parameter $\alpha_{V,seis}$. ICC-ESR-3814 4.1.11 Design Strength in Seismic Design Categories C, D, E and F: The nominal steel shear strength, V_{sa}, must be adjusted by $\alpha_{V,seis}$ ICC-ESR-3814 Table 6A <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal rod diameter (in).</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td rowspan="2">ASTM F1554 Gr. 36</td><td>Nominal strength as governed by steel strength</td><td>V_{sa}</td><td>lb</td><td>-</td><td>4940</td><td>7865</td><td>11,640</td><td>16,070</td><td>21,080</td><td>33,725</td></tr><tr><td>Reduction factor, seismic shear</td><td>$\alpha_{V,seis}$</td><td>-</td><td colspan="7">0.60</td></tr></table>	DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in).							3/8	1/2	5/8	3/4	7/8	1	1-1/4	ASTM F1554 Gr. 36	Nominal strength as governed by steel strength	V_{sa}	lb	-	4940	7865	11,640	16,070	21,080	33,725	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.60							Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for nominal steel strength in shear are given in the ICC-ESR steel design tables. PROFIS Engineering uses these values to define the nominal steel strength in shear. Adhesive anchor ICC-ESR include pre-calculated V_{sa} values for the nominal static shear steel strength of an anchor element. An additional reduction factor designated “$\alpha_{V,seis}$” is applied to the V_{sa}-value when calculating the shear nominal steel strength for seismic load conditions. $\alpha_{V,seis}$ is only used as a shear steel strength design parameter with adhesive anchor elements. $\alpha_{V,seis}$-values are derived from AC308/ACI 355.4 testing, and will be given in the ICC-ESR steel design tables. Generally speaking, when modeling static load conditions for an adhesive anchor system, the PROFIS Engineering report shows the V_{sa}-value from the ICC-ESR in the Calculations and Results section. If seismic load conditions are being modeled, PROFIS Engineering applies the $\alpha_{V,seis}$-value given in the ICC-ESR to the V_{sa}-value and shows the product of these two parameters as “$V_{sa,eq}$” in the Calculations and Results section of the report. When modeling the HIT-HY 200 adhesive anchor system for static load conditions in PROFIS Engineering, the V_{sa}-value given in the ICC-ESR is shown in the Variables section of the report as “0.6 A_{se,V} f_{uta}”. However, this parameter is still shown as “V_{sa}” in the Calculations and Results section of the report. When modeling HIT-HY 200 for seismic load conditions, the $\alpha_{V,seis}$-value is also shown in the Variables section of the report, and PROFIS Engineering shows the product “($\alpha_{V,seis}$)(0.6 A_{se,V} f_{uta})” as “V_{sa,eq}” in the Calculations and Results section of the report. Reference the Calculations and Results section of the PROFIS Engineering report for more information on: V_{sa}: Nominal (static) steel strength in shear $V_{sa,eq}$: Nominal (seismic) steel strength in shear Reference the Variables section of the PROFIS Engineering report for more information on: $A_{se,V}$: Tensile stress area of an anchor element 0.6 A_{se,V} f_{uta}: Pre-calculated V_{sa}-value from ICC-ESR
DESIGN INFORMATION						Symbol	Units	Nominal rod diameter (in).																																	
		3/8	1/2	5/8	3/4			7/8	1	1-1/4																															
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Variables ($0.6 A_{se,V} f_{uta}$)

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Calculations headed stud V_{sa}

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																													
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MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH(f _{uta}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in²)	EFFECTIVE AREA (A _{se}) (in²)																									
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PART 4 SHEAR LOAD / Steel Failure Mode

Calculations headed bolt $V_{sa} = 0.6 A_{se,V} f_{uta}$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																
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PROFIS Engineering headed bolt portfolio parameters for calculating V_{sa}. <table><thead><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_a) (in)</th><th>TENSILE STRENGTH (f_{tsa}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr></thead><tbody><tr><td rowspan="11">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="11">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td>55</td><td>2.000</td><td>75</td><td>55</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="11">ASTM F 1554</td><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></tbody></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{tsa}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	55	2.000	75	55	3.142	2.500	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900	105	2.000	125	105	3.142	2.500	ACI 318-14 Chapter 2 defines the parameter V_{sa} as follows: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. For cast-in headed bolts, PROFIS Engineering calculates V_{sa} using Equation (17.5.1.2b). The PROFIS Engineering cast-in headed bolt portfolio is as follows: • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) The table to the left shows the parameters used by PROFIS Engineering to calculate V_{sa} for the headed bolt portfolio. Reference the Equations and Results section of the report for more information on V_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,V}$ and f_{uta}.
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Alternatively, Eq. (17.5.1.2b) shall be permitted to be used. Excerpt from a mechanical anchor ICC-ESR showing V_{sa} and $V_{sa,eq}$ values. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="2">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Steel strength in shear</td><td>V_{sa}</td><td>in.</td><td>2180</td><td colspan="2">3595</td><td colspan="2">5495</td><td colspan="2">8090</td><td colspan="3">13,675</td></tr><tr><td>Steel strength in shear, seismic</td><td>$V_{sa,eq}$</td><td>in.</td><td>2180</td><td colspan="2">2255</td><td colspan="2">5495</td><td colspan="2">7600</td><td colspan="3">11,745</td></tr></table> Excerpt from an adhesive anchor ICC-ESR showing parameters for V_{sa}. ICC-ESR-3814 Table 6A <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td rowspan="2">ASTM F1554 Gr. 36</td><td>Nominal strength as governed by steel strength</td><td>V_{sa}</td><td>lb</td><td>-</td><td>4940</td><td>7865</td><td>11,640</td><td>16,070</td><td>21,080</td><td colspan="2">33,725</td></tr><tr><td>Reduction factor, seismic shear</td><td>$\alpha_{V,seis}$</td><td>-</td><td colspan="7">0.60</td><td colspan="2"></td></tr></table>	Design information	Symbol	Units	Nominal anchor diameter (in.)										3/8		1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Steel strength in shear	V_{sa}	in.	2180	3595		5495		8090		13,675			Steel strength in shear, seismic	$V_{sa,eq}$	in.	2180	2255		5495		7600		11,745			DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	ASTM F1554 Gr. 36	Nominal strength as governed by steel strength	V_{sa}	lb	-	4940	7865	11,640	16,070	21,080	33,725		Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.60									ACI 318-14 Chapter 2 defines the parameter V_{sa} as: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. Post-installed mechanical anchors can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2. Data derived from this testing is given in an ICC-ESR. Pre-calculated V_{sa}-values derived from AC193/ACI 355.2 testing are given in mechanical anchor ICC-ESR design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Mechanical anchor ICC-ESR-values are specific to static (V_{sa}) or seismic ($V_{sa,eq}$) load conditions. The Calculations section of the PROFIS Engineering report for a mechanical anchor references “V_{sa}” for static load conditions and “$V_{sa,eq}$” for seismic load conditions”. Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for V_{sa} are given in the ICC-ESR steel design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Adhesive anchor ICC-ESR V_{sa}-values are specific to static load conditions. An additional reduction factor designated “$\alpha_{V,seis}$” is applied to the V_{sa}-value when calculating nominal steel strength in shear for seismic load conditions. $\alpha_{V,seis}$-values are derived from AC308/ACI 355.4 testing, and will be given in the ICC-ESR steel design tables. The Calculations section of the PROFIS Engineering report for an adhesive anchor system references “V_{sa}” when modeling static load conditions and “$V_{sa,eq}$” when modeling seismic load conditions, where $V_{sa,eq} = \alpha_{V,seis} V_{sa}$. One exception to this nomenclature is with respect to the HIT-HY 200 adhesive system. The Equations section of the PROFIS Engineering report for HIT-HY 200 steel strength parameters references “$V_{sa} = (0.6 A_{se,V} f_{uta})$” when modeling static load conditions and “$V_{sa} = \alpha_{V,seis} (0.6 A_{se,V} f_{uta})$” when modeling seismic load conditions, but the Calculations section of the report simply references “V_{sa}” when modeling static load conditions and “$V_{sa,eq}$” when modeling seismic load conditions Reference the Equations and Results section of the report for more information on V_{sa} and $V_{sa,eq}$. Reference the Variables section of the report for more information on the parameters $A_{se,V}$, f_{uta}, $\alpha_{V,seis}$ and $(0.6 A_{se,V} f_{uta})$.
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	B	0.750	65	51	0.442																										
	B	0.875	65	51	0.601																										

Results headed bolt $V_{sa} = 0.6 A_{se,V} f_{uta}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																
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PROFIS Engineering headed bolt portfolio parameters for calculating V_{sa} <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_a) (in)</th><th>TENSILE STRENGTH (f_{tsa}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="10">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td>55</td><td>2.000</td><td>75</td><td>55</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="10">ASTM F 1554</td><td>105</td><td>0.500</td><td>125</td><td>105</td><td>0.196</td><td>0.142</td></tr><tr><td>105</td><td>0.625</td><td>125</td><td>105</td><td>0.307</td><td>0.226</td></tr><tr><td>105</td><td>0.750</td><td>125</td><td>105</td><td>0.442</td><td>0.334</td></tr><tr><td>105</td><td>0.875</td><td>125</td><td>105</td><td>0.601</td><td>0.462</td></tr><tr><td>105</td><td>1.000</td><td>125</td><td>105</td><td>0.785</td><td>0.606</td></tr><tr><td>105</td><td>1.125</td><td>125</td><td>105</td><td>0.994</td><td>0.763</td></tr><tr><td>105</td><td>1.250</td><td>125</td><td>105</td><td>1.227</td><td>0.969</td></tr><tr><td>105</td><td>1.375</td><td>125</td><td>105</td><td>1.485</td><td>1.160</td></tr><tr><td>105</td><td>1.500</td><td>125</td><td>105</td><td>1.767</td><td>1.410</td></tr><tr><td>105</td><td>1.750</td><td>125</td><td>105</td><td>2.405</td><td>1.900</td></tr><tr><td>105</td><td>2.000</td><td>125</td><td>105</td><td>3.142</td><td>2.500</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{tsa}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	55	2.000	75	55	3.142	2.500	ASTM F 1554	105	0.500	125	105	0.196	0.142	105	0.625	125	105	0.307	0.226	105	0.750	125	105	0.442	0.334	105	0.875	125	105	0.601	0.462	105	1.000	125	105	0.785	0.606	105	1.125	125	105	0.994	0.763	105	1.250	125	105	1.227	0.969	105	1.375	125	105	1.485	1.160	105	1.500	125	105	1.767	1.410	105	1.750	125	105	2.405	1.900	105	2.000	125	105	3.142	2.500	ACI 318-14 Chapter 2 defines the parameter V_{sa} as follows: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. For cast-in headed bolts, PROFIS Engineering calculates V_{sa} using Equation (17.5.1.2b). The PROFIS Engineering cast-in headed bolt portfolio is as follows: • ASTM F1554 hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy hex head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 2” nominal diameter) • ASTM F1554 square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) • ASTM F1554 heavy square head bolt, Gr. 36, Gr. 55, Gr. 105 (1/2” – 1 1/2” nominal diameter) The table to the left shows the parameters used by PROFIS Engineering to calculate V_{sa} for the headed bolt portfolio. Reference the Equations and Calculations section of the report for more information on V_{sa}. Reference the Variables section of the report for more information on the parameters $A_{se,V}$ and f_{uta}.
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH (f _{tsa}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																																																																												
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Results post-Installed anchor V_{sa}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																					
post-Installed anchor V_{sa}	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of 1.9f_y_a and 125,000 psi. (c) For post-installed anchors where sleeves extend through the shear plane, V_{sa} shall be based on the results of tests performed and evaluated according to ACI 355.2. Alternatively, Eq. (17.5.1.2b) shall be permitted to be used. $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ Excerpt from a mechanical anchor ICC-ESR showing V_{sa} and $V_{sa,eq}$ values. ICC-ESR-1917 Table 3 <table><tr><th rowspan="2">Design information</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="10">Nominal anchor diameter (in.)</th></tr><tr><th colspan="3">3/8</th><th colspan="2">1/2</th><th colspan="2">5/8</th><th colspan="3">3/4</th></tr><tr><td>Effective min. embedment</td><td>h_{ef}</td><td>in.</td><td>1-1/2</td><td>2</td><td>2-3/4</td><td>2</td><td>3-1/4</td><td>3-1/8</td><td>4</td><td>3-1/4</td><td>3-3/4</td><td>4-3/4</td></tr><tr><td>Steel strength in shear</td><td>V_{sa}</td><td>in.</td><td>2180</td><td colspan="2">3595</td><td colspan="2">5495</td><td colspan="2">8090</td><td colspan="3">13,675</td></tr><tr><td>Steel strength in shear, seismic</td><td>$V_{sa,eq}$</td><td>in.</td><td>2180</td><td colspan="2">2255</td><td colspan="2">5495</td><td colspan="2">7600</td><td colspan="3">11,745</td></tr></table> Excerpt from an adhesive anchor ICC-ESR showing parameters for V_{sa}. ICC-ESR-3814 Table 6A <table><tr><th colspan="2" rowspan="2">DESIGN INFORMATION</th><th rowspan="2">Symbol</th><th rowspan="2">Units</th><th colspan="7">Nominal rod diameter (in.)</th></tr><tr><th>3/8</th><th>1/2</th><th>5/8</th><th>3/4</th><th>7/8</th><th>1</th><th>1-1/4</th></tr><tr><td rowspan="2">ASTM F1554 Gr. 36</td><td>Nominal strength as governed by steel strength</td><td>V_{sa}</td><td>lb</td><td>-</td><td>4940</td><td>7865</td><td>11,640</td><td>16,070</td><td>21,080</td><td>33,725</td></tr><tr><td>Reduction factor, seismic shear</td><td>$\alpha_{V,seis}$</td><td>-</td><td colspan="7">0.60</td></tr></table>	Design information	Symbol	Units	Nominal anchor diameter (in.)										3/8			1/2		5/8		3/4			Effective min. embedment	h_{ef}	in.	1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	Steel strength in shear	V_{sa}	in.	2180	3595		5495		8090		13,675			Steel strength in shear, seismic	$V_{sa,eq}$	in.	2180	2255		5495		7600		11,745			DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)							3/8	1/2	5/8	3/4	7/8	1	1-1/4	ASTM F1554 Gr. 36	Nominal strength as governed by steel strength	V_{sa}	lb	-	4940	7865	11,640	16,070	21,080	33,725	Reduction factor, seismic shear	$\alpha_{V,seis}$	-	0.60							ACI 318-14 Chapter 2 defines the parameter V_{sa} as: “nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength”. V_{sa} is always calculated for a single anchor when designing with ACI 318-14 provisions. Post-installed mechanical anchors can be shown compliance under the International Building Code (IBC) via testing per the ICC-ES acceptance criteria AC193 and the ACI test standard ACI 355.2. Data derived from this testing is given in an ICC-ESR. Pre-calculated V_{sa}-values derived from AC193/ACI 355.2 testing are given in mechanical anchor ICC-ESR design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Mechanical anchor ICC-ESR-values are specific to static (V_{sa}) or seismic ($V_{sa,eq}$) load conditions. The Results section of the PROFIS Engineering report for a mechanical anchor references “V_{sa}” for static load conditions and “$V_{sa,eq}$” for seismic load conditions ”. Post-installed adhesive anchor systems can be shown compliance under the IBC via testing per the ICC-ES acceptance criteria AC308 and the ACI test standard ACI 355.4. Data derived from this testing is given in an ICC-ESR. Pre-calculated values for V_{sa} are given in the ICC-ESR steel design tables. Although parameters such as $A_{se,V}$ and f_{uta} may be given in the ICC-ESR, PROFIS Engineering uses the pre-calculated V_{sa}-values to define the nominal steel strength in shear. Adhesive anchor ICC-ESR V_{sa}-values are specific to static load conditions. An additional reduction factor designated “$\alpha_{V,seis}$” is applied to the V_{sa}-value when calculating nominal steel strength in shear for seismic load conditions. $\alpha_{V,seis}$-values are derived from AC308/ACI 355.4 testing, and will be given in the ICC-ESR steel design tables. The Results section of the PROFIS Engineering report for an adhesive anchor system references “V_{sa}” when modeling static load conditions and “$V_{sa,eq}$” when modeling seismic load conditions, where $V_{sa,eq} = \alpha_{V,seis} V_{sa}$. One exception to this nomenclature is with respect to the HIT-HY 200 adhesive system. The Equations section of the PROFIS Engineering report for HIT-HY 200 steel strength parameters references “$V_{sa} = (0.6 A_{se,V} f_{uta})$” when modeling static load conditions and “$V_{sa} = \alpha_{V,seis} (0.6 A_{se,V} f_{uta})$” when modeling seismic load conditions, but the Results section of the report simply references “V_{sa}” when modeling static load conditions and “$V_{sa,eq}$” when modeling seismic load conditions Reference the Equations and Calculations section of the report for more information on V_{sa} and $V_{sa,eq}$. Reference the Variables section of the report for more information on the parameters $A_{se,V}$, f_{uta}, $\alpha_{V,seis}$ and $(0.6 A_{se,V} f_{uta})$.
Design information	Symbol				Units	Nominal anchor diameter (in.)																																																																																																	
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PART 4 SHEAR LOAD / Steel Failure Mode

Results ϕ_{steel}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																																
ϕ_{steel}	17.3.3 Strength reduction factor ϕ-for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (a) Anchor governed by strength of a ductile steel element (i) Tension loads 0.75 (ii) Shear loads 0.65 (b) Anchor governed by strength of a brittle steel element (i) Tension loads 0.65 (ii) Shear loads 0.60 PROFIS Engineering cast-in-place anchor portfolio. • AWS D1.1: 1/2" – 7/8" diameters • Hex head, square head, heavy square head: 1/2" – 1 1/2" diameters • Heavy hex head: 1/2" – 2" diameters	ACI 318-14 strength design provisions for steel failure in shear require calculation of a nominal steel strength (V_{sa}). The nominal strength is multiplied by a strength reduction factor (ϕ_{factor}) to obtain a design strength (ϕV_{sa}). ACI 318 anchoring-to-concrete provisions have traditionally defined ductile steel elements and brittle steel elements as follows: • Ductile steel element — an element with a tensile test elongation of at least 14 percent and reduction in area of at least 30 percent • Brittle steel element — an element with a tensile test elongation of less than 14 percent, or reduction in area of less than 30 percent, or both PROFIS Engineering designates the ϕ-factor corresponding to steel failure "ϕ_{steel}". When designing cast-in-place anchors, PROFIS Engineering uses the ϕ-factors given in ACI 318-14 Section 17.3.3. The ϕ_{steel}-values for the cast-in-place anchors in the PROFIS Engineering portfolio correspond to the ϕ-factors given in Section 17.3.3 for ductile steel elements. In the absence of product-specific data, the ϕ-factors in Section 17.3.3 can be used as guide values for post-installed anchors; however, ϕ-factors derived from product-specific testing should always be used for the actual design of post-installed anchors. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. PROFIS Engineering uses the ϕ-factors derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. The ϕ-factors in the ICC-ESR correspond to the ACI 318 ϕ-factors for "ductile steel element" and "brittle steel element", as determined by the product testing and material properties for a specific anchor element. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: V_{sa} : Nominal steel strength in tension ϕV_{sa} : Design steel strength in tension $\phi_{\text{nonductile}}$: Seismic strength reduction factor																																																																																																																																																																																																																																
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Results ϕ_{steel} (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																
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Results ϕ_{eb}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕ_{eb}	17.5.1.1 The nominal strength of an anchor in shear as governed by steel, V_{sa}, shall be evaluated by calculations based on the properties of the anchor material and the physical dimensions of the anchor. Where concrete breakout is a potential failure mode, the required steel shear strength shall be consistent with the assumed breakout surface. 17.5.1.2 The nominal strength of an anchor in shear, V_{sa}, shall not exceed (a) through (c): (a) For cast-in headed stud anchor $V_{sa} = A_{se,V} f_{uta} \quad (17.5.1.2a)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of $1.9f_y$ and 125,000 psi. (b) For cast-in headed bolt and hooked bolt anchors and for post-installed anchors where sleeves do not extend through the shear plane $V_{sa} = 0.6 A_{se,V} f_{uta} \quad (17.5.1.2b)$ where $A_{se,V}$ is the effective cross-sectional area of an anchor in shear, in.², and f_{uta} shall not be taken greater than the smaller of $1.9f_y$ and 125,000 psi. (c) For post-installed anchors where sleeves extend through the shear plane, V_{sa} shall be based on the results of tests performed and evaluated according to ACI 355.2. Alternatively, Eq. (17.5.1.2b) shall be permitted to be used. 17.5.1.3 Where anchors are used with built-up grout pads, the nominal strengths of 17.5.1.2 shall be multiplied by a factor 0.80.	ACI 318-14 Section 17.5.1.2 contains provisions for calculating the nominal steel strength of an anchor in shear (V_{sa}). Section 17.5.1.3 requires the value for V_{sa} to be multiplied by a 0.80 reduction factor if the anchor application consists of a grouted stand-off. This reduction factor is only relevant with respect to ACI 318 anchoring-to-concrete provisions when a grouted stand-off is being designed, i.e., no guidance or provisions are given in ACI 318 for stand-off applications that are not grouted. PROFIS Engineering designates this 0.8-factor "ϕ_{eb}". PROFIS Engineering also includes functionality to consider anchor bending when modelling non-grouted stand-offs subject to shear load. This functionality is explained in the Design Guide section for "steel failure with lever arm". Reference the Results section of the PROFIS Engineering report for more information on the parameters ϕV_{sa} and $\phi V_{sa,eq}$.

Results $\phi_{\text{nonductile}}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
$\phi_{\text{nonductile}}$	ACI 318-14 Section 17.2.3.5.3 17.2.3.5.3 Anchors and their attachments shall be designed using one of options (a) through (c): (a) The anchor or group of anchors shall be designed for the maximum shear that can be transmitted to the anchor or group of anchors based on the development of a ductile yield mechanism in the attachment in flexure, shear, or bearing, or a combination of those conditions, and considering both material overstrength and strain hardening effects in the attachment. (b) The anchor or group of anchors shall be designed for the maximum shear that can be transmitted to the anchors by a non-yielding attachment. (c) The anchor or group of anchors shall be designed for the maximum shear obtained from design load combinations that include E, with E increased by Ω_0. The anchor design shear strength shall satisfy the shear strength requirements of 17.3.1.1. 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from ACI 318-14 Table 17.3.1.1 showing provisions for shear calculations. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{\text{steel}} V_{sa} \geq V_{ua}$</td><td>$\phi_{\text{steel}} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{\text{concrete}} V_{cb} \geq V_{ua}$</td><td></td><td>$\phi_{\text{concrete}} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{\text{concrete}} V_{cp} \geq V_{ua}$</td><td></td><td>$\phi_{\text{concrete}} V_{cng} \geq V_{ua,g}$</td></tr></table> ACI 318-08 Part D.3.3.6 D.3.3.6 — As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{\text{steel}} V_{sa} \geq V_{ua}$	$\phi_{\text{steel}} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{\text{concrete}} V_{cb} \geq V_{ua}$		$\phi_{\text{concrete}} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{\text{concrete}} V_{cp} \geq V_{ua}$		$\phi_{\text{concrete}} V_{cng} \geq V_{ua,g}$	ACI 318-14 strength design provisions for steel failure in shear require calculation of a nominal steel strength (V_{sa}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{sa}). Unlike the provisions given in ACI 318-14 Section 17.2.3.4.4 for seismic tension loading, which require an additional 0.75 reduction factor to be applied to non-steel tension design strengths; ACI 318-14 anchoring-to-concrete provisions for shear loading do not require this 0.75 reduction factor to be applied to any shear design strength when designing an anchorage subject to seismic loading in shear. The parameter "$\phi_{\text{nonductile}}$" is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor "$\phi_{\text{nonductile}}$". "$\phi_{\text{nonductile}}$" is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is always referenced in the PROFIS Engineering report for ACI 318-14 calculations as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.
Failure Mode	Single Anchor			Anchor Group																
		Individual anchor in a group	Anchors as a group																	
Steel strength in shear (17.5.1)	$\phi_{\text{steel}} V_{sa} \geq V_{ua}$	$\phi_{\text{steel}} V_{sa} \geq V_{ua,i}$																		
Concrete breakout strength in shear (17.5.2)	$\phi_{\text{concrete}} V_{cb} \geq V_{ua}$		$\phi_{\text{concrete}} V_{cbg} \geq V_{ua,g}$																	
Concrete pryout strength in shear (17.5.3)	$\phi_{\text{concrete}} V_{cp} \geq V_{ua}$		$\phi_{\text{concrete}} V_{cng} \geq V_{ua,g}$																	

