



ANCHORING TO CONCRETE BASED ON NSCP 7TH EDITION

Name

Date

Hilti Philippines, Inc.

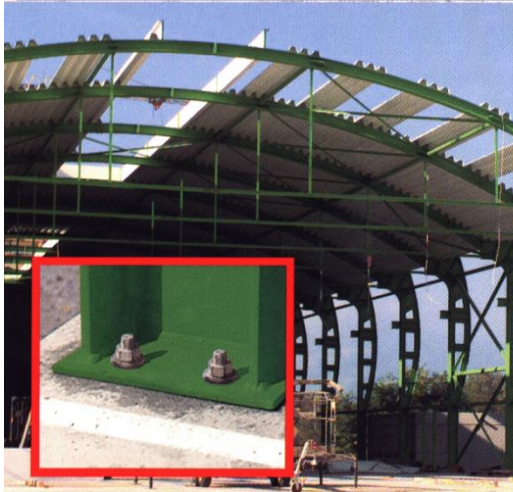


PRESENTATION OUTLINE

- 1.0 Introduction to Post – Installed Anchor [Overview]**
- 2.0 Qualification of Anchor Assembly – Code Landscape**
- 3.0 Concrete Capacity Design Provisions**
 - 2.1 Nominal Tension Strengths**
 - 2.2 Nominal Shear Strengths**
 - 2.3 Interaction Equation**
- 4.0 Conclusions and Recommendations**

ANCHORS ARE COMMONLY USED IN COMPOSITE CONSTRUCTION → TWO ELEMENTS MATERIALS ARE JOINED

COLUMN AND BEAM CONNECTIONS



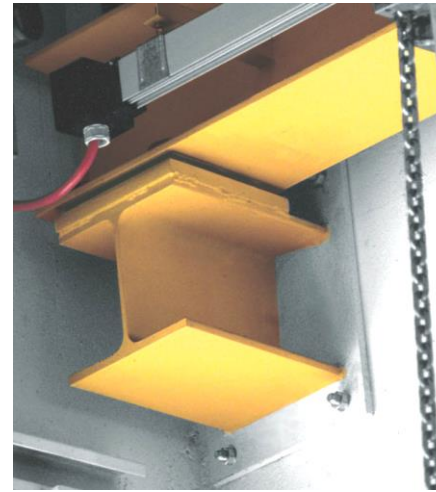
Gymnasium

- Steel column to Concrete pedestal



Overhead water Tanks

- Steel column to concrete Pedestal



Corbel Beam

- Conveyor



Steel Beam

- Concrete floor extension

ANCHORS ARE COMMONLY USED IN COMPOSITE CONSTRUCTION → TWO ELEMENTS MATERIALS ARE JOINED

EXTENSIONS AND RETROFITTING



Perimeter Wall

- Rebar Miss-outs
- Extensions



Rebar Extension

- Planted Column
- Slab Expansions



Column and Beam Retrofitting

- Concrete Jacketing
- Steel Jacketing



ANCHORS ARE COMMONLY USED IN COMPOSITE CONSTRUCTION → TWO ELEMENTS MATERIALS ARE JOINED

MACHINE, EQUIPMENT AND MISCELLEANEUOS FASTENING



Manufacturing Equipment, Machineries

- Steel column/Support to concrete pad
- Conveyors
- Lifts
- Gondola

Mechanical and Electrical utilities

- Pipe hangers and Support
- Cable Trays
- Panel Boxes

ANCHORS ARE COMMONLY USED IN COMPOSITE CONSTRUCTION → TWO ELEMENTS MATERIALS ARE JOINED

SPECIALTY APPLICATIONS



Curtain wall attachments

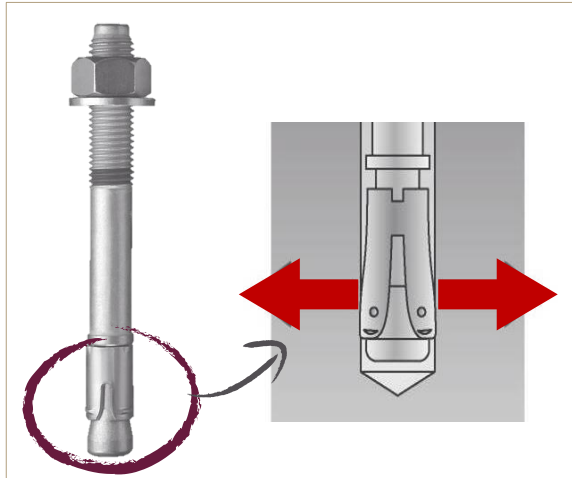
- Bracket connections
- Cast-in connections

Façade and Window Fastenings

- Aluminum composite panels
- PVC/Aluminum windows
- Stone / Granite Cladding

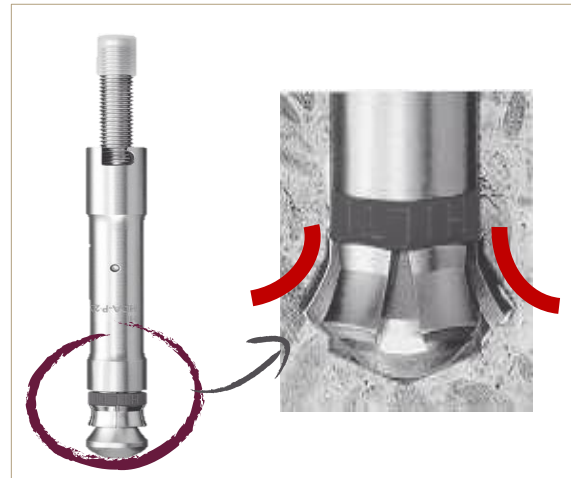
ANCHORING MECHANISM

DIFFERENT POST-INSTALLED ANCHOR WORKING PRINCIPLES



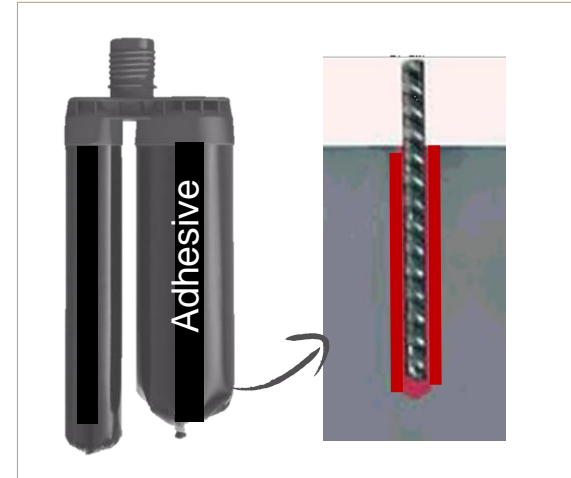
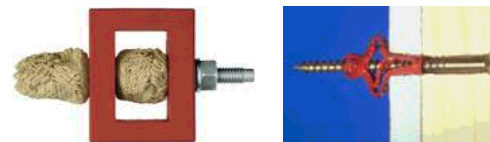
FRICTION

The tensile load, N , is transferred to the base material by friction, R . To build up the friction, an **expansion force** is necessary.



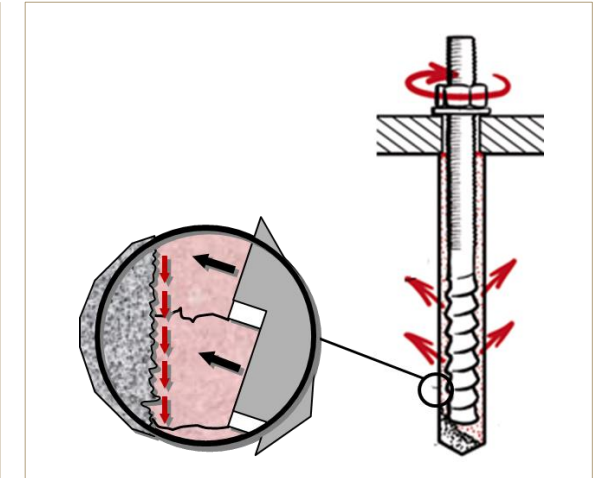
KEYING

At a certain point, the anchor has a **bigger diameter than the borehole** itself.



BONDING

Adhesive bond is produced between the anchor and the mortar and between mortar and borehole walls. A **micro keying effect** keeps the element in the borehole



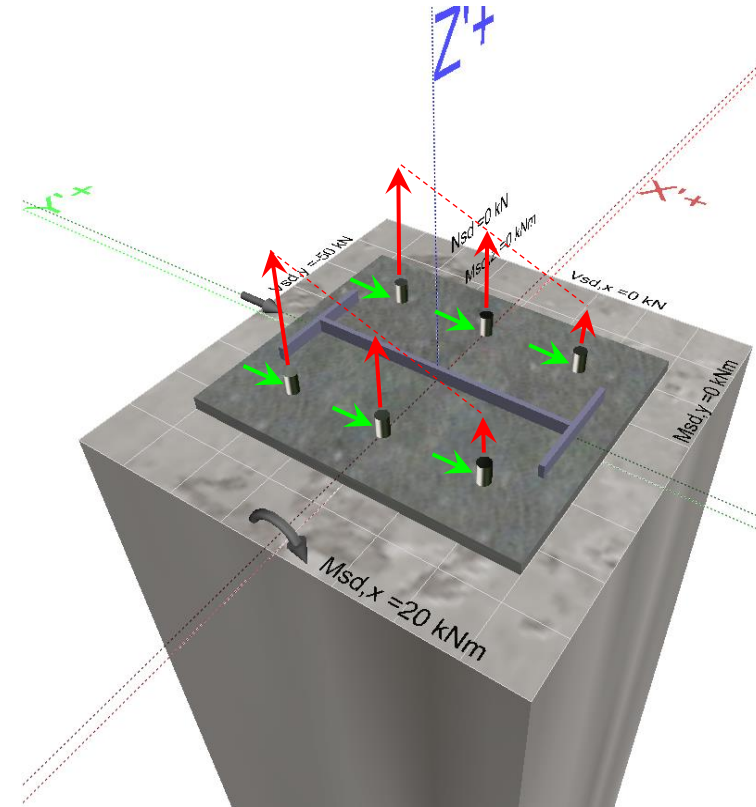
BONDING + FRICTION

Torque actuates expansion anchor characteristics. **Expansion forces increase bond to concrete** significantly