Results ϕV_{sa}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																			
ϕV_{sa}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from ACI 318-14 Table 17.3.1.1 showing provisions for shear calculations. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{steel} V_{sa} \geq V_{ua}$</td><td>$\phi_{steel} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{concrete} V_{cb} \geq V_{ua}$</td><td rowspan="2"></td><td>$\phi_{concrete} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{concrete} V_{cp} \geq V_{ua}$</td><td>$\phi_{concrete} V_{cng} \geq V_{ua,g}$</td></tr></table> Table 17.3.1.1 Failure Mode Steel Strength in Shear <table><tr><td>Single Anchor $\phi V_{sa} \geq V_{ua}$</td><td>Individual Anchor in a Group $\phi V_{sa} \geq V_{ua,i}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$	$\phi_{concrete} V_{cng} \geq V_{ua,g}$	Single Anchor $\phi V_{sa} \geq V_{ua}$	Individual Anchor in a Group $\phi V_{sa} \geq V_{ua,i}$	ACI 318-14 strength design provisions for anchors in shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). The parameter “design strength” is defined as the product of a “nominal strength” (V_N) and one or more strength reduction factors (ϕ-factors). If $\phi V_N \geq V_{ua}$ for all relevant shear failure modes, the ACI 318-14 shear provisions are satisfied. When designing with ACI 318-14 anchoring-to-concrete provisions, nominal steel strength in shear (V_{sa}) is always calculated for a single anchor, and multiplied by the ϕ-factor for steel failure. For applications consisting of only one anchor in shear, the design strength (ϕV_{sa}) is checked against the shear load acting on that anchor (V_{ua}). If $\phi V_{sa} \geq V_{ua}$, the ACI 318-14 provisions for steel failure in shear are satisfied. If an application consists of a group of anchors in shear, V_{sa} is calculated for a single anchor, and the design strength (ϕV_{sa}) is checked against the highest individual loaded anchor in shear ($V_{ua,i}$). If $\phi V_{sa} \geq V_{ua,i}$, the ACI 318-14 provisions for steel failure in shear are satisfied. The PROFIS Engineering report section for steel failure in shear uses the generic designation “V_{ua}” to reference either the only shear load acting on an anchor in shear, or the highest shear load acting on an individual anchor within an anchor group in shear. PROFIS Engineering designates the strength reduction factor for steel failure ϕ_{steel}. When modeling an anchor element in PROFIS Engineering using ACI 318-14 provisions, the calculated design steel strength in shear for static load conditions equals $\phi_{steel} V_{sa}$; however, if a grouted standoff is being modeled, an additional reduction factor (= 0.80) is applied to the nominal steel strength per Section 17.5.1.3. PROFIS Engineering designates this reduction factor “ϕ_{eb}” and shows it in the Results section of the report. The calculated design steel strength in shear for static load conditions and a grouted stand-off equals $\phi_{steel} \phi_{eb} V_{sa}$. Reference the Equations section of the PROFIS Engineering report for more information on: ϕV_{sa}: Design steel strength in shear. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{steel}: Strength reduction factor for steel failure ϕ_{eb}: Strength reduction factor for grouted standoffs V_{sa}: Nominal steel strength in shear (static load conditions) V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report
Failure Mode	Single Anchor			Anchor Group																	
		Individual anchor in a group	Anchors as a group																		
Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$																			
Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$																		
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Single Anchor $\phi V_{sa} \geq V_{ua}$	Individual Anchor in a Group $\phi V_{sa} \geq V_{ua,i}$																				

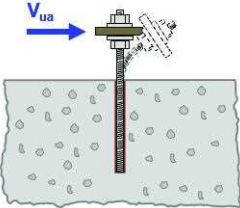
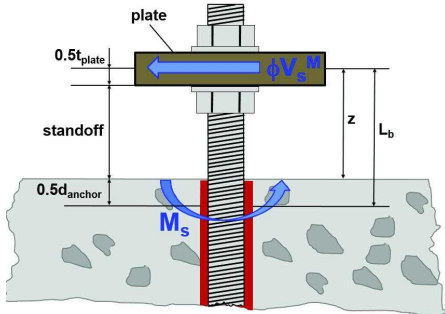
Results $\phi V_{sa,eq}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																								
$\phi V_{sa,eq}$	17.2.3.5.3 Anchors and their attachments shall be designed using one of options (a) through (c): (a) The anchor or group of anchors shall be designed for the maximum shear that can be transmitted to the anchor or group of anchors based on the development of a ductile yield mechanism in the attachment in flexure, shear, or bearing, or a combination of those conditions, and considering both material overstrength and strain hardening effects in the attachment. (b) The anchor or group of anchors shall be designed for the maximum shear that can be transmitted to the anchors by a non-yielding attachment. (c) The anchor or group of anchors shall be designed for the maximum shear obtained from design load combinations that include E, with E increased by Ω_0. The anchor design shear strength shall satisfy the shear strength requirements of 17.3.1.1. 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from ACI 318-14 Table 17.3.1.1 showing provisions for shear calculations. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{steel} V_{sa} \geq V_{ua}$</td><td>$\phi_{steel} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{concrete} V_{cb} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{concrete} V_{cp} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cng} \geq V_{ua,g}$</td></tr></table> Table 17.3.1.1 <table><tr><th>Failure Mode</th><th>Single Anchor</th><th>Individual Anchor in a Group</th></tr><tr><td>Steel Strength in Shear</td><td>$\phi V_{Vsa,eq} \geq V_{ua}$</td><td>$\phi V_{Vsa,eq} \geq V_{ua,i}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{cng} \geq V_{ua,g}$	Failure Mode	Single Anchor	Individual Anchor in a Group	Steel Strength in Shear	$\phi V_{Vsa,eq} \geq V_{ua}$	$\phi V_{Vsa,eq} \geq V_{ua,i}$	ACI 318-14 strength design provisions for anchors in shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). When designing with ACI 318-14 anchoring-to-concrete provisions, nominal steel strength in shear (V_{sa}) is always calculated for a single anchor, and multiplied by the ϕ-factor for steel failure. If the anchorage design is based on seismic load conditions, PROFIS Engineering designates "V_{sa}" as "$V_{sa,eq}$" because V_{sa}-values for some post-installed anchors in the PROFIS Engineering portfolio are specific to seismic loading. For applications consisting of only one anchor in shear, the design strength ($\phi V_{sa,eq}$) is checked against the shear load acting on that anchor (V_{ua}). If an application consists of a group of anchors in shear, $V_{sa,eq}$ is calculated for a single anchor, and the design strength ($\phi V_{sa,eq}$) is checked against the highest individual loaded anchor in shear ($V_{ua,i}$). The PROFIS Engineering report section for steel failure in shear uses the generic designation "V_{ua}" to reference either the only shear load acting on an anchor in shear, or the highest shear load acting on an individual anchor within an anchor group in shear. PROFIS Engineering designates the strength reduction factor for steel failure ϕ_{steel}. ACI 318-08 anchoring-to-concrete provisions include an additional seismic reduction factor corresponding to brittle failure modes. Design steel strengths calculated for a brittle steel anchor element using ACI 318-08 seismic provisions include an additional strength reduction factor, which PROFIS Engineering designates "$\phi_{nonductile}$". Since $\phi_{nonductile}$ is only relevant to seismic calculations with ACI 318-08 provisions, PROFIS Engineering shows "$\phi_{nonductile}$" equal to 1.0 in the Results section of reports for ACI 318-14 provisions. When modeling an anchor element in PROFIS Engineering for a grouted standoff, an additional reduction factor (= 0.80) is applied to the nominal steel strength per Section 17.5.1.3. PROFIS Engineering designates this parameter "ϕ_{eb}" and shows it in the Results section of the report. The calculated design steel strength in shear for seismic load conditions and a grouted stand-off equals $\phi_{steel} \phi_{eb} V_{sa,eq}$. Reference the Results section of the PROFIS Engineering report for more information on the following parameters: ϕ_{steel}: Strength reduction factor for steel failure ϕ_{eb}: Strength reduction factor for grouted standoffs $\phi_{nonductile}$: Seismic strength reduction factor $V_{sa,eq}$: Nominal steel strength in shear (seismic load conditions) V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.
Failure Mode	Single Anchor			Anchor Group																						
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Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{cng} \geq V_{ua,g}$																							
Failure Mode	Single Anchor	Individual Anchor in a Group																								
Steel Strength in Shear	$\phi V_{Vsa,eq} \geq V_{ua}$	$\phi V_{Vsa,eq} \geq V_{ua,i}$																								

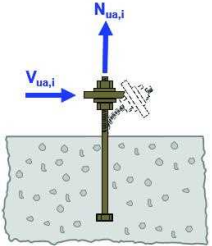
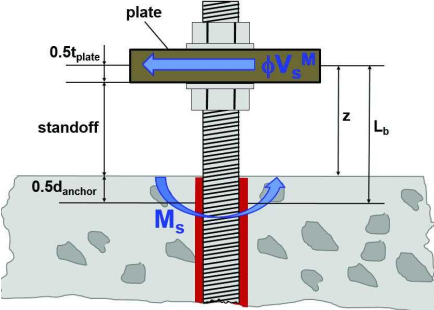
Results V_{ua}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
V_{ua}	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from ACI 318-14 Table 17.3.1.1 showing provisions for shear calculations. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{steel} V_{sa} \geq V_{ua}$</td><td>$\phi_{steel} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{concrete} V_{cb} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{concrete} V_{cp} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cng} \geq V_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{cng} \geq V_{ua,g}$	ACI 318-14 strength design provisions for steel failure in shear require calculation of a nominal steel strength (V_{sa}). The nominal strength is multiplied by a strength reduction factor (ϕ-factor) to obtain a design strength (ϕV_{sa}). Design strength is checked against a factored shear load, defined by the parameter "V_{ua}". Chapter 2 in ACI 318-14 gives the following definitions for the factored shear load parameter "V_{ua}". • V_{ua} = factored shear force applied to single anchor or group of anchors (lb) • $V_{ua,i}$ = factored shear force applied to most highly stressed anchor in a group of anchors (lb) • $V_{ua,g}$ = total factored shear force applied to anchor group (lb) The design steel strength for a single anchor in shear (ϕV_{sa}) calculated per Section 17.5.1 is checked against the factored shear load acting on the anchor, which is designated "V_{ua}" in Table 17.3.1.1. If $\phi V_{sa} \geq V_{ua}$, the provisions for considering steel failure in shear have been satisfied per Table 17.3.1.1. If an application consists of a group of anchors in shear, V_{sa} is calculated for a single anchor, and the design strength (ϕV_{sa}) is checked against the highest individually loaded anchor in shear, which is designated "$V_{ua,i}$" in Table 17.3.1.1. If $\phi V_{sa} \geq V_{ua,i}$, the provisions for considering steel failure in shear have been satisfied per Table 17.3.1.1. The PROFIS Engineering report section for steel failure in shear uses the generic designation "V_{ua}" to reference either the only shear load acting on an anchor in shear, or the highest shear load acting on an individual anchor within an anchor group in shear. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting shear loads. The software only performs shear load checks per Table 17.3.1.1 if shear loads have been input via one of the load input functionalities. If a single anchor in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{sa}, and checks this value against either (a) the factored shear load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored shear load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored shear load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the factored shear load determined to be acting on the anchor. If a group of anchors in shear is being modeled, PROFIS Engineering calculates the parameter ϕV_{sa}, and checks this value against either (a) the total factored shear load acting on the anchor group, which has been calculated using the loads input via the Load Engine, (b) the total factored shear load acting on the anchor group, which has been calculated using the loads imported from a spreadsheet or (c) the total factored shear load acting on the anchor group, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the total factored shear load determined to be acting on the anchor group. Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameter ϕV_{sa}.
Failure Mode	Single Anchor			Anchor Group																
		Individual anchor in a group	Anchors as a group																	
Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$																		
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Equations V_s^M

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$V_s^M = \frac{\alpha_M M_s}{L_b}$	ETAG 001 bending equation for stand-off $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) [N_m] \quad (5.5a)$ The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear load acts on an anchorage having standoff.  PROFIS Engineering calculation. $\phi V_s^M = \phi \left(\frac{\alpha_M M_s}{L_b} \right)$ 	Shear load acting on anchors installed with standoff creates bending in the anchors. Other than for a grouted standoff, ACI 318 anchoring-to-concrete provisions do not consider anchor bending with respect to standoff conditions; however, bending could be a controlling shear failure mode. Provisions for considering anchor bending are given in European publications such as a European Technical Approval Guideline (ETAG) published by the European Organization for Technical Approvals (EOTA). ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages includes provisions for calculating a shear resistance (strength) that results from internal anchor bending. PROFIS Engineering uses the ETAG 001 Annex C provisions to consider bolt bending as a possible shear failure mode. These provisions can be summarized as follows: If a standoff condition exists for an anchorage, an applied shear load can create bending in the anchors. An internal bending resistance ($M_{Rk,s}^0$) can be calculated using the material properties of the anchor element. $M_{Rk,s}^0$ is designated M_s^0 in PROFIS Engineering. $M_{Rk,s}^0$ can be reduced by a factor $(1 - N_{sd}/N_{Rd,s})$ if tension load also acts on the anchors to give a design bending resistance ($M_{Rk,s}$), which is designated M_s in PROFIS Engineering. The parameter N_1 corresponds to the highest “design” tension load acting on an individual anchor in the anchorage (designated N_{ua} in PROFIS Engineering), and the parameter $N_{Rd,s}$ corresponds to the calculated steel resistance for a single anchor in tension (designated ϕN_{sa} in PROFIS Engineering). The parameter “α_M” corresponds to the amount of rotational restraint the fixture is capable of undergoing; and the parameter “ℓ” (L_b in PROFIS Engineering) corresponds to the “lever arm”, which ETAG 001 Annex C defines as the distance from where the shear load is assumed to act, to the “point of fixity” in the concrete where the internal bending moment is assumed to act. The design shear resistance ($V_{Rk,s}$) can be calculated per Equation (5.5) using α_M, $M_{Rk,s}$ and ℓ. PROFIS Engineering calculates a design shear strength using α_M, M_s and L_b. This design strength (designated ϕV_s^M) is checked against the highest factored shear load acting on an individual anchor in the anchorage (V_{ua}). Reference the figures to the left. Reference the Equations and Calculations section of the report for more information on the following PROFIS Engineering parameters. The corresponding ETAG 001 Annex C parameters are noted below in parenthesis. M_s ($M_{Rk,s}$): Resultant flexural resistance of the anchor L_b (ℓ): Internal lever arm adjusted for spalling of the surface concrete Reference the Variables section of the report for more information on the following PROFIS Engineering parameters: α_M (α_M): Rotational restraint modification factor Reference the Results section of the report for more information on the following PROFIS Engineering parameters. The corresponding ETAG 001 Annex C parameter is noted below in parenthesis. V_s^M: Nominal shear strength for bending ϕV_s^M ($V_{Rk,s}$): Design shear strength (resistance) for bending

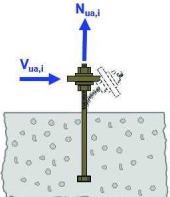
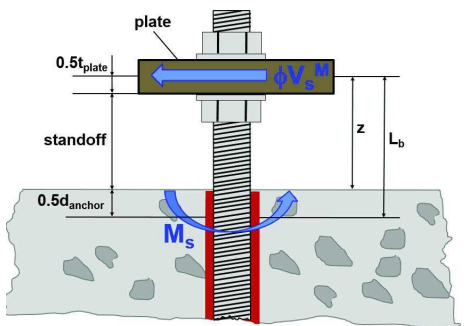
Equations $M_s = M_s^0$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$M_s = M_s^0 \left(1 - \frac{N_{ua}}{\phi N_{sa}} \right)$	ETAG 001 resultant flexural resistance of anchor $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0 = 1.2 W_{el} f_{uk} \quad [Nm] \quad (5.5b)$ The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear and tension load act on an anchorage with standoff.  PROFIS Engineering calculation. $\phi V_s^M = \phi \left(\frac{\alpha_M M_s}{L_b} \right)$ 	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ corresponds to a calculated internal “characteristic bending resistance” for the anchor element. This parameter is designated M_s^0 in PROFIS Engineering. The ETAG 001 parameter $M_{Rk,s}$ corresponds to a calculated internal “characteristic bending resistance” that is modified to account for both tension and shear load acting on the anchor element. If only a shear load acts on the anchor, $M_{Rk,s} = M_{Rk,s}^0$. If both tension and shear load act on the anchor, ETAG 001 provisions require a reduction factor $(1 - N_{sd}/N_{Rd,s})$ to be applied to $M_{Rk,s}^0$ to obtain $M_{Rk,s}$. Therefore, if tension and shear act on the anchor, $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ per ETAG 001 Equation (5.5a). PROFIS Engineering designates the parameter corresponding to $M_{Rk,s}$ as “M_s”. The parameters “N_{sd}” and “$N_{Rd,s}$” in the ETAG 001 reduction factor $(1 - N_{sd}/N_{Rd,s})$ correspond to the “design steel tension force” and the “design resistance steel force”, respectively. This reduction factor is designated $(1 - N_{ua}/\phi N_{sa})$ in PROFIS Engineering, where “N_{ua}” corresponds to the highest factored tension load acting on an individual anchor and “ϕN_{sa}” corresponds to the calculated steel design strength in tension for a single anchor. When both tension load and shear load act on an anchor with standoff, PROFIS Engineering calculates the internal bending resistance for the anchor as follows: $\phi M_s = M_s^0 (1 - N_{ua}/\phi N_{sa}).$ The ETAG 001 parameter $M_{Rk,s}^0$ is defined by Equation (5.5b) as shown to the left. The parameter W_{el} corresponds to the “elastic section modulus” of the anchor element, and the parameter f_{uk} corresponds to the “characteristic ultimate tensile strength” of the anchor element. When performing bolt bending calculations, PROFIS Engineering designates the elastic section modulus for the anchor element “S” and the ultimate tensile strength for the anchor element “$f_{u,min}$”, where “$f_{u,min}$” corresponds to the “minimum specified ultimate tensile strength” of the anchor element. The PROFIS Engineering report defines the parameter “M_s^0” using the following equation: $M_s^0 = (1.2) (S) (f_{u,min}).$ Reference the Equations section of the report for more information on the following PROFIS Engineering parameters. M_s^0 : Characteristic flexural resistance of the anchor $(1 - N_{ua}/\phi N_{sa})$: Reduction factor for tension load Reference the Variables section of the report for more information on the following PROFIS Engineering parameters: N_{ua} : Factored tension load ϕN_{sa} : Design steel strength in tension Reference the Calculations section of the report for more information on the following PROFIS Engineering parameters. M_s^0 : Characteristic flexural resistance of the anchor $(1 - N_{ua}/\phi N_{sa})$: Reduction factor for tension load M_s : Resultant flexural resistance of the anchor

Equations $M_s^0 = (1.2) (S) (f_{u,min})$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$M_s^0 = (1.2) (S) (f_{u,min})$	ETAG 001 characteristic flexural resistance of anchor $M_{Rk,s}^0 = 1.2 W_{el} f_{u,k} \quad [Nm] \quad (5.5b)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{Sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor The characteristic bending resistance $M_{Rk,s}^0$ is given in the relevant ETA. The value of $M_{Rk,s}^0$ for anchors according to current experience is obtained from Equation (5.5b). $M_{Rk,s}^0 = 1.2 W_{el} f_{u,k} \quad [Nm] \quad (5.5b)$ Equation (5.5b) may be used only if the anchor has not a significantly reduced section along the length of the bolt.	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ is defined by Equation (5.5b) as shown to the left. The parameter W_{el} corresponds to the “elastic section modulus” of the anchor element, and the parameter f_{uk} corresponds to the “characteristic ultimate tensile strength” of the anchor element. When performing bolt bending calculations, PROFIS Engineering designates the elastic section modulus for the anchor element “S” and the ultimate tensile strength for the anchor element “$f_{u,min}$”, where “$f_{u,min}$” corresponds to the “minimum specified ultimate tensile strength” of the anchor element. The PROFIS Engineering report designates the ETAG 001 parameter “$M_{Rk,s}^0$” as “M_s^0”. Using the PROFIS Engineering nomenclature, ETAG 001 Equation (5.5b) can be written as follows: $M_s^0 = (1.2) (S) (f_{u,min}) \quad \text{modified ETAG 001 Equation (5.5b).}$ PROFIS Engineering uses this equation to calculate M_s^0 for all of the cast in and post-installed anchors in its portfolio. Reference the Equations section of the report for more information on the following PROFIS Engineering parameter. S: Elastic section modulus of the anchor element Reference the Variables section of the report for more information on the following PROFIS Engineering parameter: $f_{u,min}$: Minimum specified ultimate tensile strength of the anchor element

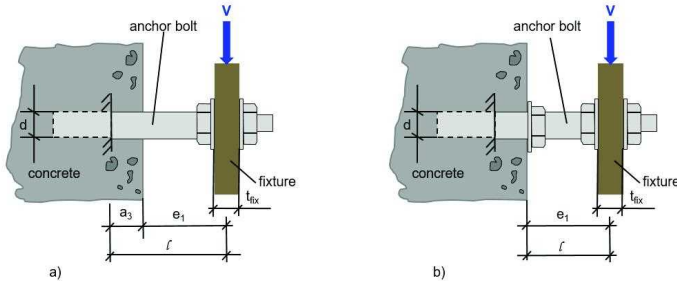
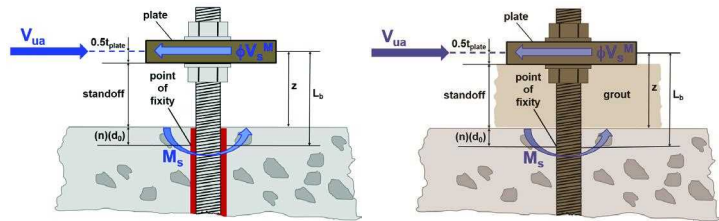
Equations $\left(1 - \frac{N_{ua}}{\phi N_{sa}}\right)$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\left(1 - \frac{N_{ua}}{\phi N_{sa}}\right)$	ETAG 001 reduction for tensile force acting simultaneously with a shear force on the anchor $(1 - N_{sd}/N_{Rd,s})$ resultant flexural resistance of anchor $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear and tension load act on an anchorage with standoff.  PROFIS Engineering calculation. $\phi V_s^M = \phi \left(\frac{\alpha_M M_s}{L_b} \right)$ 	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ corresponds to a calculated internal “characteristic bending resistance” for the anchor element. This parameter is designated M_s^0 in PROFIS Engineering. The ETAG 001 parameter $M_{Rk,s}$ corresponds to a calculated internal “characteristic bending resistance” that is modified to account for both tension and shear load acting on the anchor element. If only a shear load acts on the anchor, $M_{Rk,s} = M_{Rk,s}^0$. If both tension and shear load act on the anchor, ETAG 001 provisions require a reduction factor $(1 - N_{sd}/N_{Rd,s})$ to be applied to $M_{Rk,s}^0$ to obtain $M_{Rk,s}$. Therefore, if tension and shear act on the anchor, $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ per ETAG 001 Equation (5.5a). PROFIS Engineering designates the parameter corresponding to $M_{Rk,s}$ as “M_s”. The parameters “N_{sd}” and “$N_{Rd,s}$” in the ETAG 001 reduction factor $(1 - N_{sd}/N_{Rd,s})$ correspond to the “design steel tension force” and the “design resistance steel force”, respectively. This reduction factor is designated $(1 - N_{ua}/\phi N_{sa})$ in PROFIS Engineering, where “N_{ua}” corresponds to the highest factored tension load acting on an individual anchor and “ϕN_{sa}” corresponds to the calculated steel design strength in tension for a single anchor. When both tension load and shear load act on an anchor with standoff, PROFIS Engineering calculates the internal bending resistance for the anchor as follows: $M_s = M_s^0 (1 - N_{ua}/\phi N_{sa}).$ Reference the Variables section of the report for more information on the following PROFIS Engineering parameters: N_{ua}: Factored tension load ϕN_{sa}: Design steel strength in tension

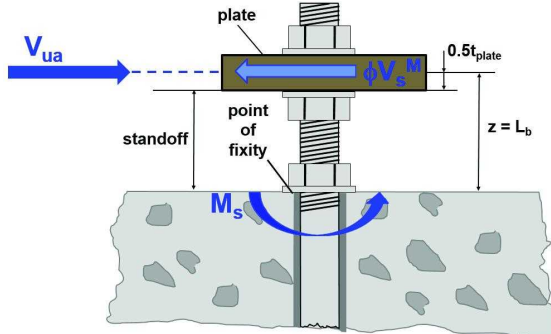
Equations $S = \frac{\pi(d)^3}{32}$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$S = \frac{\pi(d)^3}{32}$	2.3 Concrete and steel W_{el} = elastic section modulus calculated from the stressed cross section of steel ($\pi d^3/32$ for a round section with diameter d) characteristic flexural resistance of anchor 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic bending resistance $M_{Rk,s}^0$ is given in the relevant ETA. The value of $M_{Rk,s}^0$ for anchors according to current experience is obtained from Equation (5.5b). $M_{Rk,s}^0 = 1.2 W_{el} f_{u,k} \quad [Nm] \quad (5.5b)$ Equation (5.5b) may be used only if the anchor has not a significantly reduced section along the length of the bolt. 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}^0}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $N_{Rd,s} = NR_{k,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ corresponding to the “characteristic bending resistance” of the anchor is defined by Equation (5.5b) as shown to the left. The parameter W_{el} corresponds to the “elastic section modulus” of the anchor element. The PROFIS Engineering report designates the parameter “$M_{Rk,s}^0$” as “M_s^0” and the elastic section modulus for the anchor element as “S”. The “characteristic bending resistance” of the anchor is defined in PROFIS Engineering by the equation: $M_s^0 = (1.2) (S) (f_{u,min})$ where “$f_{u,min}$” corresponds to the “minimum specified ultimate tensile strength” of the anchor element. PROFIS Engineering uses this equation to calculate M_s^0 for all of the cast in and post-installed anchors in its portfolio. PROFIS Engineering calculates the section modulus (S) as follows: cast-in anchor $S = [(\pi) (d_{minor})^3]/32$ post-installed anchor calculate d using the tensile stress area of the anchor element (A_{se}). Values for A_{se} are given in the ICC-ESR for the anchor product. $d_{Ase} = [(4)(A_{se})/\pi]^{0.5}$ $S = [(\pi) (d_{Ase})^3]/32$ Reference the Equations and Calculations section of the report for more information on the following PROFIS Engineering parameter. M_s^0: Characteristic flexural resistance of the anchor element

Equations $L_b = z + (n)(d_o)$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$L_b = z + (n)(d_o)$	4.2.2.4 Shear loads with lever arm If the conditions a) and b) of 4.2.2.3 are not fulfilled the lever arm is calculated according to Equation (4.2) (see Figure 4.8) $\ell = a_3 + e_1 \quad (4.2)$ with e_1 = distance between shear load and concrete surface $a_3 = 0.5d$ $a_3 = 0$ if a washer and a nut are directly clamped to the concrete surface (see Figure 4.8b) d = nominal diameter of the anchor bolt or thread diameter (see Figure 4.8a)  ETAG 001 Annex C: Figure 4.8 Definition of lever arm 4.2.2.3 Shear loads without lever arm Shear loads acting on anchors may be assumed to act without lever arm if both of the following conditions are fulfilled: - The fixture shall be made of metal and in the area of the anchorage be fixed directly to the concrete either without an intermediate layer or with a levelling layer of mortar (compression strength $\geq 30 \text{ N/mm}^2$) with a thickness $\leq d/2$. - The fixture shall be in contact with the anchor over its entire thickness. 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [\text{N}] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M^0_{Rk,s} (1 - N_{sd}/N_{Rd,s}) \quad [\text{Nm}] \quad (5.5a)$	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The parameter “ℓ” in ETAG 001 Equation (4.2) is designated “L_b” in PROFIS Engineering. “L_b” corresponds to the “lever arm”, i.e. distance from where the shear resistance $V_{Rk,s}$ (ϕV_s^M in PROFIS Engineering) acts, to the “point of fixity” where the internal bending moment $M_{Rk,s}$ (M_s in PROFIS Engineering) acts. Bending develops within the anchor element when a shear load V (V_{ua} in PROFIS Engineering) acts on a fixture having stand-off. ETAG 001 Equation (5.5) can be modified as follows using PROFIS Engineering nomenclature: nominal shear strength (resistance): $V_s^M = \alpha_M M_s / L_b$ design shear strength (resistance): $\phi V_s^M = \phi [\alpha_M M_s / L_b]$ design check: $\phi V_s^M \geq V_{ua}$ Mechanical and adhesive anchors are installed into a hole drilled in concrete. When the anchor is subjected to bending, local concrete spalling can occur if it comes in contact with the side of the drilled hole. ETAG 001 provisions assume this spalling occurs at the surface of the concrete to a depth of one half the nominal anchor diameter. This depth is defined as “a_3” in ETAG 001 Equation (4.2), and as “$(n)(d_o)$” in PROFIS Engineering. The value for “n” in PROFIS Engineering depends on whether “stand-off without clamping”, “stand-off with clamping” or “stand-off with grouting” is selected. PROFIS Engineering assumes V_{ua} and ϕV_s^M act at the center of the fixture thickness. The distance from where V_{ua} and ϕV_s^M act to the surface of the concrete is defined as the parameter “e_1” in ETAG 001 Equation (4.2), and as “z” in PROFIS Engineering. PROFIS Engineering stand-off calculations: without clamping and with grouting t_{plate} = plate or fixture thickness $z = \text{standoff} + 0.5(t_{plate})$ $n = 0.5$ $L_b = z + (0.5)(d_o)$ d_o = nominal anchor diameter When “stand-off without clamping” or “stand-off with grouting” are selected in PROFIS Engineering, $(n)(d_o) = (0.5)(d_o)$ and $L_b = z + (0.5)(d_o)$. Adhesive anchors and cast-in anchors can be modeled in PROFIS Engineering when “stand-off without clamping” is selected. Expansion anchors cannot be modeled for this condition. 