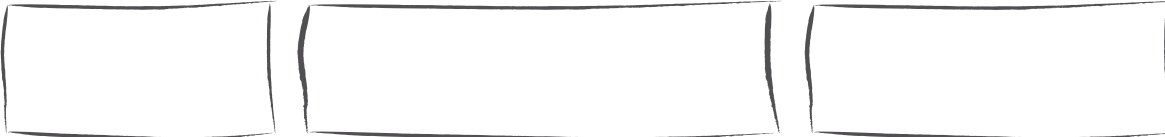
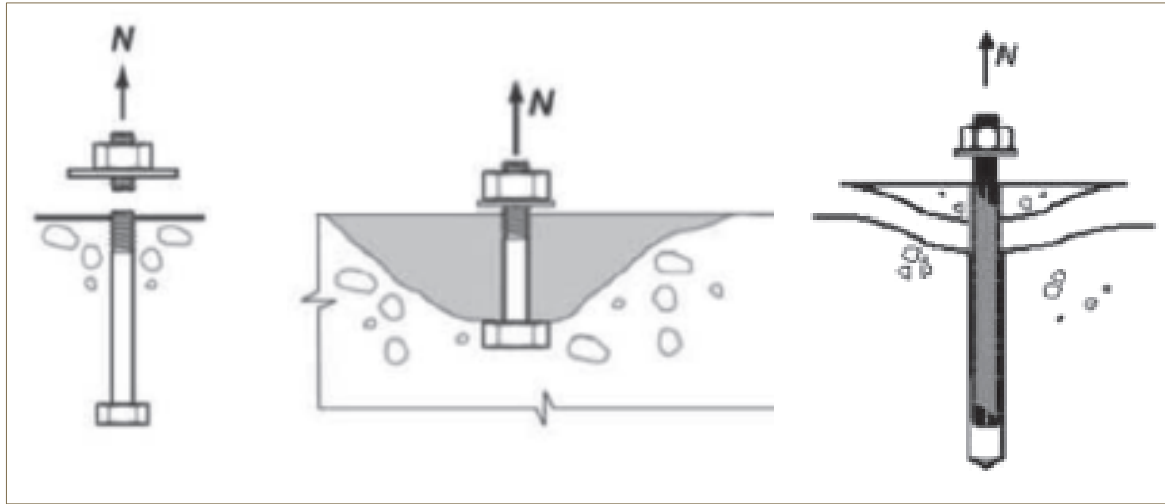
COMPOSITE CONSTRUCTION → FACTORS INFLUENCING ANCHOR PERFORMANCE

- Base Material / Strength / Mode
- Anchor Spacing and Influence of Edge Distance
- Tightening Torque requirement
- Effects of Fire
- Corrosion / Environment
- Toxicity
- Load Direction / **Mode of Loading** / Load Transfer