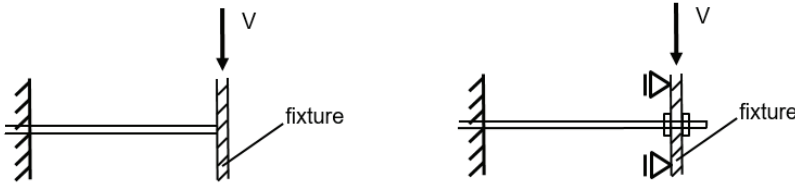
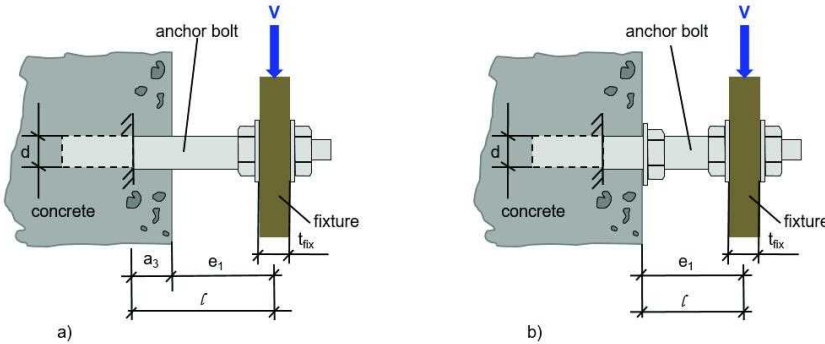
Equations $L_b = z + (n)(d_0)$ (continued)

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$L_b = z + (n)(d_o)$		PROFIS Engineering calculations for stand-off with clamping t_{plate} = plate or fixture thickness z = standoff + 0.5 (t_{plate}) $L_b = z$ Torque-controlled expansion anchors must be torqued via a nut/washer assembly at the concrete surface. If clamping via a nut/washer assembly occurs, there will be no local spalling at the concrete surface when the anchor is subjected to bending; therefore, n equals 0. When “stand-off with clamping” is selected in PROFIS Engineering, (n)(d_o) = 0 and L_b = z. For a non-grouted stand-off, expansion anchors must be modeled in PROFIS Engineering for “stand-off with clamping”.  Reference the Variables section of the report for more information on the following PROFIS Engineering parameters z, n and d_o.

Equations $\phi V_s^M \geq V_{ua}$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering												
$\phi V_s^M \geq V_{ua}$	17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Table 17.3.1.1 <table><tr><th>Failure Mode</th><th>Single Anchor</th><th>Individual Anchor in a Group</th></tr><tr><td>Steel Strength in Shear</td><td>$\phi V_{sa} \geq V_{ua}$</td><td>$\phi V_{sa} \geq V_{ua,i}$</td></tr></table> ETAG 001 ANNEX C PROVISIONS FOR BENDING 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ [Nm] (5.5a) ETAG 001 Equation (5.5) can be modified as follows using PROFIS Engineering nomenclature: <table><tr><td>nominal shear strength (resistance):</td><td>$V_s^M = \alpha_M M_s/L_b$</td></tr><tr><td>design shear strength (resistance):</td><td>$\phi V_s^M = \phi [\alpha_M M_s/L_b]$</td></tr><tr><td>design check:</td><td>$\phi V_s^M \geq V_{ua}$</td></tr></table>	Failure Mode	Single Anchor	Individual Anchor in a Group	Steel Strength in Shear	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$	nominal shear strength (resistance):	$V_s^M = \alpha_M M_s/L_b$	design shear strength (resistance):	$\phi V_s^M = \phi [\alpha_M M_s/L_b]$	design check:	$\phi V_s^M \geq V_{ua}$	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. ACI 318-14 strength design provisions for shear check a calculated design strength (ϕV_N) against a factored shear load (V_{ua}). The parameter “design strength” is defined as the product of a “nominal strength” (V_N) and one or more strength reduction factors (ϕ-factors). If $\phi V_N \geq V_{ua}$ for all relevant shear failure modes, the ACI 318-14 shear provisions are satisfied. PROFIS Engineering calculates a nominal steel strength (V_s^M) corresponding to the shear resistance in an anchor element when it is subjected to bending. PROFIS Engineering always calculates V_s^M for a single anchor. If an application consists of a group of anchors in shear, V_s^M is calculated for a single anchor, and the design strength (ϕV_s^M) is checked against the highest loaded anchor in shear. The nominal steel strength (V_s^M) is calculated using ETAG 001 provisions, and the design steel strength (ϕV_s^M) is calculated based on ACI 318-14 Section 17.3.1.1. PROFIS Engineering designates the strength reduction factor for steel failure ϕ_{steel}. When modeling cast-in anchors, PROFIS Engineering uses the ϕ-factors given in ACI 318-14 Section 17.2.3 (a) for the ϕ_{steel} value. When modeling post-installed anchors, PROFIS Engineering uses the ϕ-factors given in the anchor ICC-ESR for the ϕ_{steel} value. Reference the Results section of the PROFIS Engineering report for information on: V_s^M: Nominal steel strength in shear for bending ϕV_s^M: Design steel strength in shear for bending ϕ_{steel}: Strength reduction factor for steel failure V_{ua}: Factored load acting on anchors in shear A summary of calculated shear design strength versus the factored shear load for each shear failure mode relevant to the application is given in Part 4 Shear Load of the PROFIS Engineering report.
Failure Mode	Single Anchor	Individual Anchor in a Group												
Steel Strength in Shear	$\phi V_{sa} \geq V_{ua}$	$\phi V_{sa} \geq V_{ua,i}$												
nominal shear strength (resistance):	$V_s^M = \alpha_M M_s/L_b$													
design shear strength (resistance):	$\phi V_s^M = \phi [\alpha_M M_s/L_b]$													
design check:	$\phi V_s^M \geq V_{ua}$													

Variables α_M

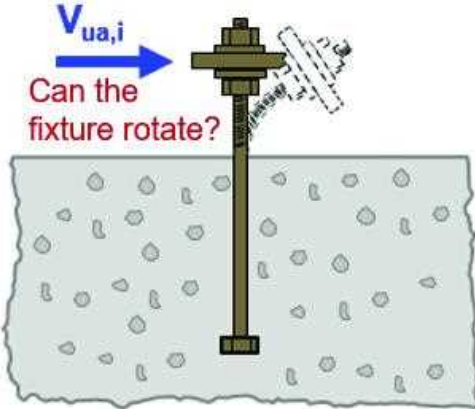
Variables	318-14 Chapter 17 Provision																										
α_M	4.2.2.4 Steel failure The value α_M depends on the degree of restraint of the anchor at the side of the fixture of the application in question and shall be judged according to good engineering practice. No restraint ($\alpha_M = 1.0$) shall be assumed if the fixture can rotate freely (see Figure 4.9a). This assumption is always conservative. Full restraint ($\alpha_M = 2.0$) may be assumed only if the fixture cannot rotate (see Figure 4.9b) and the hole clearance in the fixture is smaller than the values given in Table 4.1 or the anchor is clamped to the fixture by nut and washer (see Figure 4.8). If restraint of the anchor is assumed the fixture shall be able to take up the restraint moment.  a) $\alpha_M = 1.0$ b) $\alpha_M = 2.0$ ETAG 001 Annex C: Figure 4.9 Fixture without (a) and with (b) restraint <table><tr><td>external diameter (of anchor) $d^{(1)}$ or $d_{nom}^{(2)}$ (mm)</td><td>6</td><td>8</td><td>10</td><td>12</td><td>14</td><td>16</td><td>18</td><td>20</td><td>22</td><td>24</td><td>27</td><td>30</td></tr><tr><td>diameter d_1 of clearance hole in the fixture (mm)</td><td>7</td><td>9</td><td>12</td><td>14</td><td>16</td><td>18</td><td>20</td><td>22</td><td>24</td><td>26</td><td>30</td><td>33</td></tr></table> (1) if bolt bears against the fixture (2) if sleeve bears against the fixture ETAG 001 Annex C: Table 4.1 Diameter of clearance hole in the fixture  a) b) ETAG 001 Annex C: Figure 4.8 Definition of lever arm	external diameter (of anchor) $d^{(1)}$ or $d_{nom}^{(2)}$ (mm)	6	8	10	12	14	16	18	20	22	24	27	30	diameter d_1 of clearance hole in the fixture (mm)	7	9	12	14	16	18	20	22	24	26	30	33
external diameter (of anchor) $d^{(1)}$ or $d_{nom}^{(2)}$ (mm)	6	8	10	12	14	16	18	20	22	24	27	30															
diameter d_1 of clearance hole in the fixture (mm)	7	9	12	14	16	18	20	22	24	26	30	33															

Comments for PROFIS Engineering

PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 **Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages** to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter “ α_M ” is used to account for “rotational restraint”, corresponding to the amount or rotation a fixture can undergo when stand-off exists.

ETAG 001 Equation (5.5) defines a calculated shear resistance ($V_{Rk,s}$) in an anchor element subjected to bending. When a shear load (V) is applied to a fixture with stand-off, an internal bending resistance, designated “ $M_{Rk,s}$ ” in Equation (5.5), develops in the anchor. $M_{Rk,s}$ is an internal bending moment that is calculated using the material properties of the anchor element. Equation (5.5) defines $M_{Rk,s}$ in terms of shear resistance ($V_{Rk,s}$), a moment arm (ℓ), and fixture rotational restraint (α_M). Knowing $M_{Rk,s}$, ℓ , and α_M , Equation (5.5) permits calculation of a shear resistance ($V_{Rk,s}$) that can be checked against the shear load (V) acting on the fixture. The internal bending resistance for the anchor element is influenced by the amount of fixture rotational restraint (α_M).

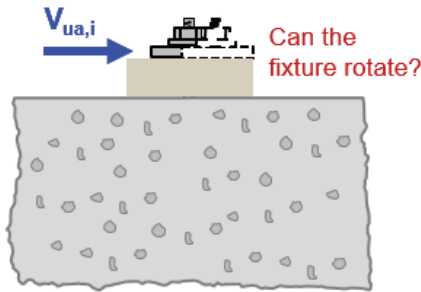
If no fixture rotational restraint exists, the fixture can rotate freely. PROFIS Engineering defaults to an α_M -value = 1.0 when the “stand-off without clamping” option is selected.



Can the fixture rotate?

$1.0 \leq \alpha_M \leq 2.0$
no rotational restraint: $\alpha_m = 1.0$

Variables α_M (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
α _M	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{Sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ PROFIS Engineering modifies ETAG 001 Equation (5.5) to use the following nomenclature: $\phi V_s^M = \phi \left(\frac{\alpha_M M_s}{L_b} \right)$ where: “ϕV_s^M” corresponds to “$V_{Rk,s}$” “M_s” corresponds to “$M_{Rk,s}$” “L_b” corresponds to “ℓ” “ϕ” is a strength reduction factor for steel failure	If full fixture rotational restraint exists, the fixture cannot rotate freely. PROFIS Engineering defaults an α_M-value = 2.0 when the “stand-off with grouting” option is selected.  1.0 ≤ α_M ≤ 2.0 full rotational restraint: α_M = 2.0 Utilizing a nut/washer assembly to permit proper torquing of an anchor (reference ETAG 001 Figure 4.8b) should not automatically be assumed to provide any rotational restraint. PROFIS Engineering defaults to an α_M-value = 1.0 when the “stand-off with clamping” option is selected. Likewise, per ETAG 001 Section 4.2.2.4 and Table 4.1, full rotational restraint should not be assumed if the hole clearance between the anchor element and fixture is significant. PROFIS Engineering users can input any α_M-value between 1.0 (no rotational restraint) and 2.0 (full rotational restraint) corresponding to the amount of fixture rotational restraint that exists for their stand-off application. Reference the Calculations section of the report for more information on the following PROFIS Engineering parameters. M_s : Internal bending resistance L_b : Internal lever arm Reference the Results section of the report for more information on the following PROFIS Engineering parameters. V_s^M : Nominal shear strength for bending φV_s^M : Nominal shear strength for bending

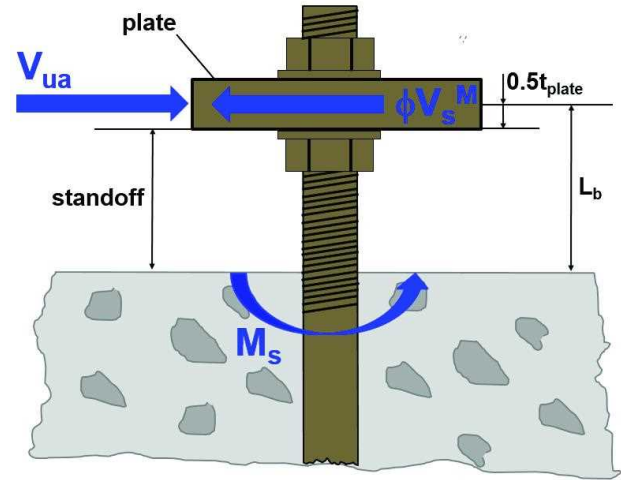
Variables $f_{u,min}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																																																																																									
$f_{u,min}$	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic bending resistance $M^0_{Rk,s}$ is given in the relevant ETA. The value of $M^0_{Rk,s}$ for anchors according to current experience is obtained from Equation (5.5b). $M^0_{Rk,s} = 1.2W_{el} f_{u,k} \quad [Nm] \quad (5.5b)$ Equation (5.5b) may be used only if the anchor has not a significantly reduced section along the length of the bolt. PROFIS Engineering cast-in anchor portfolio values for f_{uta}: <table><thead><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_s) (in)</th><th>TENSILE STRENGTH(f_{ut}) (ksi)</th><th>YIELD STRENGTH (f_y) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_e) (in²)</th></tr></thead><tbody><tr><td rowspan="4">AWS D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td><td></td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td><td></td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td><td></td></tr><tr><td rowspan="12">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="12">ASTM F 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The parameter “$f_{u,k}$” in ETAG 001 Equation (5.5) is defined as the “characteristic steel ultimate tensile strength”, and is used to calculate the “characteristic bending resistance” ($M^0_{Rk,s}$) of an anchor element. PROFIS Engineering designates $M^0_{Rk,s}$ as “M^0_s”, and the elastic section modulus “W_{el}” as “S”. PROFIS Engineering calculates M^0_s using the following equation: $M^0_s = (1.2)(S)(f_{u,min})$ where by the parameter “$f_{u,min}$” corresponds to the minimum specified ultimate tensile strength of the anchor element. The parameter “$f_{u,min}$” can also be expressed as “f_{uta}”. Minimum specified ultimate tensile strength values for the PROFIS Engineering cast-in anchor portfolio are shown to the left as “f_{uta}”. For the post-installed anchors in its portfolio, PROFIS Engineering uses the minimum specified ultimate tensile strength values given in the ICC-ESR for the anchor element that has been selected. Examples of post-installed anchor minimum specified ultimate tensile strength values are shown to the left as f_{uta}-values. Reference the Equations section of the report for more information on the following PROFIS Engineering parameters: M^0_s: Characteristic flexural resistance of the anchor element S: Elastic section modulus for the anchor element Reference the Calculations section of the report for more information on the PROFIS Engineering parameter: M^0_s: Characteristic flexural resistance of the anchor element
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _s) (in)	TENSILE STRENGTH(f _{ut}) (ksi)	YIELD STRENGTH (f _y) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _e) (in ²)																																																																																																																																																																																																																																					
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Variables $f_{u,min}$ (continued)

Variables	318-14 Chapter 17 Provision							Comments for PROFIS Engineering	
f _{u,min}	Excerpt from a mechanical anchor ICC-ESR showing f _{uta} values.								
	ICC-ESR-1917 Table 3								
	DESIGN INFORMATION	Symbol	Units	Nominal Anchor Diameter (in).					
				3/8	1/2	5/8	3/4		
	Min. specified yield strength	f _y	lb/in ²	100,000	84,800	84,800	84,800		
	Min specified ult. strength	f _{uta}	lb/in ²	125,000	106,000	106,000	106,000		
	Excerpt from an adhesive anchor ICC-ESR showing f _{uta} values.								
	ICC-ESR-3814 Table 2								
	THREADED ROD SPECIFICATION			Minimum specified ultimate strength, f _{uta}	Minimum specified yield strenght 0.2 percent offset, f _{ys}	f _{uta} /f _{ys}	Elongation, min. percent	Reduction of area, min percent	Specification for nuts
	CARBON STEEL	ASTM A193 Grade B7 ≤ 2-1/2 in.	psi	125,000	105,000	1.19	16	50	ASTM A563 Grade DH
ASTM F566 Class 5.8 M5 (1/4 in.) to M24 (1 in.) (equivalent to ISO 898-1)		psi	72,500	58,000	1.25	10	35	ASTM A563 Grade DH DIN 964 (8-A2K)	
ASTM F1554, Gr. 36		psi	58,000	36,000	1.61	23	40	ASTM A194 or ASTM A563	
ASTM F1554, Gr. 55		psi	75,000	55,000	1.36	21	30	ASTM A194 or ASTM A563	
ASTM F1554, Gr. 105		psi	125,000	105,000	1.19	15	42	ASTM A194 or ASTM A563	
ISO 898-1 Class 5.8		psi	72,500	58,000	1.25	22	-	DIN 934 Grade 6	
ISO 898-1 Class 8.8		psi	116,000	92,800	1.25	12	52	DIN 934 Grade 8	

Variables N_{ua}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
N_{ua}	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ [Nm] (5.5a) ACI 318-14 Chapter 17 Provision 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The design criteria for this failure mode consider the highest load acting on an individual anchor, and a design resistance (strength) for a single anchor. Bending develops within an anchor element when a shear load acts on a fixture having stand-off. The ETAG 001 parameter “$M_{Rk,s}$” in Equation (5.5) corresponds to an internal bending moment, which can be defined as a “characteristic bending resistance for steel failure”. $M_{Rk,s}$ is calculated for a single anchor using the material properties of the anchor. If both tension and shear loads act on the anchor, $M_{Rk,s}$ must be reduced by a factor $(1 - N_{sd}/N_{Rd,s})$ per Equation (5.5a) to account for the combined anchor loading. The parameter “N_{sd}” corresponds to the highest “design steel tensile load” acting on the anchor, and the parameter “$N_{Rd,s}$” corresponds to the “design steel tension resistance” for the anchor. PROFIS Engineering uses the following nomenclature to define ETAG 001 Equations (5.5) and (5.5a): $\phi V_s^M = \phi [(\alpha_M M_s)/L_b]$ modified ETAG 001 Equation (5.5) $M_s = M_s^0 (1 - N_{ua}/\phi N_{sa})$ modified ETAG 001 Equation (5.5a) where $V_s^M = [(\alpha_M M_s)/L_b]$ = nominal shear strength (resistance) of the anchor ϕV_s^M = shear design bending strength (resistance) of the anchor M_s = resultant flexural strength (resistance) of the anchor M_s^0 = characteristic flexural strength (resistance) of the anchor N_{ua} = highest factored tension load acting on the anchor ϕN_{sa} = tension design steel strength (resistance) of the anchor The shear design bending strength ϕV_s^M (resistance) is checked against the factored shear load (V_{ua}) acting on the anchor. 
Failure Mode	Single Anchor			Anchor Group																								
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Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$																									
Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

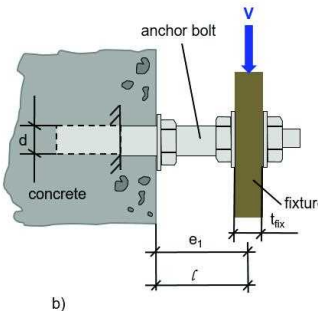
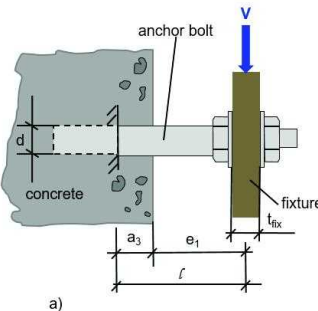
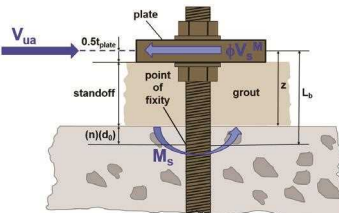
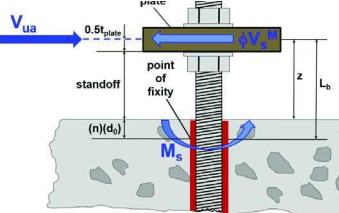
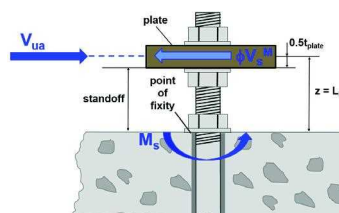
Variables N_{ua} (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
N_{ua}		PROFIS Engineering report uses the generic designation "N_{ua}" to reference either the only tension load acting on an anchor in tension, or the highest tension load acting on an individual anchor within an anchor group in tension. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. When considering the tension reduction factor $(1 - N_{ua}/\phi N_{sa})$ for stand-off calculations, PROFIS Engineering uses the N_{ua}-value (a) calculated with the Load Engine, (b) determined from the loads imported from a spreadsheet or (c) determined from the loads input in the matrix on the main screen. This value is shown as "N_{ua}" in Part 3.1 of the PROFIS Engineering report, and corresponds to the highest factored tension load determined to be acting on an individual anchor. When modeling a stand-off application subjected to shear and tension loads; PROFIS Engineering uses the N_{ua}-value in Part 3.1 of the report to calculate the tension reduction factor $(1 - N_{ua}/\phi N_{sa})$, which is used in the modified ETAG 001 Equation (5.5a) to calculate the parameter "M_s". Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameter $(1 - N_{ua}/\phi N_{sa})$.