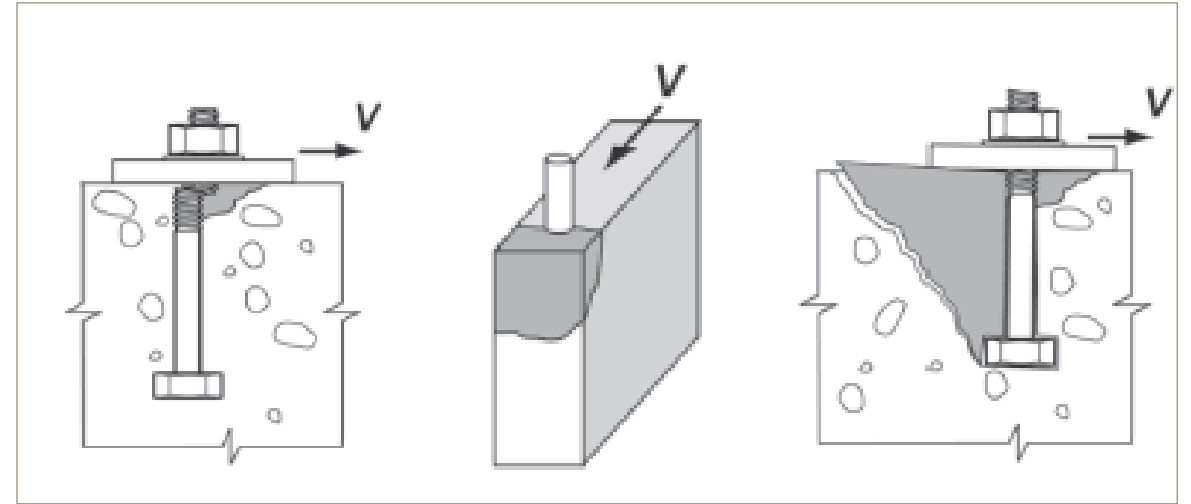


ANCHOR FAILURES

TENSILE LOADING



SHEAR LOADING



HILTI

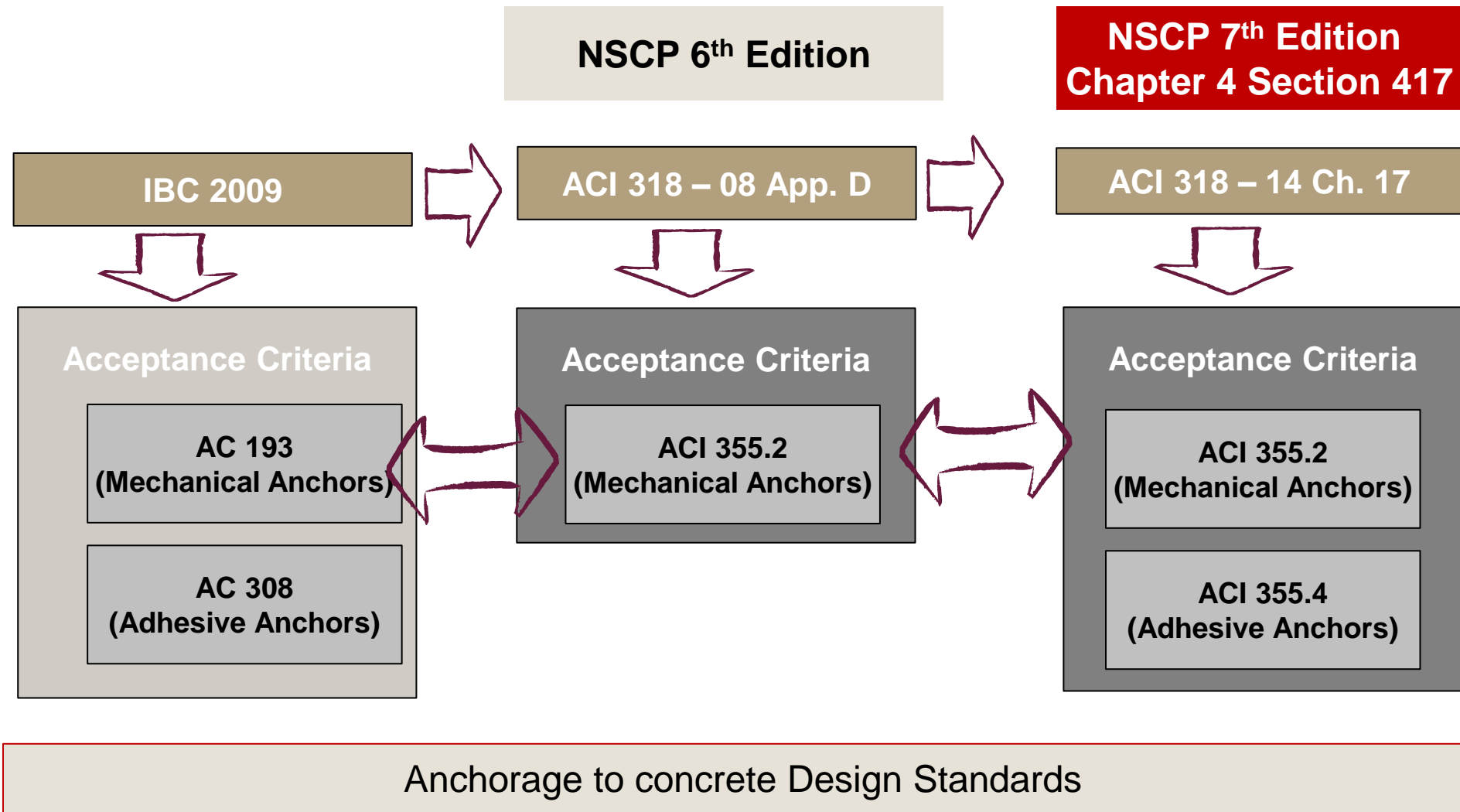
POLL QUESTION NO. 1

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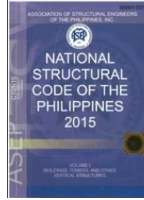


NEW ACI 318-14 ANCHORAGE TO CONCRETE DESIGN STANDARDS

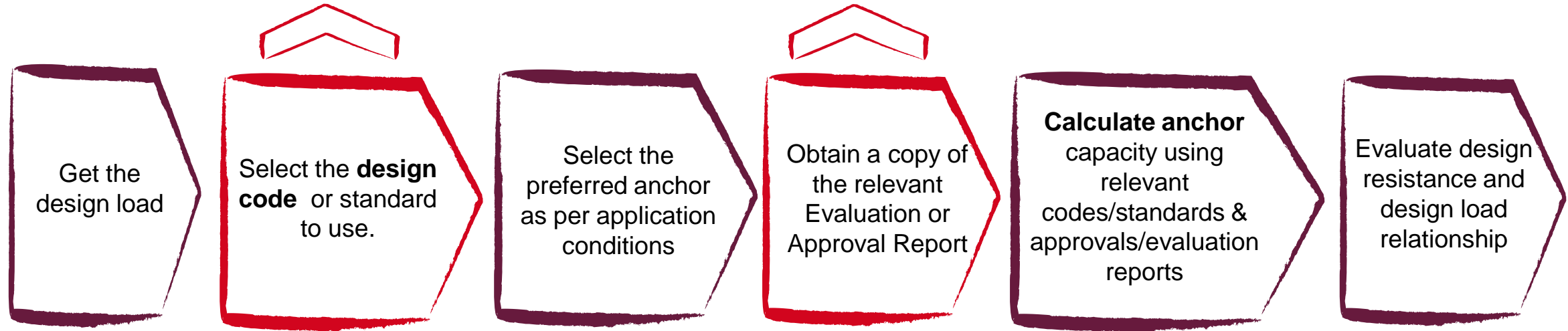


DESIGN QUALIFICATION OF POST-INSTALLED ANCHORS

NSCP Chapter 4 Sec. 417
ACI 318-14 Chapter 17



ICC Evaluation
Service Report



QUALIFICATION OF ANCHORING TO CONCRETE – CODE LANDSCAPE

ACI 318 and IBC Anchoring to Concrete Provisions

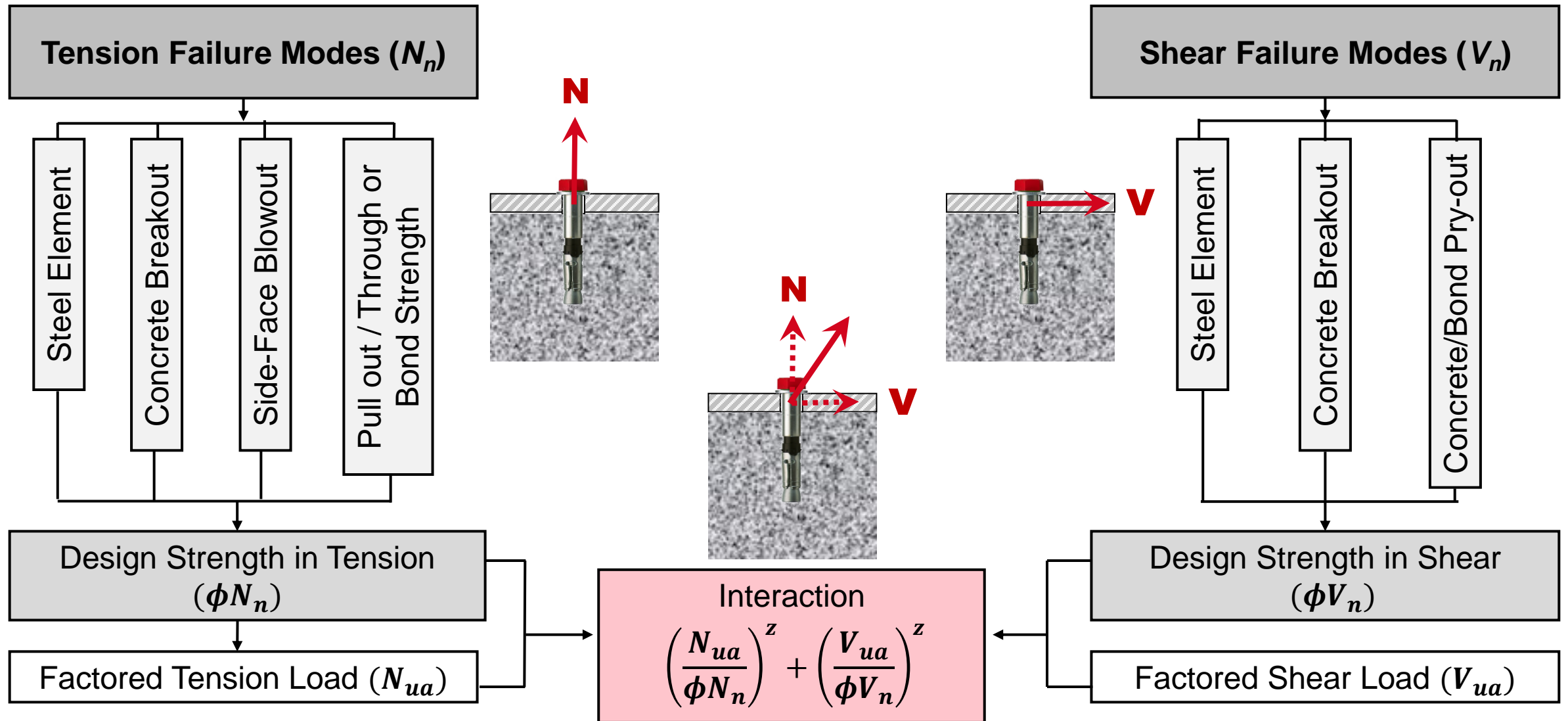
- ACI 318 provisions are design requirements for anchors used to transmit **structural loads**:
 - Between connected structural elements
 - Between safety-related attachments and structural elements
 - Reference ASCE-7 for other types of anchorages
- ACI 318 provisions consider **cracked concrete and seismic loads**
- ACI 318 and IBC provisions are written for **cast-in-place anchors**
- **Post-installed anchors must be qualified for use with ACI 318 and IBC provisions**:
 - ACI 355.2 and ICC-ES AC193 (mechanical anchor systems)
 - ACI 355.4 and ICC-ES AC308 (adhesive anchor systems)

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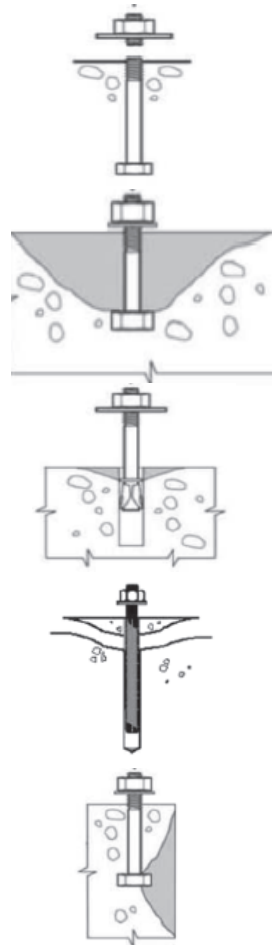
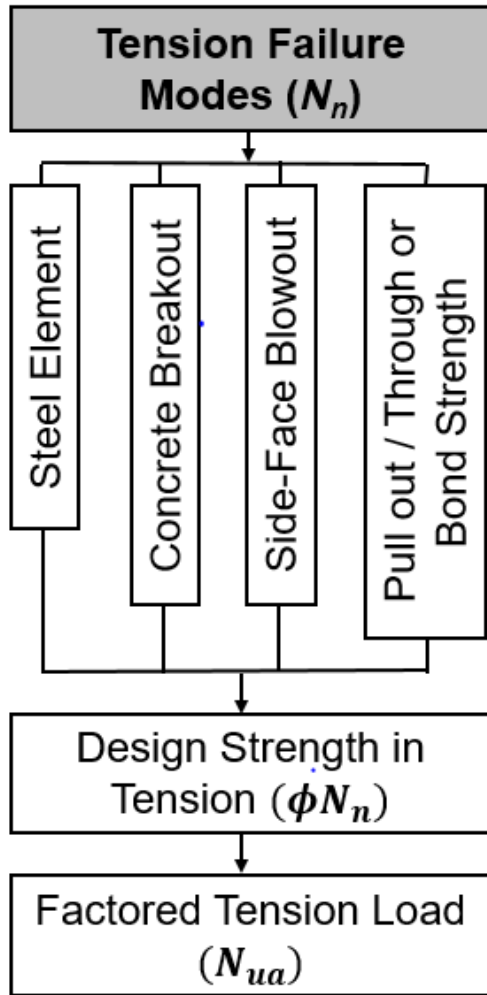
GENERAL STRENGTH DESIGN PROVISIONS