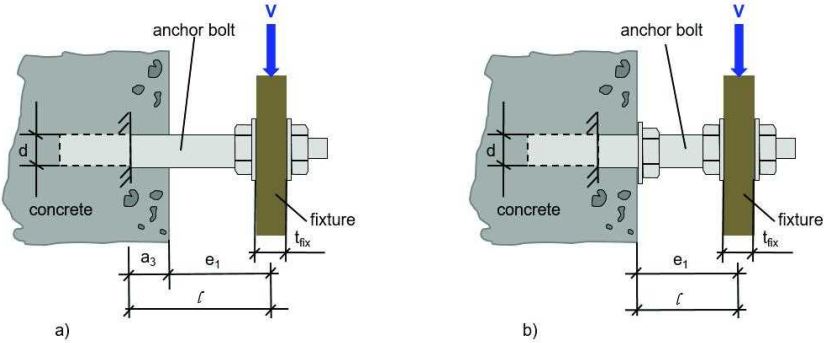
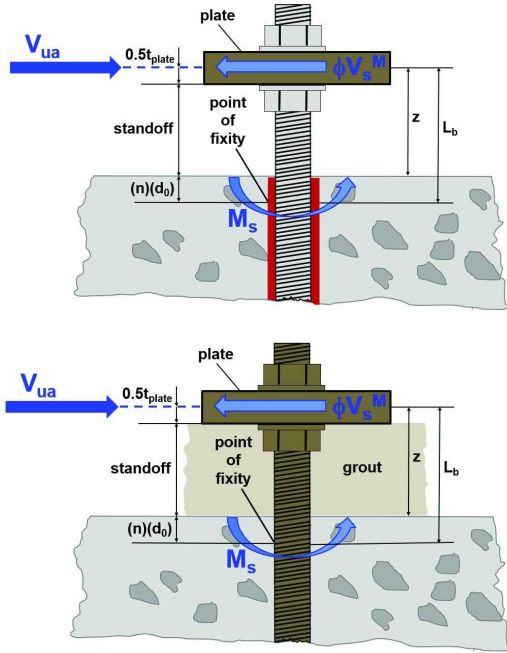
Variables ϕN_{ua}

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																										
ϕN_{ua}	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ [Nm] (5.5a) ACI 318-14 Chapter 17 Provision 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The design criteria for this failure mode consider the highest load acting on an individual anchor, and a design resistance (strength) for a single anchor. Bending develops within an anchor element when a shear load acts on a fixture having stand-off. The ETAG 001 parameter “$M_{Rk,s}$” in Equation (5.5) corresponds to an internal bending moment, which can be defined as a “characteristic bending resistance for steel failure”. $M_{Rk,s}$ is calculated for a single anchor using the material properties of the anchor. If both tension and shear loads act on the anchor, $M_{Rk,s}$ must be reduced by a factor $(1 - N_{sd}/N_{Rd,s})$ per Equation (5.5a) to account for the combined anchor loading. The parameter “N_{sd}” corresponds to the highest “design steel tensile load” acting on the anchor, and the parameter “$N_{Rd,s}$” corresponds to the “design steel tension resistance” for the anchor. PROFIS Engineering uses the following nomenclature to define ETAG 001 Equations (5.5) and (5.5a): $\phi V_s^M = \phi (\alpha_M M_s)/L_b$ modified ETAG 001 Equation (5.5) $M_s = M_s^0 (1 - N_{ua}/\phi N_{sa})$ modified ETAG 001 Equation (5.5a) where V_s^M = nominal shear strength (resistance) ϕV_s^M = shear design bending strength (resistance) of the anchor M_s = resultant flexural strength (resistance) of the anchor M_s^0 = characteristic flexural strength (resistance) of the anchor N_{ua} = highest factored tension load acting on the anchor ϕN_{sa} = tension design steel strength (resistance) of the anchor The shear design bending strength ϕV_s^M (resistance) is checked against the factored shear load (V_{ua}) acting on the anchor.
Failure Mode	Single Anchor			Anchor Group																								
		Individual anchor in a Group	Anchors as a group																									
Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$																										
Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$																									
Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$																										
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Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									

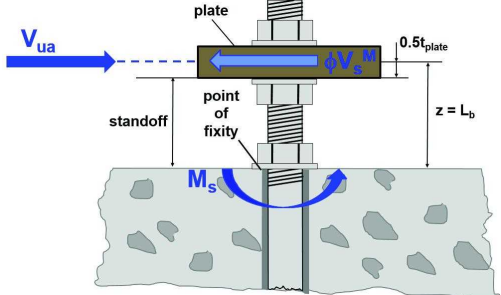
Variables z

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
z	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ 4.2.2.4 Shear loads with lever arm If the conditions a) and b) of 4.2.2.3 are not fulfilled the lever arm is calculated according to Equation (4.2) (see Figure 4.8) $\ell = a_3 + e_1 \quad (4.2)$ with e_1 = distance between shear load and concrete surface $a_3 = 0.5d$ $a_3 = 0$ if a washer and a nut are directly clamped to the concrete surface (see Figure 4.8b) d = nominal diameter of the anchor bolt or thread diameter (see Figure 4.8a)  ETAG 001 Annex C: Figure 4.8 Definition of lever arm 4.2.2.3 Shear loads without lever arm Shear loads acting on anchors may be assumed to act without lever arm if both of the following conditions are fulfilled: a) The fixture shall be made of metal and in the area of the anchorage be fixed directly to the concrete either without an intermediate layer or with a levelling layer of mortar (compression strength $\geq 30 \text{ N/mm}^2$) with a thickness $\leq d/2$. b) The fixture shall be in contact with the anchor over its entire thickness.	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The parameter “ℓ” in ETAG 001 Equation (4.2) is designated “L_b” in PROFIS Engineering. “L_b” corresponds to the “lever arm”, i.e. distance from where the shear resistance (ϕV_s^M in PROFIS Engineering) acts, to the “point of fixity” where the internal bending moment (M_s in PROFIS Engineering) acts. Bending develops within the anchor element when a shear load (V_{ua} in PROFIS Engineering) acts on a fixture having stand-off. ETAG 001 Equation (5.5) can be modified as follows using PROFIS Engineering nomenclature: nominal shear strength (resistance): $\phi V_s^M = \phi(\alpha_M M_s/L_b)$ PROFIS Engineering assumes V_{ua} and ϕV_s^M act at the center of the fixture thickness. The distance from where V_{ua} and ϕV_s^M act to the surface of the concrete is defined as the parameter “e_1” in ETAG 001 Equation (4.2), and as “z” in PROFIS Engineering. PROFIS Engineering stand-off calculations: without clamping and with grouting t_{plate} = plate or fixture thickness $n = 0.5$ d_0 = nominal anchor diameter $z = \text{standoff} + 0.5 (t_{plate})$ $L_b = z + (0.5)(d_0)$  PROFIS Engineering calculations for stand-off with clamping t_{plate} = plate or fixture thickness $z = \text{standoff} + 0.5 (t_{plate})$ $L_b = z$  Reference the Variables section of the report for more information on the following PROFIS Engineering parameters n and d_0. Reference the Equations and Calculations section of the report for more information on the PROFIS Engineering parameter L_b.

Variables n

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
n	4.2.2.4 Shear loads with lever arm If the conditions a) and b) of 4.2.2.3 are not fulfilled the lever arm is calculated according to Equation (4.2) (see Figure 4.8) $\ell = a_3 + e_1 \quad (4.2)$ with e_1 = distance between shear load and concrete surface $a_3 = 0.5d$ $a_3 = 0$ if a washer and a nut are directly clamped to the concrete surface (see Figure 4.8b) d = nominal diameter of the anchor bolt or thread diameter (see Figure 4.8a)  ETAG 001 Annex C: Figure 4.8 Definition of lever arm 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{Sd}/N_{Rd,s})$ [Nm] (5.5a)	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The parameter “ℓ” in ETAG 001 Equation (4.2) is designated “L_b” in PROFIS Engineering. “L_b” corresponds to the “lever arm”, i.e. distance from where the shear resistance $V_{Rk,s}$ (ϕV_s^M in PROFIS Engineering) acts, to the “point of fixity” where the internal bending moment $M_{Rk,s}$ (M_s in PROFIS Engineering) acts. Mechanical and adhesive anchors are installed into a hole drilled in concrete. When the anchor is subjected to bending, local concrete spalling can occur if it comes in contact with the side of the drilled hole. ETAG 001 provisions assume this spalling occurs at the surface of the concrete to a depth of one half the nominal anchor diameter. This depth is defined as “a_3” in ETAG 001 Equation (4.2), and as “$(n)(d_0)$” in PROFIS Engineering. The value for “n” in PROFIS Engineering depends on whether “stand-off without clamping”, “stand-off with clamping” or “stand-off with grouting” is selected. PROFIS Engineering stand-off calculations: without clamping and with grouting t_{plate} = plate or fixture thickness $z = \text{standoff} + 0.5(t_{plate})$ $n = 0.5$ $L_b = z + (0.5)(d_0)$ d_0 = nominal anchor diameter When “stand-off without clamping” or “stand-off with grouting” are selected in PROFIS Engineering, $(n)(d_0) = (0.5)(d_0)$ and $L_b = z + (0.5)(d_0)$. 

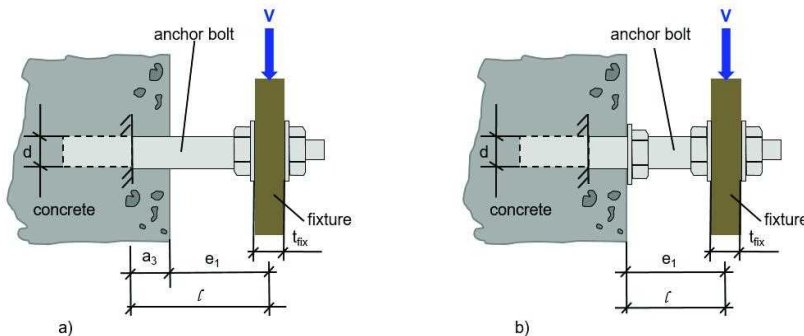
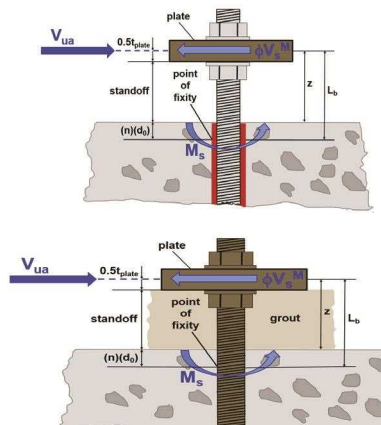
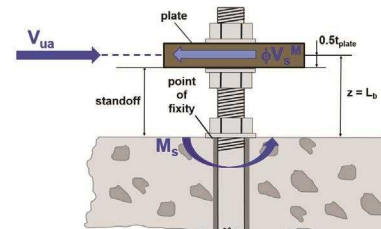
Variables n (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
n		PROFIS Engineering calculations for stand-off with clamping t_{plate} = plate or fixture thickness $z = \text{standoff} + 0.5 (t_{\text{plate}})$ $L_b = z$ Torque-controlled expansion anchors must be torqued via a nut/washer assembly at the concrete surface. If clamping via a nut/washer assembly occurs, there will be no local spalling at the concrete surface when the anchor is subjected to bending; therefore, n equals 0. When “stand-off with clamping” is selected in PROFIS Engineering, (n)(d_o) = 0. For a non-grouted stand-off, expansion anchors must be modeled in PROFIS Engineering for “stand-off with clamping”.  Reference the Variables section of the report for more information on the following PROFIS Engineering parameters z and d_o. Reference the Equations and ^{Calculations} section of the report for more information on the PROFIS Engineering parameter L_b.

Variables d_o

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
d _o	4.2.2.4 Shear loads with lever arm If the conditions a) and b) of 4.2.2.3 are not fulfilled the lever arm is calculated according to Equation (4.2) (see Figure 4.8) $\ell = a_3 + e_1 \quad (4.2)$ with e₁ = distance between shear load and concrete surface a₃ = 0.5d a₃ = 0 if a washer and a nut are directly clamped to the concrete surface (see Figure 4.8b) d = nominal diameter of the anchor bolt or thread diameter (see Figure 4.8a)	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The parameter “ℓ” in ETAG 001 Equation (4.2) is designated “L_b” in PROFIS Engineering. “L_b” corresponds to the “lever arm”, i.e. distance from where the shear resistance V_{Rk,s} (ϕV_b^M in PROFIS Engineering) acts, to the “point of fixity” where the internal bending moment M_{Rk,s} (M_s in PROFIS Engineering) acts. Mechanical and adhesive anchors are installed into a hole drilled in concrete. When the anchor is subjected to bending, local concrete spalling can occur if it comes in contact with the side of the drilled hole. ETAG 001 provisions assume this spalling occurs at the surface of the concrete to a depth of one half the nominal anchor diameter. This depth is defined as “a₃” in ETAG 001 Equation (4.2), and as “(n)(d_o)” in PROFIS Engineering. The value for “n” in PROFIS Engineering depends on whether “stand-off without clamping”, “stand-off with clamping” or “stand-off with grouting” is selected

Variables d_o (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
d_o	 ETAG 001 Annex C: Figure 4.8 Definition of lever arm 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{Sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$	PROFIS Engineering stand-off calculations: without clamping and with grouting t_{plate} = plate or fixture thickness $n = 0.5$ d_o = nominal anchor diameter $z = \text{standoff} + 0.5(t_{plate})$ $L_b = z + (0.5)(d_o)$ When “stand-off without clamping” or “stand-off with grouting” are selected in PROFIS Engineering, $(n)(d_o) = (0.5)(d_o)$ and $L_b = z + (0.5)(d_o)$.  PROFIS Engineering calculations for stand-off with clamping t_{plate} = plate or fixture thickness $z = \text{standoff} + 0.5(t_{plate})$ $L_b = z$ Torque-controlled expansion anchors must be torqued via a nut/washer assembly at the concrete surface. If clamping via a nut/washer assembly occurs, there will be no local spalling at the concrete surface when the anchor is subjected to bending; therefore, n equals 0. When “stand-off with clamping” is selected in PROFIS Engineering, $(n)(d_o) = 0$. For a non-grouted stand-off, expansion anchors must be modeled in PROFIS Engineering for “stand-off with clamping”. 

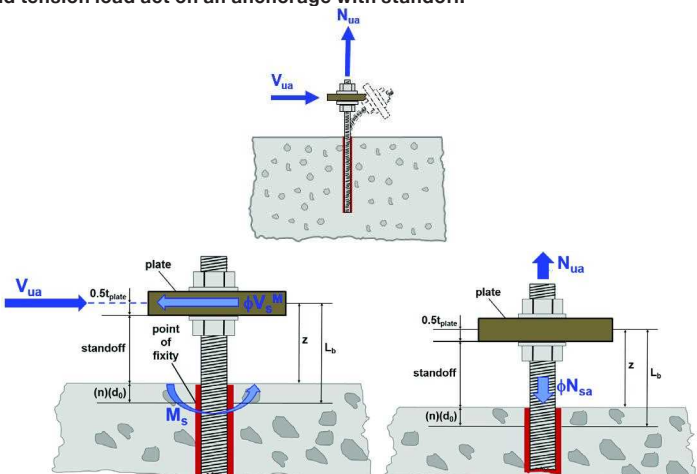
Calculations M_s^0

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
M_s^0	ETAG 001 characteristic flexural resistance of anchor $M_{Rk,s}^0 = 1.2 W_{el} f_{uk} \quad [Nm] \quad (5.5b)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor The characteristic bending resistance $M_{Rk,s}^0$ is given in the relevant ETA. The value of $M_{Rk,s}^0$ for anchors according to current experience is obtained from Equation (5.5b). $M_{Rk,s}^0 = 1.2 W_{el} f_{uk} \quad [Nm] \quad (5.5b)$ Equation (5.5b) may be used only if the anchor has not a significantly reduced section along the length of the bolt.	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ defined by Equation (5.5b) corresponds to the “characteristic bending resistance” of an individual anchor. The parameter “W_{el}” corresponds to the “elastic section modulus” of the anchor element, and the parameter “$f_{u,k}$” corresponds to the “characteristic ultimate tensile strength” of the anchor element. PROFIS Engineering designates the ETAG 001 parameters in Equation (5.5b) as follows: “$M_{Rk,s}^0$” is designated “M_s^0” “W_{el}” is designated “S” “$f_{u,k}$” is designated “$f_{u,min}$”. When modeling cast-in anchors, PROFIS Engineering calculates S using the equation: $S = [(\pi) (d_{minor})^3]/32$ When modeling post-installed anchors, PROFIS Engineering calculates S using the tensile stress area of the anchor: $d_{Ase} = [(4)(A_{se})/\pi]^{0.5}$ $S = [(\pi) (d_{Ase})^3]/32$ PROFIS Engineering uses the “minimum specified ultimate tensile strength” of the anchor element for the parameter “$f_{u,min}$”. Using the PROFIS Engineering nomenclature, ETAG 001 Equation (5.5b) can be written as follows: $M_s^0 = (1.2) (S) (f_{u,min}) \quad \text{modified ETAG 001 Equation (5.5b).}$ Reference the Equations section of the report for more information on the following PROFIS Engineering parameter. S: Elastic section modulus of the anchor element Reference the Variables section of the report for more information on the following PROFIS Engineering parameter: $f_{u,min}$: Minimum specified ultimate tensile strength of the anchor element

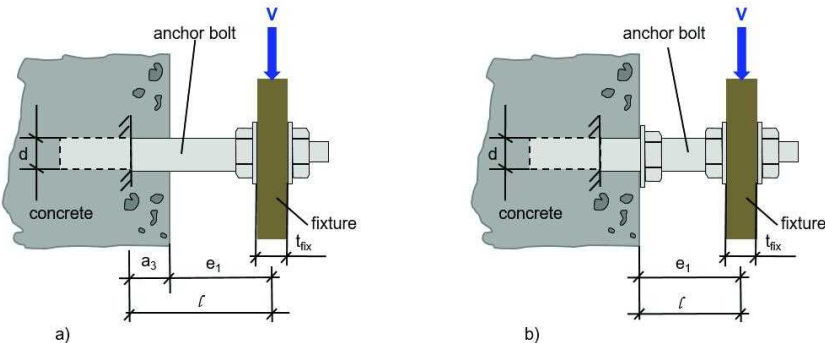
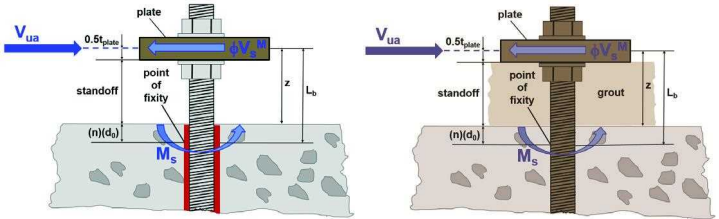
Calculations $\left(1 - \frac{N_{ua}}{\phi N_{sa}}\right)$

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\left(1 - \frac{N_{ua}}{\phi N_{sa}}\right)$	ETAG 001 reduction for tensile force acting simultaneously with a shear force on the anchor $(1 - N_{sd}/N_{Rd,s})$ resultant flexural resistance of anchor $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear and tension load act on an anchorage with standoff. PROFIS Engineering calculations $\phi V_s^M = \phi [(\alpha_M M_s)/L_b]$ $M_s = M_s^0 (1 - N_{ua}/\phi N_{sa})$ $M_s^0 = (1.2)(S)(f_{u,min})$ modified ETAG 001 Equation (5.5) modified ETAG 001 Equation (5.5a) modified ETAG 001 Equation (5.5b)	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ corresponds to a calculated internal “characteristic bending resistance” for the anchor element. If both tension and shear loads act on the anchor, ETAG 001 provisions require a reduction factor $(1 - N_{sd}/N_{Rd,s})$ to be applied to $M_{Rk,s}^0$, and the resulting parameter is designated “$M_{Rk,s}$” per Equation (5.5a). The parameters “N_{sd}” and “$N_{Rd,s}$” in Equation (5.5a) correspond to the “design steel tension force” and the “design resistance steel force”, respectively. PROFIS Engineering designates the parameters in Equation (5.5a) as follows: “$M_{Rk,s}$” is designated “M_s” “$M_{Rk,s}^0$” is designated “M_s^0” “N_{sd}” is designated “N_{ua}” “$N_{Rd,s}$” is designated “ϕN_{sa}” PROFIS Engineering defines the parameters for the Equation (5.5a) tension modification factor as follows: N_{ua} = highest factored tension load acting on an individual anchor ϕN_{sa} = design steel strength in tension for a single anchor Reference the Variables section in Part 4.2 of the PROFIS Engineering report for more information on the parameters N_{ua} and ϕN_{sa} when used in ETAG 001 Equation (5.5a). The values for N_{ua} and ϕN_{sa} are taken from Part 3.1 (steel strength in tension calculations) of the PROFIS Engineering report.

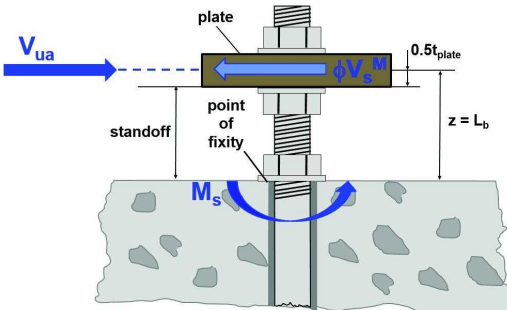
Calculations M_s

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
M_s	resultant flexural resistance of anchor $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s}) \quad [Nm] \quad (5.5a)$ $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor The value of $M_{Rk,s}^0$ for anchors according to current experience is obtained from Equation (5.5b). $M_{Rk,s}^0 = 1.2 W_{el} f_{uk} \quad [Nm] \quad (5.5b)$ The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear and tension load act on an anchorage with standoff.  PROFIS Engineering calculations $\phi V_{Ms} = \phi [(\alpha_M M_s)/L_b]$ modified ETAG 001 Equation (5.5) $M_s = M_s^0 (1 - N_{ua}/\phi N_{sa})$ modified ETAG 001 Equation (5.5a) $M_s^0 = (1.2)(S)(f_{u,min})$ modified ETAG 001 Equation (5.5b)	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The ETAG 001 parameter $M_{Rk,s}^0$ corresponds to a calculated internal “characteristic bending resistance” for the anchor element. If both tension and shear loads act on the anchor, ETAG 001 provisions require a reduction factor $(1 - N_{sd}/N_{Rd,s})$ to be applied to $M_{Rk,s}^0$, and the resulting parameter is designated “$M_{Rk,s}$” per Equation (5.5a). The parameters “N_{sd}” and “$N_{Rd,s}$” in Equation (5.5a) correspond to the “design steel tension force” and the “design resistance steel force”, respectively. PROFIS Engineering designates the parameters in Equation (5.5a) as follows: “$M_{Rk,s}$” is designated “M_s” “$M_{Rk,s}^0$” is designated “M_s^0” “N_{sd}” is designated “N_{ua}” “$N_{Rd,s}$” is designated “ϕN_{sa}” Reference the Equations and Calculations section of the PROFIS Engineering report for more information on the parameter M_s^0. Reference the Variables section of the PROFIS Engineering report for more information on the parameters N_{ua} and ϕN_{sa}.

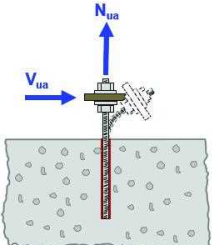
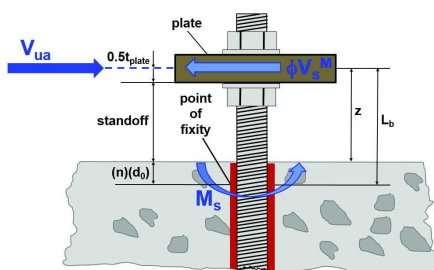
Calculations L_b

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
L_b	4.2.2.4 Shear loads with lever arm If the conditions a) and b) of 4.2.2.3 are not fulfilled the lever arm is calculated according to Equation (4.2) (see Figure 4.8) $\ell = a_3 + e_1 \quad (4.2)$ with e_1 = distance between shear load and concrete surface $a_3 = 0.5d$ $a_3 = 0$ if a washer and a nut are directly clamped to the concrete surface (see Figure 4.8b) d = nominal diameter of the anchor bolt or thread diameter (see Figure 4.8a)  ETAG 001 Annex C: Figure 4.8 Definition of lever arm 4.2.2.3 Shear loads without lever arm Shear loads acting on anchors may be assumed to act without lever arm if both of the following conditions are fulfilled: - The fixture shall be made of metal and in the area of the anchorage be fixed directly to the concrete either without an intermediate layer or with a levelling layer of mortar (compression strength $\geq 30 \text{ N/mm}^2$) with a thickness $\leq d/2$. - The fixture shall be in contact with the anchor over its entire thickness. 5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [\text{N}] \quad (5.5)$	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. The parameter “ℓ” in ETAG 001 Equation (4.2) is designated “L_b” in PROFIS Engineering. “L_b” corresponds to the “lever arm”, i.e. distance from where the shear resistance $V_{Rk,s}$ (ϕV_{sM} in PROFIS Engineering) acts, to the “point of fixity” where the internal bending moment $M_{Rk,s}$ (M_s in PROFIS Engineering) acts. Bending develops within the anchor element when a shear load V (V_{ua} in PROFIS Engineering) acts on a fixture having stand-off. Mechanical and adhesive anchors are installed into a hole drilled in concrete. When the anchor is subjected to bending, local concrete spalling can occur if it comes in contact with the side of the drilled hole. ETAG 001 provisions assume this spalling occurs at the surface of the concrete to a depth of one half the nominal anchor diameter. This depth is defined as “a_3” in ETAG 001 Equation (4.2), and as “$(n)(d_o)$” in PROFIS Engineering. The value for “n” in PROFIS Engineering depends on whether “stand-off without clamping”, “stand-off with clamping” or “stand-off with grouting” is selected. PROFIS Engineering assumes V_{ua} and ϕV_{sM} act at the center of the fixture thickness. The distance from where V_{ua} and ϕV_{sM} act to the surface of the concrete is defined as the parameter “e_1” in ETAG 001 Equation (4.2), and as “z” in PROFIS Engineering. PROFIS Engineering stand-off calculations: without clamping and with grouting t_{plate} = plate or fixture thickness z = standoff + $0.5(t_{plate})$ $n = 0.5$ $L_b = z + (0.5)(d_o)$ d_o = nominal anchor diameter When “stand-off without clamping” or “stand-off with grouting” are selected in PROFIS Engineering, $(n)(d_o) = (0.5)(d_o)$ and $L_b = z + (0.5)(d_o)$. Adhesive anchors and cast-in anchors can be modeled in PROFIS Engineering when “stand-off without clamping” is selected. Expansion anchors cannot be modeled for this condition.  PROFIS Engineering calculations for stand-off with clamping t_{plate} = plate or fixture thickness z = standoff + $0.5(t_{plate})$ $L_b = z$

Calculations L_b (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
L_b		Torque-controlled expansion anchors must be torqued via a nut/washer assembly at the concrete surface. If clamping via a nut/washer assembly occurs, there will be no local spalling at the concrete surface when the anchor is subjected to bending; therefore, n equals 0. When “stand-off with clamping” is selected in PROFIS Engineering, $(n)(d_0) = 0$ and $L_b = z$. For a non-grouted stand-off, expansion anchors must be modeled in PROFIS Engineering for “stand-off with clamping”.  Reference the Equations section of the report for more information on L_b. Reference the Variables section of the report for more information on the following PROFIS Engineering parameters z, n and d_0.