NOMINAL TENSILE STRENGTHS CALCULATION

TENSION PARAMETERS FOR DETERMINING TENSION FAILURE MODES

Determining the capacity of the anchor system through different tension failure modes



Steel Element

$$N_{ua,i} \leq \phi_{steel} N_{sa}$$

Concrete Breakout Strength

$$N_{ua(g)} \leq \phi_{concrete} N_{cb(g)}$$

Pull out

$$N_{ua,i} \leq \phi_{concrete} N_{pn}$$

Bond Strength

$$N_{ua(g)} \leq \phi_{bond} N_{a(g)}$$

Side Face Blowout

$$N_{ua(g)} \leq \phi_{concrete} N_{sb(g)}$$

*Images are taken from ACI 318-14 Chapter 17

NOMINAL TENSION STRENGTHS FOR ANCHORING TO CONCRETE DESIGN

TENSION FAILURE MODE

		CAST-IN	MECHANICAL	ADHESIVE
Steel Element Nominal steel strength for a single anchor only	N_{sa}	✓	✓	✓
Concrete Breakout Strength Nominal concrete breakout strength for a single anchor Nominal concrete breakout strength for group of anchors	N_{cb} N_{cbg}	✓	✓	✓
Pull out Nominal pullout strength for a single anchor	N_{pn}	✓	✓	
Bond Strength Nominal bond strength for a single anchor Nominal bond strength for group of anchors	N_a N_{ag}			✓
Side Face Blowout Nominal side-face blowout strength for a single anchor Nominal side-face blowout strength for group of anchors	N_{sb} N_{sbg}	✓		

STRENGTH REDUCTION FACTORS FOR NOMINAL TENSION STRENGTH CALCULATION

TENSION FAILURE MODE		CAST-IN	MECHANICAL	ADHESIVE
Steel Element Strength reduction factor for steel in tension	ϕ_s	ACI 318-14 Chapter 17 Section 17.3.3 Strength reduction factors	ACI 318-14 ICC ESR Table - Design information table	ACI 318-14 ESR Table 1-Design Table Index: Steel design information table
Concrete Breakout Strength Strength reduction factor for concrete in tension	ϕ_c	ACI 318-14 Chapter 17 Section 17.3.3 Strength reduction factors	ACI 318-14 ICC ESR Table - Design information table	ACI 318-14 ESR Table 1-Design Table Index: Concrete breakout design information table
Pull out Strength reduction factor for concrete in tension	ϕ_c	Not applicable	ACI 318-14 ICC ESR Table - Design information table	Not applicable
Bond Strength Strength reduction factor for bond in tension	ϕ_{bond}	Not applicable	Not applicable	ACI 318-14 ESR Table 1-Design Table Index: Bond strength design information table
Side Face Blowout Strength reduction factor for concrete in tension	ϕ_c	ACI 318-14 Chapter 17 Section 17.3.3 Strength reduction factors	Not applicable	Not applicable

STRENGTH REDUCTION FACTORS FOR NOMINAL TENSION STRENGTH CALCULATION

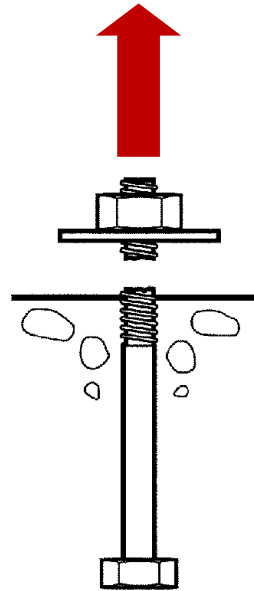
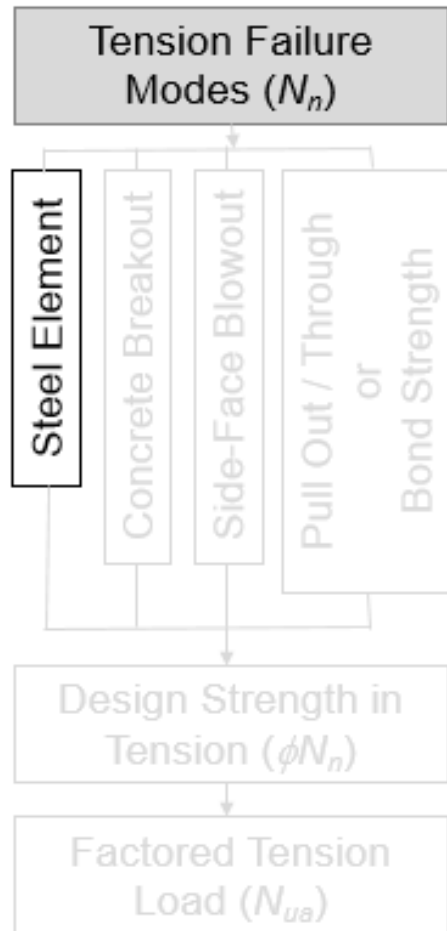
TENSION FAILURE MODE