Results V_s^M

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
V_s^M	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ [Nm] (5.5a) $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor The value of $M_{Rk,s}^0$ for anchors according to current experience is obtained from Equation (5.5b). $M_{Rk,s}^0 = 1.2 W_{el} f_{uk} \quad [Nm] \quad (5.5b)$ The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear and tension load act on an anchor having standoff.  PROFIS Engineering calculation. $\phi V_s^M = \phi \left(\frac{\alpha_M M_s}{L_b} \right)$ 	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. When a standoff condition exists for an anchorage, an applied shear load can create bending in the anchors. An internal bending resistance, designated $M_{Rk,s}^0$, can be calculated using the material properties of the anchor element. $M_{Rk,s}^0$ is designated “M_s^0” in PROFIS Engineering, and is calculated per Equation (5.5b). If tension load also acts on the anchor, $M_{Rk,s}^0$ is reduced by a factor designated $(1 - N_{sd}/N_{Rd,s})$ per Equation (5.5a), and the resultant design bending resistance is designated “$M_{Rk,s}$” in Equation (5.5). $M_{Rk,s}$ is designated “M_s” in PROFIS Engineering. The parameter “α_M” in Equation (5.5) corresponds to the amount of rotational restraint acting on the fixture, and the parameter “ℓ” (designated L_b in PROFIS Engineering) corresponds to distance from where the shear resistance is assumed to act, to the “point of fixity” in the concrete where the internal bending resistance is assumed to act. Reference the figures to the left. The parameter $V_{Rk,s}$ in Equation (5.5) corresponds to the design shear resistance. Per Equation (5.5), PROFIS Engineering calculates a design shear strength (resistance) with respect to bending using values for the parameters α_M, M_s, L_b and a strength reduction factor (ϕ-factor) for steel failure in shear. PROFIS Engineering designates this design shear strength “ϕV_s^M”. ACI 318 anchoring-to-concrete provisions require calculation of a “nominal strength” which is then multiplied by a strength reduction factor(s) (ϕ-factors) to obtain a “design strength”. The parameter “V_s^M” in PROFIS Engineering corresponds to the nominal shear strength with respect to bending, and is calculated as follows: $V_s^M = (\alpha_M M_s) / L_b$ The parameter “ϕV_s^M” in PROFIS Engineering corresponds to the design shear strength with respect to bending, and is calculated as follows: $\phi V_s^M = \phi [(\alpha_M M_s) / L_b]$ The PROFIS Engineering parameter “ϕV_s^M”, therefore, corresponds to the parameter “$V_{Rk,s}$” in Equation (5.5). Per ACI 318 anchoring-to-concrete provisions, ϕV_s^M is checked against the factored shear load (V_{ua}) acting on the anchor. Reference the Equations and Calculations section of the report for more information on the following PROFIS Engineering parameters. M_s: Resultant flexural resistance of the anchor M_s^0: Characteristic flexural resistance of the anchor L_b: Internal lever arm adjusted for spalling at the surface concrete Reference the Variables section of the report for more information on the following PROFIS Engineering parameters: α_M: Rotational restraint modification factor Reference the Results section of the report for more information on the following PROFIS Engineering parameters. ϕ_{steel}: Strength reduction factor for steel failure in shear ϕV_s^M: Design shear strength (resistance) for bending ϕV_{ua}: Factored shear load acting on the anchor

Results ϕ_{steel}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																																																																																																																			
Φ_{steel}	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ PROFIS Engineering calculations for shear resistance of an anchor subjected to bending: $\Phi V_s^M = \Phi (\alpha_M M_s)/L_b \quad \text{modified ETAG 001 Equation (5.5)}$ ACI 318-14 Chapter 17 provisions and ICC-ES data for Φ-factors 17.3.3 Strength reduction factor Φ for anchors in concrete shall be as follows when the load combinations of 5.3 are used: (a) Anchor governed by strength of a ductile steel element (i) Tension loads..... 0.75 (ii) Shear loads 0.65 (b) Anchor governed by strength of a brittle steel element (i) Tension loads..... 0.65 (ii) Shear loads 0.60 PROFIS Engineering cast-in-place anchor portfolio. • AWS D1.1: 1/2" – 7/8" diameters • Hex head, square head, heavy square head: 1/2" – 1 1/2" diameters • Heavy hex head: 1/2" – 2" diameters <table><tr><th>MATERIAL SPECIFICATION</th><th>GRADE OR TYPE</th><th>DIAMETER (d_a) (in)</th><th>TENSILE STRENGTH(f_{t,2s}) (ksi)</th><th>YIELD STRENGTH (f_{ys}) (ksi)</th><th>GROSS AREA (in²)</th><th>EFFECTIVE AREA (A_{se}) (in²)</th></tr><tr><td rowspan="4">AWS D1.1</td><td>B</td><td>0.500</td><td>65</td><td>51</td><td>0.196</td><td rowspan="4"></td></tr><tr><td>B</td><td>0.625</td><td>65</td><td>51</td><td>0.307</td></tr><tr><td>B</td><td>0.750</td><td>65</td><td>51</td><td>0.442</td></tr><tr><td>B</td><td>0.875</td><td>65</td><td>51</td><td>0.601</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>36</td><td>0.500</td><td>58</td><td>36</td><td>0.196</td><td>0.142</td></tr><tr><td>36</td><td>0.625</td><td>58</td><td>36</td><td>0.307</td><td>0.226</td></tr><tr><td>36</td><td>0.750</td><td>58</td><td>36</td><td>0.442</td><td>0.334</td></tr><tr><td>36</td><td>0.875</td><td>58</td><td>36</td><td>0.601</td><td>0.462</td></tr><tr><td>36</td><td>1.000</td><td>58</td><td>36</td><td>0.785</td><td>0.606</td></tr><tr><td>36</td><td>1.125</td><td>58</td><td>36</td><td>0.994</td><td>0.763</td></tr><tr><td>36</td><td>1.250</td><td>58</td><td>36</td><td>1.227</td><td>0.969</td></tr><tr><td>36</td><td>1.375</td><td>58</td><td>36</td><td>1.485</td><td>1.160</td></tr><tr><td>36</td><td>1.500</td><td>58</td><td>36</td><td>1.767</td><td>1.410</td></tr><tr><td>36</td><td>1.750</td><td>58</td><td>36</td><td>2.405</td><td>1.900</td></tr><tr><td>36</td><td>2.000</td><td>58</td><td>36</td><td>3.142</td><td>2.500</td></tr><tr><td rowspan="12">ASTM F 1554</td><td>55</td><td>0.500</td><td>75</td><td>55</td><td>0.196</td><td>0.142</td></tr><tr><td>55</td><td>0.625</td><td>75</td><td>55</td><td>0.307</td><td>0.226</td></tr><tr><td>55</td><td>0.750</td><td>75</td><td>55</td><td>0.442</td><td>0.334</td></tr><tr><td>55</td><td>0.875</td><td>75</td><td>55</td><td>0.601</td><td>0.462</td></tr><tr><td>55</td><td>1.000</td><td>75</td><td>55</td><td>0.785</td><td>0.606</td></tr><tr><td>55</td><td>1.125</td><td>75</td><td>55</td><td>0.994</td><td>0.763</td></tr><tr><td>55</td><td>1.250</td><td>75</td><td>55</td><td>1.227</td><td>0.969</td></tr><tr><td>55</td><td>1.375</td><td>75</td><td>55</td><td>1.485</td><td>1.160</td></tr><tr><td>55</td><td>1.500</td><td>75</td><td>55</td><td>1.767</td><td>1.410</td></tr><tr><td>55</td><td>1.750</td><td>75</td><td>55</td><td>2.405</td><td>1.900</td></tr><tr><td>55</td><td>2.000</td><td>75</td><td>55</td><td>3.142</td><td>2.500</td></tr></table>	MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH(f _{t,2s}) (ksi)	YIELD STRENGTH (f _{ys}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)	AWS D1.1	B	0.500	65	51	0.196		B	0.625	65	51	0.307	B	0.750	65	51	0.442	B	0.875	65	51	0.601	ASTM F 1554	36	0.500	58	36	0.196	0.142	36	0.625	58	36	0.307	0.226	36	0.750	58	36	0.442	0.334	36	0.875	58	36	0.601	0.462	36	1.000	58	36	0.785	0.606	36	1.125	58	36	0.994	0.763	36	1.250	58	36	1.227	0.969	36	1.375	58	36	1.485	1.160	36	1.500	58	36	1.767	1.410	36	1.750	58	36	2.405	1.900	36	2.000	58	36	3.142	2.500	ASTM F 1554	55	0.500	75	55	0.196	0.142	55	0.625	75	55	0.307	0.226	55	0.750	75	55	0.442	0.334	55	0.875	75	55	0.601	0.462	55	1.000	75	55	0.785	0.606	55	1.125	75	55	0.994	0.763	55	1.250	75	55	1.227	0.969	55	1.375	75	55	1.485	1.160	55	1.500	75	55	1.767	1.410	55	1.750	75	55	2.405	1.900	55	2.000	75	55	3.142	2.500	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible steel failure mode in shear. When a standoff condition exists for an anchorage, an applied shear load can create bending in the anchors. A shear resistance ($V_{Rk,s}$) for the anchor element is calculated per ETAG Equation (5.5). ACI 318 anchoring-to-concrete provisions require calculation of a “nominal strength” which is then multiplied by a strength reduction factor(s) (Φ-factor) to obtain a “design strength”. The parameter “V_s^M” in PROFIS Engineering corresponds to the “nominal shear strength” with respect to bending, and is calculated as follows: $V_s^M = (\alpha_M M_s)/L_b$ The parameter “ΦV_s^M” in PROFIS Engineering corresponds to the “design shear strength” with respect to bending, and is calculated as follows: $\Phi V_s^M = \Phi [(\alpha_M M_s)/L_b].$ Therefore, the PROFIS Engineering parameter “ΦV_s^M”, corresponds to the parameter “$V_{Rk,s}$” in Equation (5.5). PROFIS Engineering designates the Φ-factor corresponding to steel failure “Φ_{steel}”. When designing cast-in-place anchors, PROFIS Engineering uses the Φ-factors given in ACI 318-14 Section 17.3.3. The Φ_{steel}-values for the cast-in-place anchors in the PROFIS Engineering portfolio correspond to the Φ-factors given in Section 17.3.3 for ductile steel elements. In the absence of product-specific data, the Φ-factors in Section 17.3.3 can be used as guide values for post-installed anchors; however, Φ-factors derived from product-specific testing should always be used for the actual design of post-installed anchors. Post-installed mechanical anchors can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC193 in conjunction with the ACI standard ACI 355.2. Post-installed adhesive anchor systems can be shown compliance under the International Building Code via testing per the ICC-ES acceptance criteria AC308 in conjunction with the ACI standard ACI 355.4. PROFIS Engineering uses the Φ-factors derived from AC193/ACI 355.2 or AC308/ACI 355.4 testing, as given in the ICC-ESR for the anchor. The Φ-factors in the ICC-ESR correspond to the ACI 318 Φ-factors for “ductile steel element” and “brittle steel element”, as determined by the product testing and material properties for a specific anchor element. Reference the Results section of the report for more information on the following PROFIS Engineering parameters. V_s^M: Nominal shear strength (resistance) for bending ΦV_s^M: Design shear strength (resistance) for bending
MATERIAL SPECIFICATION	GRADE OR TYPE	DIAMETER (d _a) (in)	TENSILE STRENGTH(f _{t,2s}) (ksi)	YIELD STRENGTH (f _{ys}) (ksi)	GROSS AREA (in ²)	EFFECTIVE AREA (A _{se}) (in ²)																																																																																																																																																															
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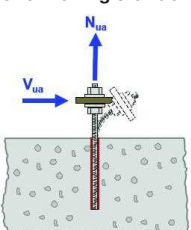
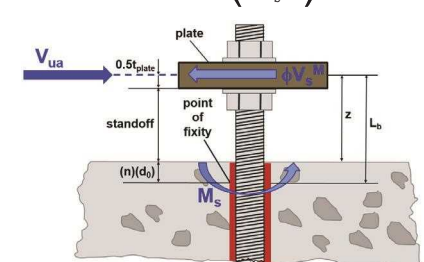
Results ϕ_{steel} (continued)

Results	318-14 Chapter 17 Provision												Comments for PROFIS Engineering	
ϕ_{steel}	Cast-in-place anchor portfolio parameters for elongation and reduction of area.													
	Bolt Type		Grade or Type		diameter (in)		f_{ys} (psi)		futa (psi)		elongation (min)		reduction of area (min)	
	ASW D1.1		B		1/2 – 1		51,000		65,000		20%		50%	
	ASTM F1554		36		≤ 2		36,000		58,000		23%		40%	
			55		≤ 2		55,000		75,000		21%		30%	
			105		≤ 2		105,000		125,000		15%		45%	
	Excerpt of mechanical anchor ICC-ESR showing (ϕ -factors) for steel failure in shear.													
	ICC-ESR-1917 Table 3													
	DESIGN INFORMATION		Symbol	Units	Nominal anchor diameter (in.)									
	Effective min. embedment		h_{ef}	in.	3/8		1/2		5/8		3/4			
				1-1/2	2	2-3/4	2	3-1/4	3-1/8	4	3-1/4	3-3/4	4-3/4	
Strength reduction ϕ factor for tension, steel failure modes			0.75											
Excerpt of adhesive anchor ICC-ESR showing (ϕ -factors) for steel failure in shear														
ICC-ESR-3187 Table 11														
DESIGN INFORMATION			Symbol	Units	Nominal rod diameter (in.)									
					3/8	1/2	5/8	3/4	7/8	1	1-1/4			
ASTM F1554 Gr. 36	Nominal strength as governed by steel strength		V_{sa}	lb	-	4940	7865	11,640	16,070	21,080	33,725			
	Reduction factor, seismic shear		$\alpha_{V,seis}$	-	0.60									
	Strength reduction factor ϕ for shear		ϕ	-	0.65									

Results $\phi_{\text{nonductile}}$

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
$\phi_{\text{nonductile}}$	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ PROFIS Engineering calculations for shear resistance of an anchor subjected to bending: $\phi V_s^M = \phi [(\alpha_M M_s) / L_b] \quad \text{modified ETAG 001 Equation (5.5)}$ ACI 318-08 Part D.3.3.6 D.3.3.6 – As an alternative to D.3.3.4 and D.3.3.5, it shall be permitted to take the design strength of the anchors as 0.4 times the design strength determined in accordance with D.3.3.3. For the anchors of stud bearing walls, it shall be permitted to take the design strength of the anchors as 0.5 times the design strength determined in accordance with D.3.3.3.	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible steel failure mode in shear. When a standoff condition exists for an anchorage, an applied shear load can create bending in the anchors. A shear resistance ($V_{Rk,s}$) for the anchor element is calculated per ETAG Equation (5.5). ACI 318 anchoring-to-concrete provisions require calculation of a “nominal strength” which is then multiplied by a strength reduction factor(s) (ϕ-factor) to obtain a “design strength”. The parameter “V_s^M” in PROFIS Engineering corresponds to the “nominal shear strength” with respect to bending, and is calculated as follows: $V_s^M = (\alpha_M M_s) / L_b$ The parameter “ϕV_s^M” in PROFIS Engineering corresponds to the “design shear strength” with respect to bending, and is calculated as follows: $\phi V_s^M = \phi [(\alpha_M M_s) / L_b]$ where “ϕ” corresponds to the PROFIS Engineering parameter “ϕ_{steel}” for steel failure in shear. Therefore, the PROFIS Engineering parameter “$\phi_{\text{steel}} V_s^M$”, corresponds to the parameter “$V_{Rk,s}$” in Equation (5.5). The parameter “$\phi_{\text{nonductile}}$” is a reduction factor for seismic load conditions that is given in Part D.3.3.6 of the anchoring-to-concrete provisions in ACI 318-08 Appendix D. This reduction factor can range from a value of 0.4 to 1.0, depending on the application, and PROFIS Engineering designates this factor “$\phi_{\text{nonductile}}$”. “$\phi_{\text{nonductile}}$” is not a relevant parameter for seismic design per ACI 318-14 Chapter 17; therefore, it is referenced in the PROFIS Engineering report for ACI 318-14 calculations (including steel failure with lever arm calculations) as equal to 1.0. Reference the PROFIS Engineering Design Guide for ACI 318-08 anchoring-to-concrete provisions for more information on $\phi_{\text{nonductile}}$.

Results ϕV_s^M

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
ϕV_s^M	5.2.3.2 Steel failure b) Shear load with lever arm $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ where α_M = see 4.2.2.4 ℓ = lever arm according to Equation (4.2) $M_{Rk,s} = M_{Rk,s}^0 (1 - N_{sd}/N_{Rd,s})$ [Nm] (5.5a) $N_{Rd,s} = N_{Rk,s} / \gamma_{Ms}$ $N_{Rk,s}$, γ_{Ms} to be taken from the relevant ETA $M_{Rk,s}^0$ = characteristic bending resistance of an individual anchor The value of $M_{Rk,s}^0$ for anchors according to current experience is obtained from Equation (5.5b). $M_{Rk,s}^0 = 1.2 W_{el} f_{uk} \quad [Nm] \quad (5.5b)$ The figures below illustrate ETAG 001 design assumptions with respect to bolt bending. PROFIS Engineering nomenclature for ACI 318 calculations is used in the illustrations. Shear and tension load act on an anchor having standoff.  PROFIS Engineering calculation. $\phi V_s^M = \phi \left(\frac{\alpha_M M_s}{L_b} \right)$ 	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. When a standoff condition exists for an anchorage, an applied shear load can create bending in the anchors. An internal bending resistance, designated $M_{Rk,s}^0$, can be calculated using the material properties of the anchor element. $M_{Rk,s}^0$ is designated “M_s^0” in PROFIS Engineering, and is calculated per Equation (5.5b). If tension load also acts on the anchor, $M_{Rk,s}^0$ is reduced by a factor designated $(1 - N_{sd}/N_{Rd,s})$ per Equation (5.5a), and the resultant design bending resistance is designated “$M_{Rk,s}$” in Equation (5.5). $M_{Rk,s}$ is designated “M_s” in PROFIS Engineering. The parameter “α_M” in Equation (5.5) corresponds to the amount of rotational restraint acting on the fixture, and the parameter “ℓ” (designated L_b in PROFIS Engineering) corresponds to distance from where the shear resistance is assumed to act, to the “point of fixity” in the concrete where the internal bending resistance is assumed to act. Reference the figures to the left. The parameter $V_{Rk,s}$ in Equation (5.5) corresponds to the design shear resistance. Per Equation (5.5), PROFIS Engineering calculates a design shear resistance; however, the calculations are based on ACI 318-14 strength design provisions. Therefore, PROFIS Engineering calculates a “design strength” with respect to bending which it designates “ϕV_s^M” using values for the parameters α_M, M_s, L_b and a strength reduction factor (ϕ_{steel}) for steel failure in shear. ACI 318 anchoring-to-concrete provisions require calculation of a “nominal strength” which is then multiplied by a strength reduction factor(s) (ϕ-factors) to obtain a “design strength”. The parameter “V_s^M” in PROFIS Engineering corresponds to the nominal shear strength with respect to bending, and is calculated as follows: $V_s^M = (\alpha_M M_s) / L_b$ The parameter “ϕV_s^M” in PROFIS Engineering corresponds to the design shear strength with respect to bending, and is calculated as follows: $\phi V_s^M = \phi_{steel} [(\alpha_M M_s) / L_b]$ The PROFIS Engineering parameter “ϕV_s^M”, therefore, corresponds to the parameter “$V_{Rk,s}$” in Equation (5.5). Per ACI 318 anchoring-to-concrete provisions, ϕV_s^M is checked against the factored shear load (V_{ua}) acting on the anchor. Reference the Equations and Calculations section of the report for more information on the following PROFIS Engineering parameters. M_s: Resultant flexural resistance of the anchor M_s^0: Characteristic flexural resistance of the anchor L_b: Internal lever arm adjusted for spalling at the surface concrete Reference the Variables section of the report for more information on the following PROFIS Engineering parameters: α_M: Rotational restraint modification factor Reference the Results section of the report for more information on the following PROFIS Engineering parameters. V_s^M: Nominal shear strength (resistance) for bending ϕ_{steel}: Strength reduction factor for steel failure in shear V_{ua}: Factored shear load acting on the anchor

Results V_{ua}

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																		
V_{ua}	5.2.3.2 Steel failure b) Shear load with lever arm The characteristic resistance of an anchor, $V_{Rk,s}$, is given by Equation (5.5). $V_{Rk,s} = \frac{\alpha_M M_{Rk,s}}{\ell} \quad [N] \quad (5.5)$ ACI 318-14 Section 17.3.1.1 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from ACI 318-14 Table 17.3.1.1 showing provisions for shear calculations. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{steel} V_{sa} \geq V_{ua}$</td><td>$\phi_{steel} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{concrete} V_{cb} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{concrete} V_{cp} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{ag} \geq V_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{ag} \geq V_{ua,g}$	PROFIS Engineering uses the provisions given in the European Technical Approval Guideline (ETAG) titled ETAG 001 Metal Anchors for Use in Concrete Annex C: Design Methods for Anchorages to consider bolt bending as a possible shear failure mode. When a standoff condition exists for an anchorage, an applied shear load can create bending in the anchors. The parameter $V_{Rk,s}$ in Equation (5.5) corresponds to the design shear resistance. Per Equation (5.5), PROFIS Engineering calculates a design shear resistance; however, the calculations are based on ACI 318-14 strength design provisions. Therefore, PROFIS Engineering calculates a “design strength” with respect to bending, which it designates “ϕV_s^M”, using values for the parameters α_M, M_s, L_b and a strength reduction factor (ϕ_{steel}) for steel failure in shear. ACI 318 anchoring-to-concrete provisions require calculation of a “nominal strength” which is then multiplied by a strength reduction factor(s) (ϕ-factors) to obtain a “design strength”. The parameter “ϕV_s^M” in PROFIS Engineering corresponds to the design shear strength with respect to bending, and is calculated as follows: $\phi V_s^M = \phi_{steel} [(\alpha_M M_s) / L_b].$ The PROFIS Engineering parameter “$\phi_{V_{saM}}$”, therefore, corresponds to the parameter “$V_{Rk,s}$” in Equation (5.5). PROFIS Engineering calculates ϕV_s^M for a single anchor and checks this “design strength” against a factored shear load (V_{ua}). If the application consists of a single anchor in shear, ϕV_s^M is checked against the factored shear load acting on the anchor. If the application consists of a group of anchors in shear, ϕV_s^M is checked against the highest individually loaded anchor in shear. The PROFIS Engineering report uses the generic designation “V_{ua}” to reference either the only shear load acting on an anchor in shear, or the highest shear load acting on an individual anchor within an anchor group in shear. PROFIS Engineering considers the provisions for steel failure in shear with respect to bolt bending to have been satisfied if $\phi V_s^M \geq V_{ua}$. The PROFIS Engineering Load Engine permits users to input service loads that will then be factored per IBC factored load equations. Users can also import factored load combinations via a spreadsheet, or input factored load combinations directly on the main screen. PROFIS Engineering users are responsible for inputting shear loads. If a single anchor in shear is being modeled, PROFIS Engineering calculates ϕV_s^M, and checks this value against either (a) the factored shear load acting on the anchor, which has been calculated using the loads input via the Load Engine, (b) the factored shear load acting on the anchor, which has been calculated using the loads imported from a spreadsheet or (c) the factored shear load acting on the anchor, which has been calculated using the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the factored shear load determined to be acting on the anchor. If a group of anchors in shear is being modeled, PROFIS Engineering calculates ϕV_s^M, and checks this value against either (a) the highest factored shear load acting on an individual anchor that is calculated with the Load Engine, (b) the highest factored shear load acting on an individual anchor that is determined from the loads imported from a spreadsheet or (c) the highest factored shear load acting on an individual anchor that is determined from the loads input in the matrix on the main screen. The value for V_{ua} shown in the report corresponds to the highest factored shear load determined to be acting on an individual anchor within the group of anchors that are in shear. Reference the Equations section of the report for more information on: $\phi V_s^M \geq V_{ua}$: ACI 318-14 design check for bending Reference the Results section of the report for more information on the following PROFIS Engineering parameters. ϕ_{steel}: Strength reduction factor for steel failure in shear ϕV_s^M: Design shear strength (resistance) for bending
Failure Mode	Single Anchor			Anchor Group																
		Individual anchor in a Group	Anchors as a group																	
Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$																		
Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$																	
Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{ag} \geq V_{ua,g}$																	

PART 5

COMBINED TENSION AND SHEAR LOAD



3.0 INTERACTION

347

3.1 Parabolic

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3.2 Tri-Linear

358

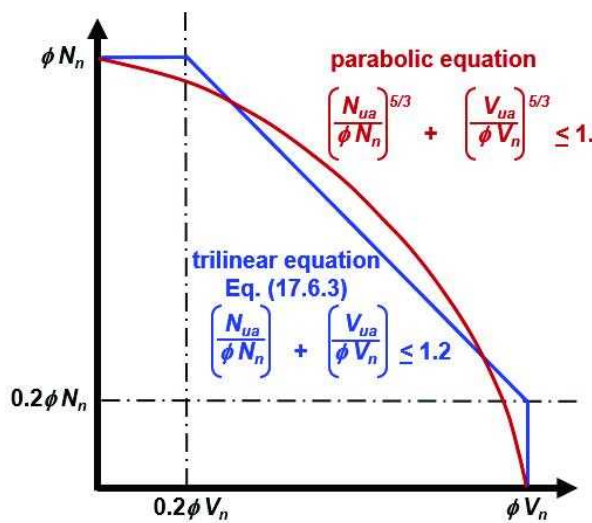
Equations $\beta_{NV} = \beta_N^\varepsilon + \beta_V^\varepsilon \leq 1.0$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																									
$\beta_{NV} = \beta_N^\varepsilon + \beta_V^\varepsilon \leq 1.0$	R17.6 – Interaction of tensile and shear forces The shear-tension interaction expression has traditionally been expressed as $\left(\frac{N_{ua}}{N_n}\right)^\varepsilon + \left(\frac{V_{ua}}{V_n}\right)^\varepsilon \leq 1.0$ where ε varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\varepsilon = 5/3$. The limits were chosen to eliminate the requirement for computation of interaction effects where very small values of the second force are present. Any other interaction expression that is verified by test data, however, can be used to satisfy 17.3.1.3. Reference ACI 318-14 Fig. R17.6.	ACI 318-14 anchoring-to-concrete provisions default to what is known as a trilinear interaction equation, which is given in Eq. (17.6.3). PROFIS Engineering checks both Eq. (17.6.3) and the parabolic interaction equation given in the ACI 318-14 commentary R17.6. The PROFIS Engineering report shows the most favorable results. The failure mode for a given tension or shear load condition can be expressed as a ratio of factored load to design strength: • Factored tension load/tension design strength = $(N_{ua}/\phi N_n)$ • Factored shear load/shear design strength = $(V_{ua}/\phi V_n)$ The “governing” failure mode can be defined as the highest (factored load/design strength) ratio for the failure modes being considered. PROFIS Engineering defines the calculated results using the parabolic interaction equation via the parameter “β_{NV}”. Part 3 of the PROFIS Engineering report shows the ratio of factored tension load (N_{ua}) to tension design strength (ϕN_n) via the parameter β_N. For the example below, concrete breakout failure is the governing failure mode for tension because it has the highest utilization ($\beta_N = 51\%$). 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension)		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK
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Concrete breakout Failure**	10,000	19,971	51	OK																							

Equations $\beta_{NV} = \beta_N^\epsilon + \beta_V^\epsilon \leq 1.0$ (continued)

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																																					
$\beta_{NV} = \beta_N^{\epsilon} + \beta_V^{\epsilon} \leq 1.0$	17.3.1.3 When both N_{ua} and V_{ua} are present, interaction effects shall be considered using an interaction expression that results in computation of strength in substantial agreement with results of comprehensive tests. This requirement shall be considered satisfied by 17.6 Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table> Excerpt from Table 17.3.1.1 showing the shear failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{steel} V_{sa} \geq V_{ua}$</td><td>$\phi_{steel} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{concrete} V_{cb} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{concrete} V_{cp} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{ag} \geq V_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{ag} \geq V_{ua,g}$	Part 4 of the PROFIS Engineering report shows the ratio of factored shear load (V_{ua}) to shear design strength (ϕV_n) via the parameter β_v. For the example below, concrete edge failure in direction x* is the governing failure mode for shear because it has the highest utilization (β_v = 60%). 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization β_N = V_{ua}/ϕV_n</th><th>Status</th></tr><tr><td>Steel strength*</td><td>1,500</td><td>4,540</td><td>33</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>6,000</td><td>52,765</td><td>12</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x***</td><td>6,000</td><td>10,080</td><td>60</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) For the examples above, PROFIS Engineering would perform the combined interaction check using the parabolic interaction equation as follows: $\beta_{NV} = (\beta_N)^{5/3} + (\beta_V)^{5/3} \quad \text{check: } \beta_{NV} \leq 1.0$ $= (0.51)^{5/3} + (0.6)^{5/3}$ $= 0.752 \quad \text{check: } 0.752 < 1.0 \quad \text{OK}$ Reference the PROFIS Engineering design guide section on the trilinear interaction equation for additional information about PROFIS Engineering interaction calculations.		Load V _{ua} [lb]	Capacity ϕV _n [lb]	Utilization β _N = V _{ua} /ϕV _n	Status	Steel strength*	1,500	4,540	33	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	6,000	52,765	12	OK	Concrete edge failure in direction x***	6,000	10,080	60	OK
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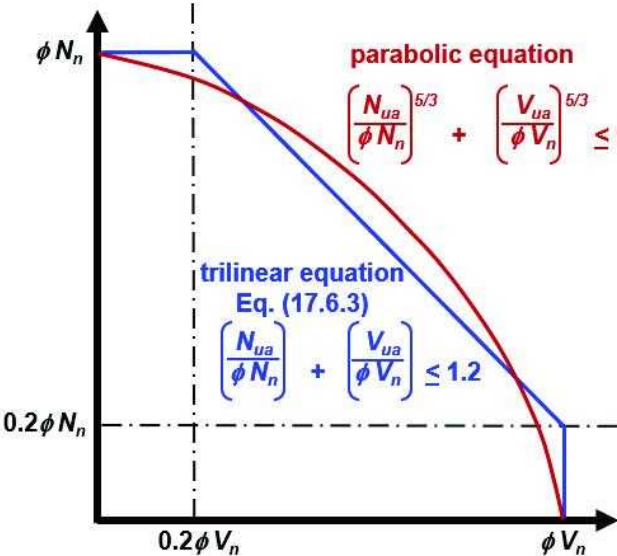
Variables β_N

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																		
β_N	R17.6 – Interaction of tensile and shear forces The shear-tension interaction expression has traditionally been expressed as $\left(\frac{N_{ua}}{N_n}\right)^{\varepsilon} + \left(\frac{V_{ua}}{V_n}\right)^{\varepsilon} \leq 1.0$ where ε varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\varepsilon = 5/3$. The limits were chosen to eliminate the requirement for computation of interaction effects where very small values of the second force are present. Any other interaction expression that is verified by test data, however, can be used to satisfy 17.3.1.3.  Reference ACI 318-14 Fig. R17.6.	Part 3 of the PROFIS Engineering report shows the ratio of factored tension load (N_{ua}) to tension design strength (ϕN_n) via the parameter β_N. PROFIS Engineering calculates β_N for each tension failure mode relevant to a particular anchor type. Per ACI 318-14 Table 17.3.1.1, the tension provisions of Chapter 17 are satisfied if all the calculated design strengths for tension failure modes are greater than or equal to the corresponding factored load. When PROFIS Engineering calculates β_N, it rounds up the result to the nearest whole number. The β_N-values given in Part 3 of the report correspond to a percentage. The PROFIS Engineering report shows “OK” under the Status heading if the β_N-value is $\leq 100\%$. The highest β_N-value corresponds to the “controlling” or “governing” failure mode in tension. This value is used as the tension component in the interaction equation. For the example below, all the calculated β_N-values are $\leq 100\%$, and concrete breakout failure is the governing failure mode for tension because it has the highest utilization ($\beta_N = 51\%$). The tension provisions of Chapter 17 have been satisfied. 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua} / \phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) When N_{ua} is greater than ϕN_n, the β_N-value will be greater than 100%. The tension provisions of Chapter 17 are not satisfied when N_{ua} is greater than ϕN_n. The PROFIS Engineering report shows “not recommended” under the Status heading if the β_N-value is $\geq 100\%$. For the example below, the β_N-values for bond strength and concrete breakout failure are $> 100\%$; therefore, the PROFIS Engineering report shows “not recommended” under the Status heading for these failure modes to indicate that the Chapter 17 provisions have not been satisfied. 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua} / \phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>10,000</td><td>26,347</td><td>38</td><td>OK</td></tr><tr><td>Bond strength**</td><td>40,000</td><td>33,922</td><td>118</td><td>not recommended</td></tr><tr><td>Sustained tension load bond strength*</td><td>5,000</td><td>11,495</td><td>44</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>40,000</td><td>26,603</td><td>151</td><td>not recommended</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) Reference the PROFIS Engineering design guide section on β_V for additional information about PROFIS Engineering interaction calculations.		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua} / \phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua} / \phi N_n$	Status	Steel strength*	10,000	26,347	38	OK	Bond strength**	40,000	33,922	118	not recommended	Sustained tension load bond strength*	5,000	11,495	44	OK	Concrete breakout Failure**	40,000	26,603	151	not recommended
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	Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$																									
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Variables β_N (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
β_N	The following tension failure modes are considered for each type of anchor in the PROFIS Engineering portfolio: post-installed mechanical anchor steel strength: $\beta_N = N_{ua(i)}/\phi_{steel} N_{sa}$ pullout strength: $\beta_N = N_{ua(i)}/\phi_{concrete} N_{pn,f'c}$ concrete breakout strength: $\beta_N = N_{ua(i)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ post-installed adhesive anchor steel strength: $\beta_N = N_{ua(i)}/\phi_{steel} N_{sa}$ bond strength: $\beta_N = N_{ua(i)}/\phi_{bond} N_a$ or $\beta_N = N_{ua(g)}/\phi_{bond} N_{ag}$ sustained tension load (for bond strength): $\beta_N = N_{ua(i)}/0.55\phi_{bond} N_{ba}$ concrete breakout strength: $\beta_N = N_{ua(i)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ cast-in anchor steel strength: $\beta_N = N_{ua(i)}/\phi_{steel} N_{sa}$ pullout strength: $\beta_N = N_{ua(i)}/\phi_{concrete} N_{pn,f'c}$ concrete breakout strength: $\beta_N = N_{ua(i)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ side-face blowout strength: $\beta_N = N_{ua(i)}/\phi_{concrete} N_{sb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{sbg}$ where $N_{ua(i)}$ corresponds to the highest factored tension load acting on an individual anchor and $N_{ua(g)}$ corresponds to the total factored tension load acting on a group of anchors.	

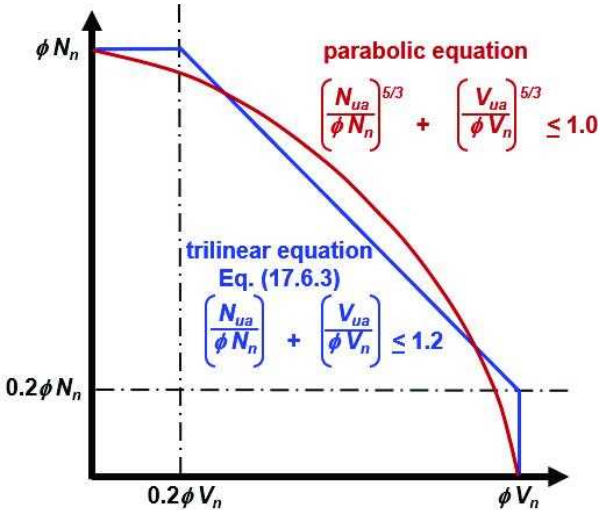
Variables β_v

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																		
β_v	R17.6 — Interaction of tensile and shear forces The shear-tension interaction expression has traditionally been expressed as $\left(\frac{N_{ua}}{N_n}\right)^{\varepsilon} + \left(\frac{V_{ua}}{V_n}\right)^{\varepsilon} \leq 1.0$ where ε varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\varepsilon = 5/3$. The limits were chosen to eliminate the requirement for computation of interaction effects where very small values of the second force are present. Any other interaction expression that is verified by test data, however, can be used to satisfy 17.3.1.3.  Reference ACI 318-14 Fig. R17.6.	Part 4 of the PROFIS Engineering report shows the ratio of factored shear load (V_{ua}) to shear design strength (ϕV_n) via the parameter β_v. PROFIS Engineering calculates β_v for each shear failure mode relevant to a particular anchor type. Per ACI 318-14 Table 17.3.1.1, the shear provisions of Chapter 17 are satisfied if all the calculated design strengths for shear failure modes are greater than or equal to the corresponding factored load. When PROFIS Engineering calculates β_v, it rounds up the result to the nearest whole number. The β_v-values given in Part 4 of the report correspond to a percentage. The PROFIS Engineering report shows “OK” under the Status heading if the β_v-value is $\leq 100\%$. The highest β_v-value corresponds to the “controlling” or “governing” failure mode in shear. This value is used as the shear component in the interaction equation. For the example below, all the calculated β_v-values are $\leq 100\%$, and concrete edge failure in direction x* is the governing failure mode for shear because it has the highest utilization ($\beta_v = 60\%$). The shear provisions of Chapter 17 have been satisfied. 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_v = V_{ua} / \phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>1,500</td><td>4,540</td><td>33</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>6,000</td><td>52,765</td><td>12</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x**</td><td>6,000</td><td>10,080</td><td>60</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) When V_{ua} is greater than ϕV_n, the β_v-value will be greater than 100%. The shear provisions of Chapter 17 are not satisfied when V_{ua} is greater than ϕV_n. The PROFIS Engineering report shows “not recommended” under the Status heading if the β_v-value is $\geq 100\%$. For the example below, the β_v-value for concrete edge failure in direction x* is $> 100\%$; therefore, the PROFIS Engineering report shows “not recommended” under the Status heading for this failure mode to indicate that the Chapter 17 provisions have not been satisfied. 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_v = V_{ua} / \phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>3,750</td><td>8,221</td><td>46</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>15,000</td><td>76,400</td><td>20</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x**</td><td>15,000</td><td>11,592</td><td>130</td><td>not recommended</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) Reference the PROFIS Engineering design guide section on β_n for additional information about PROFIS Engineering interaction calculations.		Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_v = V_{ua} / \phi V_n$	Status	Steel strength*	1,500	4,540	33	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	6,000	52,765	12	OK	Concrete edge failure in direction x**	6,000	10,080	60	OK		Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_v = V_{ua} / \phi V_n$	Status	Steel strength*	3,750	8,221	46	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	15,000	76,400	20	OK	Concrete edge failure in direction x**	15,000	11,592	130	not recommended
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Variables β_v (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering
β_v	The PROFIS Engineering anchor portfolio includes post-installed mechanical anchors, post-installed adhesive anchors, and cast-anchors. The following shear failure modes are considered for each type of anchor: post-installed mechanical anchor steel strength: $\beta_v = V_{ua(l)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ post-installed adhesive anchor steel strength: $\beta_v = V_{ua(l)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ cast-in anchor steel strength: $\beta_v = V_{ua(l)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ where $V_{ua(l)}$ corresponds to the highest factored shear load acting on an individual anchor and $V_{ua(g)}$ corresponds to the total factored shear load acting on a group of anchors.	

Variables $\mathcal{E}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering										
$\mathcal{E}$	R17.6 – Interaction of tensile and shear forces The shear-tension interaction expression has traditionally been expressed as $\left(\frac{N_{ua}}{N_n}\right)^{\mathcal{E}} + \left(\frac{V_{ua}}{V_n}\right)^{\mathcal{E}} \leq 1.0$ where $\mathcal{E}$ varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\mathcal{E} = 5/3$. The limits were chosen to eliminate the requirement for computation of interaction effects where very small values of the second force are present. Any other interaction expression that is verified by test data, however, can be used to satisfy 17.3.1.3.  Reference ACI 318-14 Fig. R17.6.	ACI 318-14 anchoring-to-concrete provisions default to what is known as a trilinear interaction equation, which is given in Eq. (17.6.3). PROFIS Engineering checks both Eq. (17.6.3) and the parabolic interaction equation given in the ACI 318-14 commentary R17.6. The PROFIS Engineering report shows the most favorable results. The failure mode for a given tension or shear load condition can be expressed as a ratio of factored load to design strength: - Factored tension load/tension design strength = $(N_{ua}/\phi N_n)$ - Factored shear load/shear design strength = $(V_{ua}/\phi V_n)$ The “governing” failure mode can be defined as the highest (factored load/design strength) ratio for the failure modes being considered. The generalized interaction equation given in the commentary R17.6 permits the governing tension component $(N_{ua}/\phi N_n)$ and the governing shear component $(V_{ua}/\phi V_n)$ to be raised to any power ($\mathcal{E}$) between 1 and 2. When PROFIS Engineering checks combined tension/shear interaction with the parabolic equation, the governing tension component $(N_{ua}/\phi N_n)$ and the governing shear component $(V_{ua}/\phi V_n)$ are raised to the 5/3 power, so $\mathcal{E} = 5/3$. Below is an example of how the PROFIS Engineering report shows the parameters used in the parabolic interaction equation. The parameter “β_N” corresponds to the governing tension component $(N_{ua}/\phi N_n)$ and the parameter “β_V” corresponds to the governing shear component $(V_{ua}/\phi V_n)$. Since $(N_{ua}/\phi N_n)$ and $(V_{ua}/\phi V_n)$ are each raised to the 5/3 power when the parabolic equation is used, the parameter “$\mathcal{E}$” is shown as 5/3 in the report. The parameter “Utilization $\beta_{N,V}$” is calculated as follows: $\beta_{N,V} = (\beta_N)^{5/3} + (\beta_V)^{5/3} \leq 1.0$$\beta_{N,V} = (\beta_N)^{5/3} + (\beta_V)^{5/3} \leq 1.0$$= (0.693)^{5/3} + (0.475)^{5/3}$$= 0.832$ Fig. R17.6 PROFIS Engineering $\beta_{N,V} < 1.0$ OK 5 Combined tension and shear loads <table><tr><th>β_N</th><th>β_V</th><th>$\mathcal{E}$</th><th>Utilization β_N [%]</th><th>Status</th></tr><tr><td>0.693</td><td>0.475</td><td>5/3</td><td>84</td><td>OK</td></tr></table> $\beta_{N,V} = \beta_N^{\mathcal{E}} + \beta_V^{\mathcal{E}} < 1$ Reference the PROFIS Engineering design guide section on the trilinear interaction equation for additional information about PROFIS Engineering interaction calculations.	β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status	0.693	0.475	5/3	84	OK
β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status								
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Calculations Utilization $\beta_{N,V}$ [%]

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																												
Utilization $\beta_{N,V}$ [%]	R17.6 – Interaction of tensile and shear forces The shear-tension interaction expression has traditionally been expressed as $\left(\frac{N_{ua}}{N_n}\right)^{\mathcal{E}} + \left(\frac{V_{ua}}{V_n}\right)^{\mathcal{E}} \leq 1.0$ where $\mathcal{E}$ varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\mathcal{E} = 5/3$. The limits were chosen to eliminate the requirement for computation of interaction effects where very small values of the second force are present. Any other interaction expression that is verified by test data, however, can be used to satisfy 17.3.1.3. Reference ACI 318-14 Fig. R17.6.	The failure mode for a given tension or shear load condition can be expressed as a ratio of factored load to design strength: - Factored tension load/tension design strength = $(N_{ua}/\phi N_n)$ - Factored shear load/shear design strength = $(V_{ua}/\phi V_n)$ PROFIS Engineering references these ratios as “utilizations”, and shows them in the report as a percentage. Part 3 of the PROFIS Engineering report shows the utilizations for each tension failure mode being considered and designates “tension utilizations” via the parameter “β_N”. 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) Part 4 of the PROFIS Engineering report shows the utilizations for each shear failure mode being considered and designates “shear utilizations” via the parameter “β_V”. 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_N = V_{ua}/\phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>1,500</td><td>4,540</td><td>33</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>6,000</td><td>52,765</td><td>12</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x***</td><td>6,000</td><td>10,080</td><td>60</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) The “governing” failure mode can be defined as the highest utilization for the failure modes being considered. PROFIS Engineering designates the sum of the utilization for the governing failure mode in tension and the utilization for the governing failure mode in shear as “$\beta_{N,V}$”, and shows it as a percentage in Part 5 of the report. For the examples above, concrete breakout failure is the governing tension failure mode ($\beta_N = 51\%$) and concrete edge failure in direction x* is the governing shear failure mode ($\beta_V = 60\%$). PROFIS Engineering would calculate $\beta_{N,V}$ per the parabolic equation defined in Fig. R17.6 as follows: $\beta_{N,V} = (\beta_N)^{5/3} + (\beta_V)^{5/3} = (0.51)^{5/3} + (0.6)^{5/3} = 0.752$ 5 Combined tension and shear loads <table><tr><th>β_N</th><th>β_V</th><th>$\mathcal{E}$</th><th>Utilization β_N [%]</th><th>Status</th></tr><tr><td>0.693</td><td>0.475</td><td>5/3</td><td>84</td><td>OK</td></tr></table> $\beta_{N,V} = \beta_N^{\mathcal{E}} + \beta_V^{\mathcal{E}} \leq 1$ Reference the PROFIS Engineering design guide section on the trilinear interaction equation for additional information about PROFIS Engineering interaction calculations.		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK		Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_N = V_{ua}/\phi V_n$	Status	Steel strength*	1,500	4,540	33	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	6,000	52,765	12	OK	Concrete edge failure in direction x***	6,000	10,080	60	OK	β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status	0.693	0.475	5/3	84	OK
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Results Utilization Status (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering										
Status	The following shear failure modes are considered for each type of anchor: post-installed mechanical anchor steel strength: $\beta_v = V_{ua(i)} / \phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(i)} / \phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)} / \phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(i)} / \phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)} / \phi_{concrete} V_{cpg}$ post-installed adhesive anchor steel strength: $\beta_v = V_{ua(i)} / \phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(i)} / \phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)} / \phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(i)} / \phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)} / \phi_{concrete} V_{cpg}$ cast-in anchor steel strength: $\beta_v = V_{ua(i)} / \phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(i)} / \phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)} / \phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(i)} / \phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)} / \phi_{concrete} V_{cpg}$ where $V_{ua(i)}$ corresponds to the highest factored shear load acting on an individual anchor and $V_{ua(g)}$ corresponds to the total factored shear load acting on a group of anchors.	When the governing β_N-value (51%) and the governing β_v-value (130%) for the example above are used in the parabolic equation; the calculation results would be shown in PROFIS Engineering as follows: $\beta_{N,v} = (\beta_N)^{5/3} + (\beta_v)^{5/3}$ $= (0.51)^{5/3} + (1.3)^{5/3} = 1.874$ The parabolic equation has not been satisfied, so the report shows the “Status” as “not recommended”. 5 Combined tension and shear loads <table><tr><th>β_N</th><th>β_v</th><th>ξ</th><th>Utilization β_N [%]</th><th>Status</th></tr><tr><td>0.510</td><td>1.300</td><td>5/3</td><td>188</td><td>Not recommended</td></tr></table> $\beta_{Nv} = \beta_N^\xi \cdot \beta_v^\xi < 1$ Part 5 of the PROFIS Engineering report shows the “Status” for parabolic equation calculation results as either “OK” if the equation is satisfied, or “not recommended” if it is not satisfied. PROFIS Engineering considers the parabolic equation to be satisfied if $(\beta_N)^{5/3} + (\beta_v)^{5/3}$ is ≤ 1.0. Reference the PROFIS Engineering design guide section on Utilization β_{Nv} [%] for additional information about PROFIS Engineering interaction calculations.	β_N	β_v	ξ	Utilization β_N [%]	Status	0.510	1.300	5/3	188	Not recommended
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Equations Utilization $\beta_{NV} = (\beta_N + \beta_V)/1.2 \leq 1$

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																			
$\beta_{NV} = (\beta_N + \beta_V)/1.2 \leq 1$	17.6 – Interaction of tensile and shear forces Unless determined in accordance with 17.3.1.3, anchors or groups of anchors that are subjected to both shear and axial loads shall be designed to satisfy the requirements of 17.6.1 through 17.6.3. The values of ϕN_n and ϕV_n shall be the required strengths as determined from 17.3.1.1 or from 17.2.3. 17.6.1 If $V_{ua}/(\phi V_n) \leq 0.2$ for the governing strength in shear, then full strength in tension shall be permitted: $\phi N_n \geq N_{ua}$. 17.6.2 If $N_{ua}/(\phi N_n) \leq 0.2$ for the governing strength in tension, then full strength in shear shall be permitted: $\phi V_n \geq V_{ua}$. 17.6.3 If $V_{ua}/(\phi V_n) > 0.2$ for the governing strength in shear and $N_{ua}/(\phi N_n) > 0.2$ for the governing strength in tension, then $\frac{N_{ua}}{\phi_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad (17.6.3)$ 17.3.1.1 The design of anchors shall be in accordance with Table 17.3.1.1. In addition, the design of anchors shall satisfy 17.2.3 for earthquake loading and 17.3.1.2 for adhesive anchors subject to sustained tensile loading. Excerpt from Table 17.3.1.1 showing the tension failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond strength of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond strength of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	ACI 318-14 anchoring-to-concrete provisions default to what is known as a trilinear interaction equation, which is given in Eq. (17.6.3). PROFIS Engineering checks both Eq. (17.6.3) and the parabolic interaction equation given in the ACI 318-14 commentary R17.6. The PROFIS Engineering report shows the most favorable results. The failure mode for a given tension or shear load condition can be expressed as a ratio of factored load to design strength: - Factored tension load/tension design strength = $(N_{ua}/\phi N_n)$ - Factored shear load/shear design strength = $(V_{ua}/\phi V_n)$ The “governing” failure mode can be defined as the highest (factored load/design strength) ratio for the failure modes being considered. Section 17.6.1 permits the interaction check defined by Eq. (17.6.3) to be waived if $V_{ua}/(\phi V_n) \leq 0.2$ for the “governing”, i.e. “highest” (factored load/design strength) ratio, for the shear failure modes being considered. Section 17.6.2 permits the interaction check defined by Eq. (17.6.3) to be waived if $N_{ua}/(\phi N_n) \leq 0.2$ for the “governing”, i.e. “highest” (factored load/design strength) ratio, for the tension failure modes being considered. Per Section 17.6.3, if the provisions in Section 17.6.1 and Section 17.6.2 cannot be satisfied; combined tension/shear interaction is checked per Eq. (17.6.3). PROFIS Engineering defines the calculated results for Eq. (17.6.3) via the parameter “β_{NV}”. Part 3 of the PROFIS Engineering report shows the ratio of factored tension load (N_{ua}) to tension design strength (ϕN_n) via the parameter β_N. For the example below, concrete breakout failure is the governing failure mode for tension because it has the highest utilization ($\beta_N = 51\%$). Example: 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension)		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK
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Equations Utilization $\beta_{NV} = (\beta_N + \beta_V)/1.2 \leq 1$ (continued)