17.3.3 – Strength Reduction factor ϕ for anchors in concrete

Steel Element Strength reduction factor for steel in tension	ϕ_s
Concrete Breakout Strength Strength reduction factor for concrete in tension	ϕ_c
Pull out Strength reduction factor for concrete in tension	ϕ_c
Bond Strength Strength reduction factor for bond in tension	ϕ_{bond}
Side Face Blowout Strength reduction factor for concrete in tension	ϕ_c

Conditions	Condition A	Condition B
Failure governed by strength of steel element		
Ductile Steel Failure		
Tensile Failure	0.75	
Shear Failure	0.65	
Brittle Steel Failure		
Tensile Failure	0.65	
Shear Failure	0.60	
Failure governed by strength of concrete		
Shear	0.75	0.70
Tension, Cast-in	0.75	0.70
Tension, Post-Installed		
Category 1	0.75	0.65
Category 2	0.65	0.55
Category 3	0.55	0.45

DETERMINING NOMINAL STEEL STRENGTH IN TENSION



Cast-In-Place Anchor

Use ACI 318 equation to calculate the nominal steel strength for CIP anchors

$$N_{sa} = A_{se} \cdot f_{uta}$$

A_{se} = tension area of the steel element

f_{uta} = ultimate tensile strength

Check if:

$$\phi_{steel} \cdot N_{sa} \geq N_{ua,i}$$

Check the anchorage capacity with respect to the steel strength of the anchor element.

DETERMINING NOMINAL STEEL STRENGTH IN TENSION

Post-Installed Anchor (Adhesive and Mechanical)

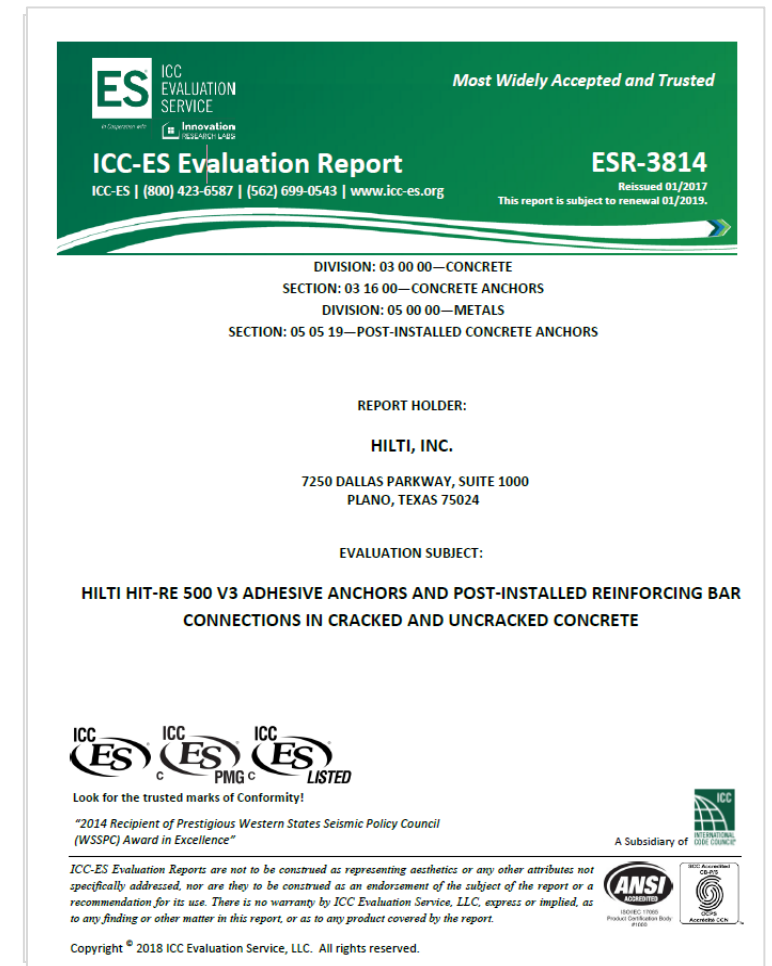
Use ICC-ES ESR to determine nominal steel strength for post-installed anchors

- 1 Locate the 'Steel Design' Table in the ESR
- 2 Find the type of steel element you are using on the left hand side
- 3 Find the appropriate diameter along the top line
- 4 This intersection is the nominal steel strength, N_{sa}
- 5 The strength reduction factor, ϕ , is listed below the nominal steel strength