Equations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																											
$\beta_{NV} = (\beta_N + \beta_V)/1.2 \leq 1$	Excerpt from Table 17.3.1.1 showing the shear failure modes considered in ACI 318-14 anchoring-to-concrete provisions. Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in shear (17.5.1)</td><td>$\phi_{steel} V_{sa} \geq V_{ua}$</td><td>$\phi_{steel} V_{sa} \geq V_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in shear (17.5.2)</td><td>$\phi_{concrete} V_{cb} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{cbg} \geq V_{ua,g}$</td></tr><tr><td>Concrete pryout strength in shear (17.5.3)</td><td>$\phi_{concrete} V_{cp} \geq V_{ua}$</td><td></td><td>$\phi_{concrete} V_{ag} \geq V_{ua,g}$</td></tr></table> 17.3.1.3 When both N_{ua} and V_{ua} are present, interaction effects shall be considered using an interaction expression that results in computation of strength in substantial agreement with results of comprehensive tests. This requirement shall be considered satisfied by 17.6	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{ag} \geq V_{ua,g}$	Part 4 of the PROFIS Engineering report shows the ratio of factored shear load (V_{ua}) to shear design strength (ϕV_n) via the parameter β_v. For the example below, concrete edge failure in direction x* is the governing failure mode for shear because it has the highest utilization (β_v = 60%). Example: 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization β_N = V_{ua}/ϕV_n</th><th>Status</th></tr><tr><td>Steel strength*</td><td>1,500</td><td>4,540</td><td>33</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>6,000</td><td>52,765</td><td>12</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x***</td><td>6,000</td><td>10,080</td><td>60</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) For the examples above, both the governing tension failure mode (β_N = 51%) and the governing shear failure mode (β_v = 60%) are greater than 20%; therefore, PROFIS Engineering would perform the combined interaction check per Eq. (17.6.3) as follows: $\beta_{NV} = (\beta_N + \beta_V)/1.2$$= (0.51 + 0.6)/1.2$$= 0.925$ check: $\beta_{NV} \leq 1.0$ check: $0.925 \leq 1.0$ OK Reference the PROFIS Engineering design guide section on the parabolic interaction equation for additional information about PROFIS Engineering interaction calculations.		Load V _{ua} [lb]	Capacity ϕV _n [lb]	Utilization β _N = V _{ua} /ϕV _n	Status	Steel strength*	1,500	4,540	33	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	6,000	52,765	12	OK	Concrete edge failure in direction x***	6,000	10,080	60	OK
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Variables Utilization β_N

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																			
β_N	17.6 – Interaction of tensile and shear forces Unless determined in accordance with 17.3.1.3, anchors or groups of anchors that are subjected to both shear and axial loads shall be designed to satisfy the requirements of 17.6.1 through 17.6.3. The values of ϕN_n and ϕV_n shall be the required strengths as determined from 17.3.1.1 or from 17.2.3. 17.6.1 If $V_{ua}/(\phi V_n) \leq 0.2$ for the governing strength in shear, then full strength in tension shall be permitted: $\phi N_n \geq N_{ua}$. 17.6.2 If $N_{ua}/(\phi N_n) \leq 0.2$ for the governing strength in tension, then full strength in shear shall be permitted: $\phi V_n \geq V_{ua}$. 17.6.3 If $V_{ua}/(\phi V_n) > 0.2$ for the governing strength in shear and $N_{ua}/(\phi N_n) > 0.2$ for the governing strength in tension, then $\frac{N_{ua}}{\phi_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad (17.6.3)$ Table 17.3.1.1 — Required strength of anchors, except as noted in 17.2.3 <table><tr><th rowspan="2">Failure Mode</th><th rowspan="2">Single Anchor</th><th colspan="2">Anchor Group</th></tr><tr><th>Individual anchor in a Group</th><th>Anchors as a group</th></tr><tr><td>Steel strength in tension (17.4.1)</td><td>$\phi N_{sa} \geq N_{ua}$</td><td>$\phi N_{sa} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete breakout strength in tension (17.4.2)</td><td>$\phi N_{cb} \geq N_{ua}$</td><td></td><td>$\phi N_{cbg} \geq N_{ua,g}$</td></tr><tr><td>Pullout strength in tension (17.4.3)</td><td>$\phi N_{pn} \geq N_{ua}$</td><td>$\phi N_{pn} \geq N_{ua,i}$</td><td></td></tr><tr><td>Concrete side-face blowout strength in tension (17.4.4)</td><td>$\phi N_{sb} \geq N_{ua}$</td><td></td><td>$\phi N_{sbg} \geq N_{ua,g}$</td></tr><tr><td>Bond streng of adhesive anchor in tension (17.4.5)</td><td>$\phi N_a \geq N_{ua}$</td><td></td><td>$\phi N_{ag} \geq N_{ua,g}$</td></tr></table>	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in tension (17.4.1)	$\phi N_{sa} \geq N_{ua}$	$\phi N_{sa} \geq N_{ua,i}$		Concrete breakout strength in tension (17.4.2)	$\phi N_{cb} \geq N_{ua}$		$\phi N_{cbg} \geq N_{ua,g}$	Pullout strength in tension (17.4.3)	$\phi N_{pn} \geq N_{ua}$	$\phi N_{pn} \geq N_{ua,i}$		Concrete side-face blowout strength in tension (17.4.4)	$\phi N_{sb} \geq N_{ua}$		$\phi N_{sbg} \geq N_{ua,g}$	Bond streng of adhesive anchor in tension (17.4.5)	$\phi N_a \geq N_{ua}$		$\phi N_{ag} \geq N_{ua,g}$	Part 3 of the PROFIS Engineering report shows the ratio of factored tension load (N_{ua}) to tension design strength (ϕN_n) via the parameter β_N. PROFIS Engineering calculates β_N for each tension failure mode relevant to a particular anchor type. Per ACI 318-14 Table 17.3.1.1, the tension provisions of Chapter 17 are satisfied if all the calculated design strengths for tension failure modes are greater than or equal to the corresponding factored load. When PROFIS Engineering calculates β_N, it rounds up the result to the nearest whole number. The β_N-values given in Part 3 of the report correspond to a percentage. The PROFIS Engineering report shows “OK” under the Status heading if the β_N-value is < 100%. The highest β_N-value corresponds to the “controlling” or “governing” failure mode in tension. This value is used as the tension component in Eq. (17.6.3). For the example below, all the calculated β_N-values are $\leq 100\%$, and concrete breakout failure is the governing failure mode for tension because it has the highest utilization ($\beta_N = 51\%$). The tension provisions of Chapter 17 have been satisfied. Example: 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) When N_{ua} is greater than ϕN_n, the β_N-value will be greater than 100%. The tension provisions of Chapter 17 are not satisfied when N_{ua} is greater than ϕN_n. The PROFIS Engineering report shows “not recommended” under the Status heading if the β_N-value is > 100%. For the example below, the β_N-values for bond strength and concrete breakout failure are > 100%; therefore, the PROFIS Engineering report shows “not recommended” under the Status heading for these failure modes to indicate that the Chapter 17 provisions have not been satisfied.		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK
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Variables Utilization β_N (continued)

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																									
β_N	The PROFIS Engineering anchor portfolio includes post-installed mechanical anchors, post-installed adhesive anchors, and cast-anchors. The following tension failure modes are considered for each type of anchor: post-installed mechanical anchor steel strength: $\beta_N = N_{ua(l)}/\phi_{steel} N_{sa}$ pullout strength: $\beta_N = N_{ua(l)}/\phi_{concrete} N_{pn,f'c}$ concrete breakout strength: $\beta_N = N_{ua(l)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ post-installed adhesive anchor steel strength: $\beta_N = N_{ua(l)}/\phi_{steel} N_{sa}$ bond strength: $\beta_N = N_{ua(l)}/\phi_{bond} N_a$ or $\beta_N = N_{ua(g)}/\phi_{bond} N_{ag}$ sustained tension load (for bond strength): $\beta_N = N_{ua(l)}/0.55\phi_{bond} N_{ba}$ concrete breakout strength: $\beta_N = N_{ua(l)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ cast-in anchor steel strength: $\beta_N = N_{ua(l)}/\phi_{steel} N_{sa}$ pullout strength: $\beta_N = N_{ua(l)}/\phi_{concrete} N_{pn,f'c}$ concrete breakout strength: $\beta_N = N_{ua(l)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ side-face blowout strength: $\beta_N = N_{ua(l)}/\phi_{concrete} N_{sb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{sbg}$ where $N_{ua(l)}$ corresponds to the highest factored tension load acting on an individual anchor and $N_{ua(g)}$ corresponds	Example: 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>10,000</td><td>26,347</td><td>38</td><td>OK</td></tr><tr><td>Bond strength**</td><td>40,000</td><td>33,922</td><td>118</td><td>not recommended</td></tr><tr><td>Sustained tension load bond strength*</td><td>5,000</td><td>11,495</td><td>44</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>40,000</td><td>26,603</td><td>151</td><td>not recommended</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) Reference the PROFIS Engineering design guide section on β_v for additional information about PROFIS Engineering interaction calculations.		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	10,000	26,347	38	OK	Bond strength**	40,000	33,922	118	not recommended	Sustained tension load bond strength*	5,000	11,495	44	OK	Concrete breakout Failure**	40,000	26,603	151	not recommended
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The following shear failure modes are considered for each type of anchor: post-installed mechanical anchor steel strength: $\beta_v = V_{ua(i)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(i)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(i)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ post-installed adhesive anchor steel strength: $\beta_v = V_{ua(i)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(i)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(i)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ cast-in anchor steel strength: $\beta_v = V_{ua(i)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(i)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(i)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ where $V_{ua(i)}$ corresponds to the highest factored shear load acting on an individual anchor and $V_{ua(g)}$ corresponds to the total factored shear load acting on a group of anchors.	Failure Mode	Single Anchor	Anchor Group		Individual anchor in a Group	Anchors as a group	Steel strength in shear (17.5.1)	$\phi_{steel} V_{sa} \geq V_{ua}$	$\phi_{steel} V_{sa} \geq V_{ua,i}$		Concrete breakout strength in shear (17.5.2)	$\phi_{concrete} V_{cb} \geq V_{ua}$		$\phi_{concrete} V_{cbg} \geq V_{ua,g}$	Concrete pryout strength in shear (17.5.3)	$\phi_{concrete} V_{cp} \geq V_{ua}$		$\phi_{concrete} V_{cpg} \geq V_{ua,g}$	Part 4 of the PROFIS Engineering report shows the ratio of factored shear load (V_{ua}) to shear design strength (ϕV_n) via the parameter β_v. PROFIS Engineering calculates β_v for each shear failure mode relevant to a particular anchor type. Per ACI 318-14 Table 17.3.1.1, the shear provisions of Chapter 17 are satisfied if all the calculated design strengths for shear failure modes are greater than or equal to the corresponding factored load. When PROFIS Engineering calculates β_v, it rounds up the result to the nearest whole number. The β_v-values given in Part 4 of the report correspond to a percentage. The PROFIS Engineering report shows “OK” under the Status heading if the β_v-value is < 100%. The highest β_v-value corresponds to the “controlling” or “governing” failure mode in shear. This value is used as the shear component in Eq. (17.6.3). For the example below, all the calculated β_v-values are $\leq 100\%$, and concrete edge failure in direction x* is the governing failure mode for shear because it has the highest utilization ($\beta_v = 60\%$). The shear provisions of Chapter 17 have been satisfied. Example: 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_N = V_{ua}/\phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>1,500</td><td>4,540</td><td>33</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>6,000</td><td>52,765</td><td>12</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x**</td><td>6,000</td><td>10,080</td><td>60</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) When V_{ua} is greater than ϕV_n, the β_v-value will be greater than 100%. The shear provisions of Chapter 17 are not satisfied when V_{ua} is greater than ϕV_n. The PROFIS Engineering report shows “not recommended” under the Status heading if the β_v-value is $\geq 100\%$. For the example below, the β_v-value for concrete edge failure in direction x* is > 100%; therefore, the PROFIS Engineering report shows “not recommended” under the Status heading for this failure mode to indicate that the Chapter 17 provisions have not been satisfied. Example: 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_N = V_{ua}/\phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>3,750</td><td>8,221</td><td>46</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>15,000</td><td>76,400</td><td>20</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x**</td><td>15,000</td><td>11,592</td><td>130</td><td>not recommended</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors) Reference the PROFIS Engineering design guide section on β_N for additional information about PROFIS Engineering interaction calculations.		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Variables Utilization $\mathcal{E}$

Variables	318-14 Chapter 17 Provision	Comments for PROFIS Engineering										
$\mathcal{E}$	17.6 – Interaction of tensile and shear forces Unless determined in accordance with 17.3.1.3, anchors or groups of anchors that are subjected to both shear and axial loads shall be designed to satisfy the requirements of 17.6.1 through 17.6.3. The values of ϕN_n and ϕV_n shall be the required strengths as determined from 17.3.1.1 or from 17.2.3. 17.6.1 If $V_{ua}/(\phi V_n) \leq 0.2$ for the governing strength in shear, then full strength in tension shall be permitted: $\phi N_n \geq N_{ua}$. 17.6.2 If $N_{ua}/(\phi N_n) \leq 0.2$ for the governing strength in tension, then full strength in shear shall be permitted: $\phi V_n \geq V_{ua}$. 17.6.3 If $V_{ua}/(\phi V_n) > 0.2$ for the governing strength in shear and $N_{ua}/(\phi N_n) > 0.2$ for the governing strength in tension, then $\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad (17.6.3)$ R17.6 – Interaction of tensile and shear forces The shear-tension interaction expression has traditionally been expressed as $\left(\frac{N_{ua}}{N_n} \right)^{\mathcal{E}} + \left(\frac{V_{ua}}{V_n} \right)^{\mathcal{E}} \leq 1.0$ where $\mathcal{E}$ varies from 1 to 2. The current trilinear recommendation is a simplification of the expression where $\mathcal{E} = 5/3$. The limits were chosen to eliminate the requirement for computation of interaction effects where very small values of the second force are present. Another interaction expression that is verified by test data, however, can be used to satisfy 17.3.1.3. Reference ACI 318-14 Fig. R17.6.	ACI 318-14 anchoring-to-concrete provisions default to what is known as a trilinear interaction equation, which is given in Eq. (17.6.3). PROFIS Engineering checks both Eq. (17.6.3) and the parabolic interaction equation given in the ACI 318-14 commentary R17.6. The PROFIS Engineering report shows the most favorable results. The failure mode for a given tension or shear load condition can be expressed as a ratio of factored load to design strength: - Factored tension load/tension design strength = $(N_{ua}/\phi N_n)$ - Factored shear load/shear design strength = $(V_{ua}/\phi V_n)$. The “governing” failure mode can be defined as the highest (factored load/design strength) ratio for the failure modes being considered. The generalized interaction equation given in the commentary R17.6 permits the governing tension component $(N_{ua}/\phi N_n)$ and the governing shear component $(V_{ua}/\phi V_n)$ to be raised to any power ($\mathcal{E}$) between 1 and 2. When checking combined tension/shear interaction with Eq. (17.6.3), the governing tension component $(N_{ua}/\phi N_n)$ and the governing shear component $(V_{ua}/\phi V_n)$ are not raised to any power, so $\mathcal{E} = 1.0$. Below is an example of how the PROFIS Engineering report shows the parameters used in the tri-linear interaction equation (17.6.3). The parameter “β_N” corresponds to the governing tension component $(N_{ua}/\phi N_n)$ and the parameter “β_V” corresponds to the governing shear component $(V_{ua}/\phi V_n)$. Since $(N_{ua}/\phi N_n)$ and $(V_{ua}/\phi V_n)$ are not raised to any power ($\mathcal{E}$) when Eq. (17.6.3) is used, the parameter “$\mathcal{E}$” is shown as 1.0 in the report. The parameter “Utilization $\beta_{N,V}$” is calculated as follows: $\beta_{N,V} = (\beta_N)1.0 + (\beta_V)1.0 \leq 1.2 \quad \text{Eq. (17.6.3)}$ $\beta_{N,V} = (\beta_N + \beta_V)/1.2 \leq 1.0 \quad \text{PROFIS Engineering}$ $= (0.693 + 0.475)/1.2 = 0.973 \quad \beta_{N,V} < 1.0 \quad \text{OK}$ Example: 5 Combined tension and shear loads <table><tr><th>β_N</th><th>β_V</th><th>$\mathcal{E}$</th><th>Utilization β_N [%]</th><th>Status</th></tr><tr><td>0.693</td><td>0.475</td><td>1.000</td><td>0.973</td><td>OK</td></tr></table> $\beta_{N,V} = (\beta_N + \beta_V) 1.2 < = 1$ Reference the PROFIS Engineering design guide section on the parabolic interaction equation for additional information about PROFIS Engineering interaction calculations.	β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status	0.693	0.475	1.000	0.973	OK
β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status								
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Calculations Utilization $\beta_{N,V}$ [%]

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																		
Utilization $\beta_{N,V}$ [%]	17.6 – Interaction of tensile and shear forces Unless determined in accordance with 17.3.1.3, anchors or groups of anchors that are subjected to both shear and axial loads shall be designed to satisfy the requirements of 17.6.1 through 17.6.3. The values of ϕN_n and ϕV_n shall be the required strengths as determined from 17.3.1.1 or from 17.2.3. 17.6.1 If $V_{ua}/(\phi V_n) \leq 0.2$ for the governing strength in shear, then full strength in tension shall be permitted: $\phi N_n \geq N_{ua}$. 17.6.2 If $N_{ua}/(\phi N_n) \leq 0.2$ for the governing strength in tension, then full strength in shear shall be permitted: $\phi V_n \geq V_{ua}$. 17.6.3 If $V_{ua}/(\phi V_n) > 0.2$ for the governing strength in shear and $N_{ua}/(\phi N_n) > 0.2$ for the governing strength in tension, then $\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad (17.6.3)$	The failure mode for a given tension or shear load condition can be expressed as a ratio of factored load to design strength: - Factored tension load/tension design strength = $(N_{ua}/\phi N_n)$ - Factored shear load/shear design strength = $(V_{ua}/\phi V_n)$ PROFIS Engineering references these ratios as “utilizations”, and shows them in the report as a percentage. Part 3 of the PROFIS Engineering report shows the utilizations for each tension failure mode being considered and designates “tension utilizations” via the parameter “β_N”. 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) Part 4 of the PROFIS Engineering report shows the utilizations for each shear failure mode being considered and designates “shear utilizations” via the parameter “β_V”. 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_N = V_{ua}/\phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>1,500</td><td>4,540</td><td>33</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>6,000</td><td>52,765</td><td>12</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x***</td><td>6,000</td><td>10,080</td><td>60</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors)		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK		Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_N = V_{ua}/\phi V_n$	Status	Steel strength*	1,500	4,540	33	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	6,000	52,765	12	OK	Concrete edge failure in direction x***	6,000	10,080	60	OK
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Calculations Utilization $\beta_{N,V}$ [%] (continued)

Calculations	318-14 Chapter 17 Provision	Comments for PROFIS Engineering										
Utilization $\beta_{N,V}$ [%]		The “governing” failure mode can be defined as the highest utilization for the failure modes being considered. PROFIS Engineering designates the sum of the utilization for the governing failure mode in tension and the utilization for the governing failure mode in shear as “$\beta_{N,V}$”, and shows it as a percentage in Part 5 of the report. For the examples above, concrete breakout failure is the governing tension failure mode ($\beta_N = 51\%$) and concrete edge failure in direction x* is the governing shear failure mode ($\beta_V = 60\%$). PROFIS Engineering would calculate $\beta_{N,V}$ per Eq. (17.6.3) as follows: $\beta_{N,V} = (\beta_N + \beta_V)/1.2$ $= (0.51 + 0.6)/1.2 = 0.925$ Example: 5 Combined tension and shear loads <table><tr><th>β_N</th><th>β_V</th><th>$\mathcal{E}$</th><th>Utilization β_N [%]</th><th>Status</th></tr><tr><td>0.510</td><td>0.600</td><td>1.000</td><td>0.925</td><td>OK</td></tr></table> $\beta_{N,V} = (\beta_N + \beta_V) / 1.2 \leq 1$ Reference the PROFIS Engineering design guide section on the parabolic interaction equation for additional information about PROFIS Engineering interaction calculations.	β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status	0.510	0.600	1.000	0.925	OK
β_N	β_V	$\mathcal{E}$	Utilization β_N [%]	Status								
0.510	0.600	1.000	0.925	OK								

Results Status

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering																																																		
Status	17.6 – Interaction of tensile and shear forces Unless determined in accordance with 17.3.1.3, anchors or groups of anchors that are subjected to both shear and axial loads shall be designed to satisfy the requirements of 17.6.1 through 17.6.3. The values of ϕN_n and ϕV_n shall be the required strengths as determined from 17.3.1.1 or from 17.2.3. 17.6.1 If $V_{ua}/(\phi V_n) \leq 0.2$ for the governing strength in shear, then full strength in tension shall be permitted: $\phi N_n \geq N_{ua}$. 17.6.2 If $N_{ua}/(\phi N_n) \leq 0.2$ for the governing strength in tension, then full strength in shear shall be permitted: $\phi V_n \geq V_{ua}$. 17.6.3 If $V_{ua}/(\phi V_n) > 0.2$ for the governing strength in shear and $N_{ua}/(\phi N_n) > 0.2$ for the governing strength in tension, then $\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad (17.6.3)$ The PROFIS Engineering anchor portfolio includes post-installed mechanical anchors, post-installed adhesive anchors, and cast-anchors. The following tension failure modes are considered for each type of anchor: post-installed mechanical anchor steel strength: $\beta_N = N_{ua(f)}/\phi_{steel} N_{sa}$ pullout strength: $\beta_N = N_{ua(f)}/\phi_{concrete} N_{pn,f\ c}$ concrete breakout strength: $\beta_N = N_{ua(f)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ post-installed adhesive anchor steel strength: $\beta_N = N_{ua(f)}/\phi_{steel} N_{sa}$ bond strength: $\beta_N = N_{ua(f)}/\phi_{bond} N_a$ or $\beta_N = N_{ua(g)}/\phi_{bond} N_{ag}$ sustained tension load (for bond strength): $\beta_N = N_{ua(f)}/0.55\phi_{bond} N_{ba}$ concrete breakout strength: $\beta_N = N_{ua(f)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ cast-in anchor steel strength: $\beta_N = N_{ua(f)}/\phi_{steel} N_{sa}$ pullout strength: $\beta_N = N_{ua(f)}/\phi_{concrete} N_{pn,f\ c}$ concrete breakout strength: $\beta_N = N_{ua(f)}/\phi_{concrete} N_{cb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{cbg}$ side-face blowout strength: $\beta_N = N_{ua(f)}/\phi_{concrete} N_{sb}$ or $\beta_N = N_{ua(g)}/\phi_{concrete} N_{sbg}$	PROFIS Engineering designates the parameter ($N_{ua}/\phi N_n$) as "β_N", and shows it as a percentage (%) in the report under the heading "Status". ACI 318-14 anchoring-to-concrete provisions for tension are satisfied if all the β_N-values for the tension failure modes being considered are $\leq 100\%$. The highest β_N-value corresponds to the "controlling" or "governing" failure mode in tension, and is used as the tension component in Eq. (17.6.3). PROFIS Engineering designates the parameter ($V_{ua}/\phi V_n$) as "β_V", and shows it as a percentage (%) in the report under the heading "Status". ACI 318-14 anchoring-to-concrete provisions for shear are satisfied if all the β_V-values for the shear failure modes being considered are $\leq 100\%$. The highest β_V-value corresponds to the "controlling" or "governing" failure mode in shear, and is used as the shear component in Eq. (17.6.3). For the example below, all the β_N-values are $\leq 100\%$; therefore, PROFIS Engineering shows the "Status" for each value as "OK" since ACI 318 anchoring-to-concrete provisions are satisfied. Concrete Breakout Failure is the governing failure mode for tension because it has the highest utilization ($\beta_N = 51\%$). This value is used as the tension component in Eq. (17.6.3). However, the β_V-value for Concrete Edge Failure in direction x* is $> 100\%$ ($\beta_V = 130\%$); therefore, PROFIS Engineering shows the "Status" for this β_V-value as "not recommended" since ACI 318 anchoring-to-concrete provisions are not satisfied. $\beta_V = 130\%$ is also the governing failure mode for shear because it has the highest utilization. This value is used as the shear component in Eq. (17.6.3). Example: 3 Tension load <table><tr><th></th><th>Load N_{ua} [lb]</th><th>Capacity ϕN_n [lb]</th><th>Utilization $\beta_N = N_{ua}/\phi N_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>5,000</td><td>14,550</td><td>35</td><td>OK</td></tr><tr><td>Bond strength**</td><td>10,000</td><td>31,564</td><td>32</td><td>OK</td></tr><tr><td>Sustained tension load bond strength*</td><td>3,450</td><td>16,800</td><td>21</td><td>OK</td></tr><tr><td>Concrete breakout Failure**</td><td>10,000</td><td>19,971</td><td>51</td><td>OK</td></tr></table> * highest loaded anchor ** Anchor group (anchors in tension) 4 Shear load <table><tr><th></th><th>Load V_{ua} [lb]</th><th>Capacity ϕV_n [lb]</th><th>Utilization $\beta_V = V_{ua}/\phi V_n$</th><th>Status</th></tr><tr><td>Steel strength*</td><td>3,750</td><td>8,221</td><td>46</td><td>OK</td></tr><tr><td>Steel failure with lever arm*</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr><tr><td>Pryout (bond strength controls)*</td><td>15,000</td><td>76,400</td><td>20</td><td>OK</td></tr><tr><td>Concrete edge failure in direction x***</td><td>15,000</td><td>11,592</td><td>130</td><td>not recommended</td></tr></table> * highest loaded anchor ** Anchor group (relevant anchors)		Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status	Steel strength*	5,000	14,550	35	OK	Bond strength**	10,000	31,564	32	OK	Sustained tension load bond strength*	3,450	16,800	21	OK	Concrete breakout Failure**	10,000	19,971	51	OK		Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_V = V_{ua}/\phi V_n$	Status	Steel strength*	3,750	8,221	46	OK	Steel failure with lever arm*	N/A	N/A	N/A	N/A	Pryout (bond strength controls)*	15,000	76,400	20	OK	Concrete edge failure in direction x***	15,000	11,592	130	not recommended
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Results Status (continued)

Results	318-14 Chapter 17 Provision	Comments for PROFIS Engineering										
Status	The following shear failure modes are considered for each type of anchor: post-installed mechanical anchor steel strength: $\beta_v = V_{ua(l)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ post-installed adhesive anchor steel strength: $\beta_v = V_{ua(l)}/\phi_{steel} V_a$ concrete breakout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ cast-in anchor steel strength: $\beta_v = V_{ua(l)}/\phi_{steel} V_{sa}$ concrete breakout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cb}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cbg}$ concrete pryout strength: $\beta_v = V_{ua(l)}/\phi_{concrete} V_{cp}$ or $\beta_v = V_{ua(g)}/\phi_{concrete} V_{cpg}$ where $V_{ua(l)}$ corresponds to the highest factored shear load acting on an individual anchor and $V_{ua(g)}$ corresponds to the total factored shear load acting on a group of anchors.	When the governing β_N-value (51%) and the governing β_v-value (130%) for the example above are used in Eq. (17.6.3), the calculation results would be shown in PROFIS Engineering as follows: $\beta_{N,v} = (\beta_N + \beta_v)/1.2$ $= (0.51 + 1.3)/1.2 = 1.508$ Eq. (17.6.3) has not been satisfied, so the report shows the “Status” as “not recommended”. Example: 5 Combined tension and shear loads <table><tr><th>β_N</th><th>β_v</th><th>$\mathcal{E}$</th><th>Utilization β_N [%]</th><th>Status</th></tr><tr><td>0.510</td><td>0.600</td><td>1.000</td><td>1.508</td><td>OK</td></tr></table> $\beta_{Nv} = (\beta_N + \beta_v) / 1.2 < = 1$ Part 5 of the PROFIS Engineering report shows the “Status” for Eq. (17.6.3) calculation results as either “OK” if Eq. (17.6.3) is satisfied, or “not recommended” if Eq. (17.6.3) is not satisfied. PROFIS Engineering considers Eq. (17.6.3) to be satisfied if $(\beta_N + \beta_v)/1.2 \leq 1.0$. Reference the PROFIS Engineering design guide section on Utilization β_{Nv} [%] for additional information about PROFIS Engineering interaction calculations.	β_N	β_v	$\mathcal{E}$	Utilization β_N [%]	Status	0.510	0.600	1.000	1.508	OK
β_N	β_v	$\mathcal{E}$	Utilization β_N [%]	Status								
0.510	0.600	1.000	1.508	OK								

DESIGN GUIDE REPORT ACI 318-14 ADHESIVE ANCHOR GROUP



Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

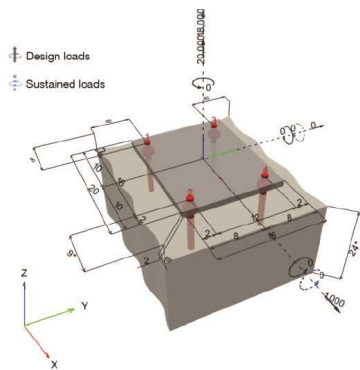
1 Input data

Anchor type and diameter:	HIT-HY 200 + HAS-V-36 (ASTM F1554 Gr. 36) 1
Item number:	not available (element) / 2022793 HIT-HY 200-R (adhesive)
Effective embedment depth:	$h_{ef, opt} = 20.000$ in. ($h_{limit} = -$ in.)
Material:	ASTM A 1554 Grade 36
Evaluation Service Report:	ICC-ESR3187
Issued Valid:	4/1/2019 3/1/2020
Proof:	Design Method ACI 318-14 / Chem
Stand-off installation:	without clamping (anchor); restraint level (anchor plate): 1.00; $e_b = 2.000$ in.; $t = 1.000$ in.
Anchor plate ^R :	$l_x \times l_y \times t = 20.000$ in. x 16.000 in x 1.00 in.; (Recommended plate thickness: not calculated)
Profile:	no profile
Base material:	cracked lightweight concrete, 4000, $f'_c = 4000$ psi; $h = 24.000$ in., Temp. short/long: 68/68 °F

Installation:	hammer drilled hole, installation condition: Dry
Reinforcement: tension:	condition B, shear: condition B; no supplemental splitting reinforcement present
edge reinforcement:	none or < No. 4 bar
Seismic loads (cat. C, D, E, or F) Tension load:	yes (17.2.3.4.3 (d))
Shear load:	yes (17.2.3.5.3 (c))

^R – The anchor calculation is based on a rigid anchor plate assumption

Geometry [in.] & Loading [lb, in.lb]



1.1 Design results

Case	Description	Forces [lb] / Moments [in.lb]	Seismic	Max. Util. Anchor [%]
1	Combination 1	$N = 20,000; V_x = 1000; V_y = 0$ $M_x = 0; M_y = 0; M_z = 0;$ $N_{sus} = 18,000; M_{x, sus} = 0; M_{y, sus} = 0;$	no	100

Input data and results must be checked for conformity with the existing conditions and for plausibility! * PROFIS Engineering (c) 2003-2018 Hilti AG, FL-9494 Schaan Hilti is a registered Trademark of Hilti AG, Schaan

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

2 Load case/Resulting anchor forces

Load case: Design Loads

Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	5,000	250	250	0
2	5,000	250	250	0
3	5,000	250	250	0
4	5,000	250	250	0

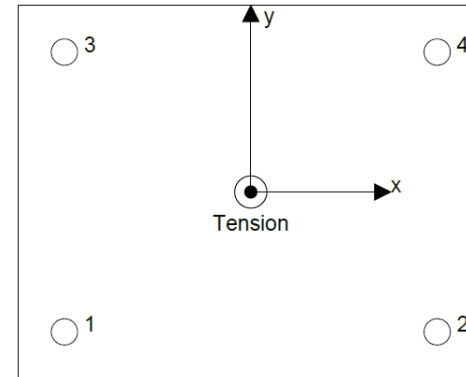
max. concrete compressive strain: - [0/00]

max. concrete compressive stress: - [psi]

resulting tension force in (x/y)=(0.000/0.000): 20,000 [lb]

resulting compression force in (x/y)=(0.000/0.000): 0 [lb]

Anchor forces are calculated based on the assumption of a rigid anchor plate.



3 Tension Load

	Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status
Steel Strength*	5,000	26,437	19	OK
Bond Strength**	20,000	40,774	50	OK
Sustained Tension Load Bond Strength*	4,500	14,038	33	OK
Concrete Breakout Failure**	20,000	42,756	47	OK

* highest loaded anchor ** anchor group (anchors in tension)

3.1 Steel Strength

$N_{sa} =$ ICC-ESR value refer to ICC-ESR-3187
 $\phi N_{sa} \geq N_{ua}$ ACI 318-14 Table 17.3.1.1

Variables

A_{se} [in ²]	f_{uta} [psi]
0.61	58,000

Calculations

N_{sa} [lb]
35,130

Results

N_{sa} [lb]	ϕ_{steel}	$\phi_{nonductile}$	ϕN_{sa} [lb]	N_{ua} [lb]
35,130	0.750	1.0	26,347	5000

Input data and results must be checked for conformity with the existing conditions and for plausibility! * PROFIS Engineering (c) 2003-2018 Hilti AG, FL-9494 Schaan Hilti is a registered Trademark of Hilti AG, Schaan

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

3.2 Bond Strength

$$N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \quad (17.4.5.1b)$$

ACI 318-14 Eq. (17.4.5.1b)

$$\phi N_{ag} \geq N_{ua}$$

ACI 318-14 Table 17.3.1.1

$$A_{Na} = \text{see ACI 318-14, Section 17.4.5.1, Fig. R17.4.5.1(b)}$$

$$A_{Na0} = (2c_{Na})^2$$

ACI 318-14 Eq. (17.4.5.1c)

$$c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{1100}}$$

ACI 318-14 Eq. (17.4.5.1d)

$$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}}\right)}$$

ACI 318-14 Eq. (17.4.5.3)

$$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \leq 1.0$$

ACI 318-14 Eq. (17.4.5.4b)

$$\psi_{cp,Na} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}} \right) \leq 1.0$$

ACI 318-14 Eq. (17.4.5.5b)

$$N_{ba} = \lambda_a \tau_{k,c} \alpha_{N,seis} \pi d_a h_{ef}$$

ACI 318-14 Eq. (17.4.5.2)

Variables

$t_{k,c,uncr}$ [psi]	d_a [in.]	h_{ef} [in.]	$c_{a,min}$ [in.]	$t_{k,c}$ [psi]
2,327	1.000	20.000	30.000	1,389
$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	c_{ac} [in.]	λ_a	$\alpha_{N,sei}$
0.000	0.000	57,969	0.45	0.970

Calculations

c_{Na} [in.]	A_{Na} [in. ²]	A_{Na0} [in. ²]	$\psi_{ed,Na}$
14.478	1,841.29	838.50	1.00
$\psi_{ec1,Na}$	$\psi_{ec2,Na}$	$\psi_{cp,Na}$	N_{ba} [lb]
1.000	1.000	1.000	38,088

Results

N_{ag} [lb]	ϕ_{bond}	$\phi_{seismic}$	$\phi_{nonductile}$	ϕN_{ag} [lb]	N_{ua} [lb]
83,640	0.650	0.750	1.000	40,774	20,000

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

3.3 Sustained Tension Load Bond Strength

$$0.55 \phi N_{ba} \geq N_{ua,s}$$
$$N_{ba} = \lambda_a \tau_{kc} \pi d_a h_{ef}$$

ACI 318-14 Eq. (17.3.1.2)

ACI 318-14 Eq. (17.4.5.2)

Variables

λ_a	τ_{kc} [psi]	d_a [in.]	h_{ef} [in.]
0.450	1,389	1.000	20.000

Calculations

N_{ba} [lb]
39,266

Results

N_{ba} [lb]	ϕ_{bond}	$0.55 \phi N_{ba}$ [lb]	N_{uas} [lb]
39,266	0.650	14,038	4,500

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

3.4 Concrete Breakout Failure

$$N_{cbg} = \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b$$
$$\phi N_{cbg} \geq N_{ua}$$
$$A_{Nc} = \text{see ACI 318-14, Section 17.4.2.1, Fig. R17.4.2.1(b)}$$
$$A_{Nc0} = 9 h_{ef}^2$$
$$\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_{c,N}}{3h_{ef}}\right)} \leq 1.0$$
$$\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}}\right) \leq 1.0$$
$$\psi_{cp,N} = \text{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5h_{ef}}{c_{ac}}\right) \leq 1.0$$
$$N_b = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5}$$

14 Eq. (17.4.2.1b)

ACI 318-14 Table 17.3.1.1

ACI 318-14 Eq. (17.4.2.1c)

ACI 318-14 Eq. (17.4.2.4)

ACI 318-14 Eq. (17.4.2.5b)

ACI 318-14 Eq. (17.4.2.7b)

ACI 318-14 Eq. (17.4.2.2a)

Variables

h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]	$\psi_{c,N}$
20.000	0.000	0.000	30.000	1.000
c_{ac} [in.]	k_c	λ_a	f'_c [psi]	
57.969	17	0.600	4000	

Calculations

A_{Nc} [in. ²]	A_{Nc0} [in. ²]	$\psi_{c1,N}$	$\psi_{c2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
5,472.00	3,600.00	1.000	1.000	1.00	1.000	57,700

Results

N_{cbg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	ϕN_{cbg} [lb]	N_{ua} [lb]
87,704	0.650	0.750	1.000	42,756	20,000

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

4 Shear Load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_v = V_{ua} / \phi V_n$	Status
Steel Strength*	250	8,221	4	OK
Bond Strength**	250	812	31	OK
Pryout Strength (Bond Strength controls)**	1,000	117,095	1	OK
Concrete edge failure in direction x+**	1,000	32,513	4	OK

* highest loaded anchor ** anchor group (anchors in tension)

4.1 Steel Strength

$$V_{sa} = \alpha_{v,seis} (0.6 A_{se,V} f_{uta})$$
$$\phi V_{steel} \geq V_{ua}$$

refer to ICC-ESR-3187
ACI 318-14 Table 17.3.1.1

Variables

$A_{se,V}$ [in²]	f_{uta} [psi]	$\alpha_{v,seis}$	$0.6 A_{se,V} f_{uta}$ [lb]
0.61	58,000	0.6000	21,080

Calculations

$V_{sa,eq}$ [lb]
12,648

Results

V_{sa} [lb]	ϕ_{steel}	$\phi V_{sa,eq}$ [lb]	V_{ua} [lb]
12,648	0.650	8,221	250

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

4.2 Steel failure (with lever arm)

$$V_s^M = \frac{\alpha_m M_s}{L_b}$$

bending equation for stand-off

$$M_s = M_s^0 \left(1 - \frac{N_{ua}}{\phi N_{sa}} \right)$$

resultant flexural resistance of anchor

$$M_s^0 = (1.2) (S) (f_{u,min}) [1 - (N_{ua} / \phi N_{sa})]$$

characteristic flexural resistance of anchor
reduction for tensile force acting simultaneously with a shear force on the anchor

$$S = \left(\frac{\pi (d)^3}{32} \right)$$

elastic section modulus of anchor bolt at concrete surface

$$L_b = z + (n)(d_o)$$

internal lever arm adjusted for spalling of the surface concrete

$$\phi V_s^M \geq V_{ua}$$

ACI 318-14 Table 17.3.1.1

Variables

α_m	$f_{u,min}$ [psi]	N_{ua} [lb]	ϕN_{sa} [lb]	z [in]	n	d_o [in]
1.000	58,000	5,000	26,347	2.500	0.500	1.00

Calculations

M_s^0 [in.lb]	$[1 - (N_{ua} / \phi N_{sa})]$	M_s [in.lb]	L_b [in]
4,628	0.810	3,749	3.000

Results

V_s^M [lb]	ϕ_{steel}	ϕV_s^M [lb]	V_{ua} [lb]
1,250	0.650	812	250

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

4.3 Pryout Strength (Bond Strength controls)

$$V_{cpg} = k_{cp} \left[\left(\frac{A_{Na}}{A_{Na0}} \right) \psi_{ec1,Na} \psi_{ec2,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba} \right]$$

ACI 318-14 Eq. (17.5.3.1b)

$$\phi V_{cpg} \geq V_{ua}$$

ACI 318-14 Table 17.3.1.1

$$A_{Na} = \text{see ACI 318-14, Section 17.4.5.1, Fig. R17.4.5.1(b)}$$

$$A_{Na0} = (2 c_{Na})^2$$

ACI 318-14 Eq. (17.4.5.1c)

$$c_{Na} = 10d_a \sqrt{\frac{T_{uncr}}{1100}}$$

ACI 318-14 Eq. (17.4.5.1d)

$$\psi_{ec,Na} = \frac{1}{\left(1 + \frac{e'_N}{c_{Na}} \right)}$$

ACI 318-14 Eq. (17.4.5.3)

$$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{Na}} \right) \leq 1.0$$

ACI 318-14 Eq. (17.4.5.4b)

$$\psi_{cp,Na} = \text{MAX} \left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}} \right) \leq 1.0$$

ACI 318-14 Eq. (17.4.5.5b)

$$N_{ba} = \lambda_a T_{k,c} \alpha_{N,seis} \pi d_a h_{ef}$$

ACI 318-14 Eq. (17.4.5.5b)

Variables

k_{cp}	$t_{k,c,uncr}$ [psi]	d_a [in.]	h_{ef} [in.]	$c_{a,min}$ [in.]	$t_{k,c}$ [psi]
2	2,327	1.000	20.000	30.000	1,389
$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	c_{ac} [in.]	λ_a	$\alpha_{N,seis}$	
0.000	0.000	57,969	0.450	0.970	

Calculations

c_{Na} [in.]	A_{Na} [in. ²]	A_{Na0} [in. ²]	$\psi_{ed,Na}$
14.478	1,841.29	838.50	1.00
$\psi_{ec1,Na}$	$\psi_{ec2,Na}$	$\psi_{cp,Na}$	N_{ba} [lb]
1.000	1.000	1.000	38,088

Results

V_{cpg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	ϕV_{cpg} [lb]	V_{ua} [lb]
167,279	0.700	1.00	1.000	117,095	1,000

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

4.4 Concrete edge failure in direction x+

$$V_{cbg} = \frac{A_{vc}}{A_{vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} \psi_{parallel,V} V_b$$

ACI 318-14 Eq. (17.5.2.1b)

$$\phi V_{cbg} \geq V_{ua}$$

ACI 318-14 Table 17.3.1.1

$$AVC = \text{see ACI 318-14, Section 17.5.2.1, Fig. R17.5.2.1(b)}$$

$$A_{vc0} = 4.5 c_{a1}^2$$

ACI 318-14 Eq. (17.5.2.1c)

$$\psi_{ec,V} = \frac{1}{\left(1 + \frac{2e'_v}{3c_{a1}}\right)} \leq 1.0$$

ACI 318-14 Eq. (17.5.2.5)

$$\psi_{ed,V} = 0.7 + 0.3 \left(\frac{c_{a2}}{1.5c_{a1}} \right) \leq 1.0$$

ACI 318-14 Eq. (17.5.2.6b)

$$\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \geq 1.0$$

ACI 318-14 Eq. (17.5.2.8)

$$V_b = 9\lambda_a \sqrt{f'_c} (c_{a1})^{1.5}$$

ACI 318-14 Eq. (17.5.2.2b)

Variables

c_{a1} [in.]	c_{a2} [in.]	e_{cV} [in.]	$\psi_{c,V}$	h_a [in.]
30.000	-	0.000	1.000	24.000
l_e [in.]	λ_a	d_a [in.]	f'_c [psi]	$\psi_{parallel,v}$
8.000	0.600	1.000	4000	1.000

Calculations

A_{vc} [in. ²]	A_{vc0} [in. ²]	$\psi_{ec,V}$	$\psi_{ed,V}$	$\psi_{h,V}$	V_b [lb]
2,448.00	4,050.00	1.000	1.000	1.369	56,118

Results

V_{cbg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	ϕV_{cbg} [lb]	V_{ua} [lb]
46,448	0.700	1.000	1.000	32,513	1,000

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

5 Combined tension and shear loads

β_N	β_V	ε	Utilization $\beta_{N,V}$ [%]	Status
0.491	0.308	5/3	45	OK

$$\beta_{NV} = \beta_N^{\varepsilon} + \beta_V^{\varepsilon} \leq 1$$

6 Warnings

- The anchor design methods in PROFIS Engineering require rigid anchor plates per current regulations (AS 5216:2018, ETAG 001/Annex C, EOTA TR029 etc.). This means load re-distribution on the anchors due to elastic deformations of the anchor plate are not considered — the anchor plate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the design loading. PROFIS Engineering calculates the minimum required anchor plate thickness with CBFEM to limit the stress of the anchor plate based on the assumptions explained above. The proof if the rigid anchor plate assumption is valid is not carried out by PROFIS Engineering. Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Condition A applies where the potential concrete failure surfaces are crossed by supplementary reinforcement proportioned to tie the potential concrete failure prism into the structural member. Condition B applies where such supplementary reinforcement is not provided, or where pullout or pryout strength governs.
- ACI 318 does not specifically address anchor bending when a stand-off condition exists. PROFIS Engineering calculates a shear load corresponding to anchor bending when stand-off exists and includes the results as a shear Design Strength!
- Design Strengths of adhesive anchor systems are influenced by the cleaning method. Refer to the INSTRUCTIONS FOR USE given in the Evaluation Service Report for cleaning and installation instructions.
- For additional information about ACI 318 strength design provisions, please go to <https://submittals.us.hilti.com/PROFISAnchorDesignGuide/>
- An anchor design approach for structures assigned to Seismic Design Category C, D, E or F is given in ACI 318-14, Chapter 17, Section 17.2.3.4.3 (a) that requires the governing design strength of an anchor or group of anchors be limited by ductile steel failure. If this is NOT the case, the connection design (tension) shall satisfy the provisions of Section 17.2.3.4.3 (b), Section 17.2.3.4.3 (c), or Section 17.2.3.4.3 (d). The connection design (shear) shall satisfy the provisions of Section 17.2.3.5.3 (a), Section 17.2.3.5.3 (b), or Section 17.2.3.5.3 (c).
- Section 17.2.3.4.3 (b) / Section 17.2.3.5.3 (a) require the attachment the anchors are connecting to the structure be designed to undergo ductile yielding at a load level corresponding to anchor forces no greater than the controlling design strength. Section 17.2.3.4.3 (c) / Section 17.2.3.5.3 (b) waive the ductility requirements and require the anchors to be designed for the maximum tension / shear that can be transmitted to the anchors by a non-yielding attachment. Section 17.2.3.4.3 (d) / Section 17.2.3.5.3 (c) waive the ductility requirements and require the design strength of the anchors to equal or exceed the maximum tension / shear obtained from design load combinations that include E, with E increased by W0.
- Installation of Hilti adhesive anchor systems shall be performed by personnel trained to install Hilti adhesive anchors. Reference ACI 318-14, Section 17.8.1

Fastening meets the design criteria!

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

7 Installation data

Profile:	no profile	Anchor type and diameter:	HIT-HY 200 + HAS-V-36 (ASTM F1554 Gr.36) ¹
Hole diameter in the fixture:	d _f = 1.125 in.	Item number:	not available (element) / 2022793 HIT-HY 200-R (adhesive)
Plate thickness (input):	1.000 in.	Installation torque:	1,800 in.lb
Recommended plate thickness:	not calculated	Hole diameter in the base material:	1.125 in.
Drilling method:	Hammer drilled	Hole depth in the base material:	20.000 in.
Cleaning:	Compressed air cleaning of the drilled hole according to instructions for use is required	Minimum thickness of the base material:	22.250 in.

1 Hilti HAS Carbon steel threaded rod with Hilti HIT-HY 200 Safe Set System

7.1 Recommended accessories

Drilling	Cleaning	Setting
• Suitable Rotary Hammer • Properly sized drill bit	• Compressed air with required accessories to blow from the bottom of the hole • Proper diameter wire brush	• Dispenser including cassette and mixer • Torque wrench

Coordinates Anchor in.

Anchor	x	y	c _{-x}	c _{+x}	c _{-y}	c _{+y}
1	8.000	-6.000	-	46.000	-	-
2	8.000	6.000	-	30.000	-	-
3	8.000	6.000	-	46.000	-	-
4	8.000	6.000	-	30.000	-	-

Example PROFIS Engineering Report for an adhesive anchor group

Group calculations are for N_{cbg} , N_{ag} , V_{cbg} , and V_{cpg}

8 Remarks; Your Cooperation Duties

- Any and all information and data contained in the Software concern solely the use of Hilti products and are based on the principles, formulas and security regulations in accordance with Hilti's technical directions and operating, mounting and assembly instructions, etc., that must be strictly complied with by the user. All figures contained therein are average figures, and therefore use-specific tests are to be conducted prior to using the relevant Hilti product. The results of the calculations carried out by means of the Software are based essentially on the data you put in. Therefore, you bear the sole responsibility for the absence of errors, the completeness and the relevance of the data to be put in by you. Moreover, you bear sole responsibility for having the results of the calculation checked and cleared by an expert, particularly with regard to compliance with applicable norms and permits, prior to using them for your specific facility. The Software serves only as an aid to interpret norms and permits without any guarantee as to the absence of errors, the correctness and the relevance of the results or suitability for a specific application.
- You must take all necessary and reasonable steps to prevent or limit damage caused by the Software. In particular, you must arrange for the regular backup of programs and data and, if applicable, carry out the updates of the Software offered by Hilti on a regular basis. If you do not use the AutoUpdate function of the Software, you must ensure that you are using the current and thus up-to-date version of the Software in each case by carrying out manual updates via the Hilti Website. Hilti will not be liable for consequences, such as the recovery of lost or damaged data or programs, arising from a culpable breach of duty by you.



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