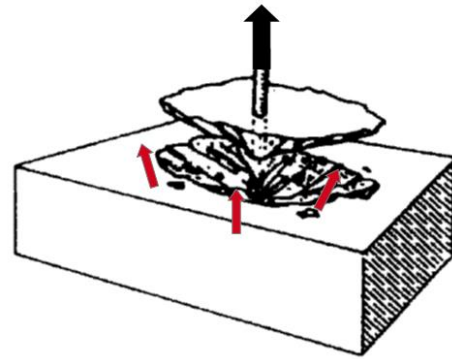
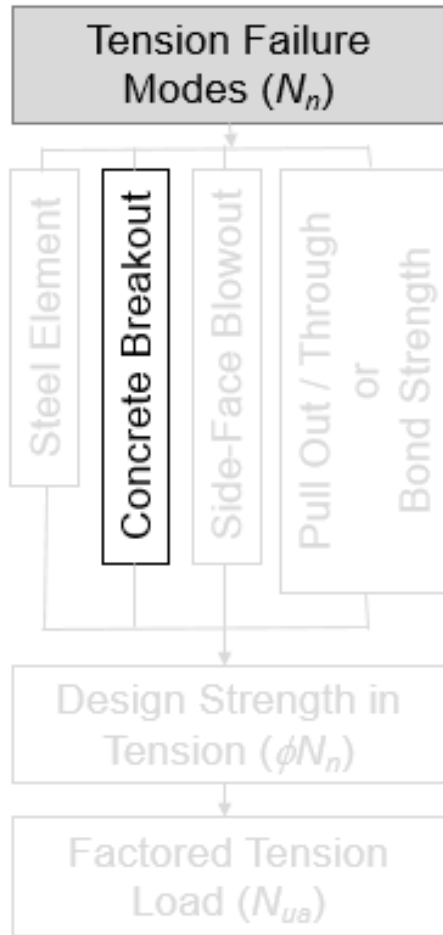
Check if:

$$\phi_{steel} \cdot N_{sa} \geq N_{ua,i}$$

Check the anchorage capacity with respect to the steel strength of the anchor element.



DETERMINATION OF NOMINAL CONCRETE BREAKOUT STRENGTH IN TENSION



Single Anchor

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_b$$

Group of Anchors

$$N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ec,N} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_b$$

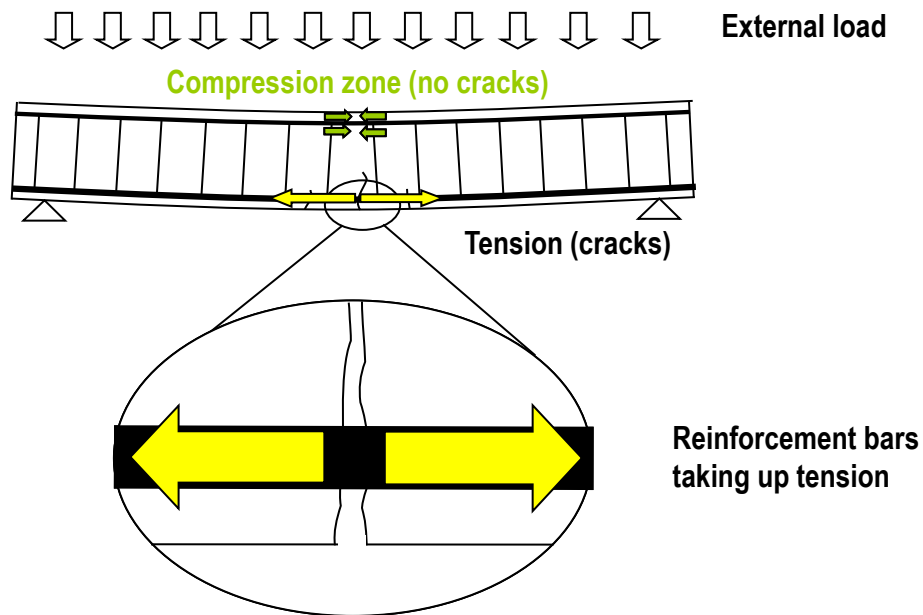
Check if:

$$\phi_{concrete} \cdot N_{cb(g)} \geq N_{ua,g}$$

Check the anchorage capacity with respect to concrete breakout

DETERMINATION OF CONCRETE BREAKOUT STRENGTH IN TENSION

$$N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ec,N} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_b$$

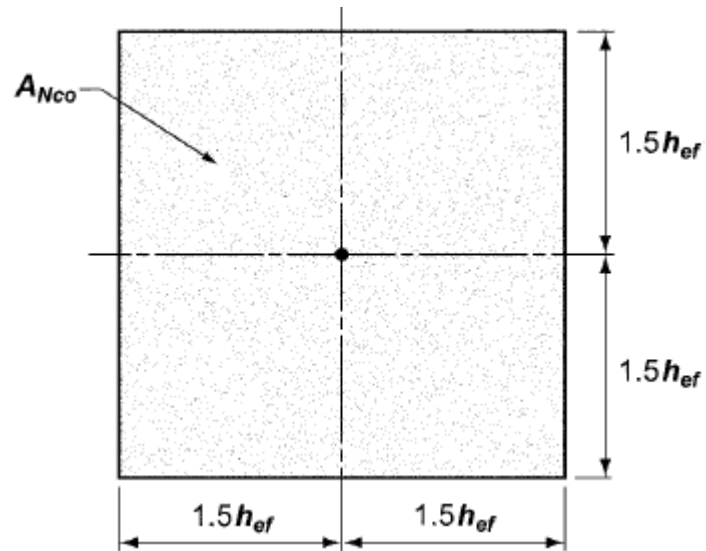


$\psi_{c,N} = 1.00$ for anchors in cracked concrete

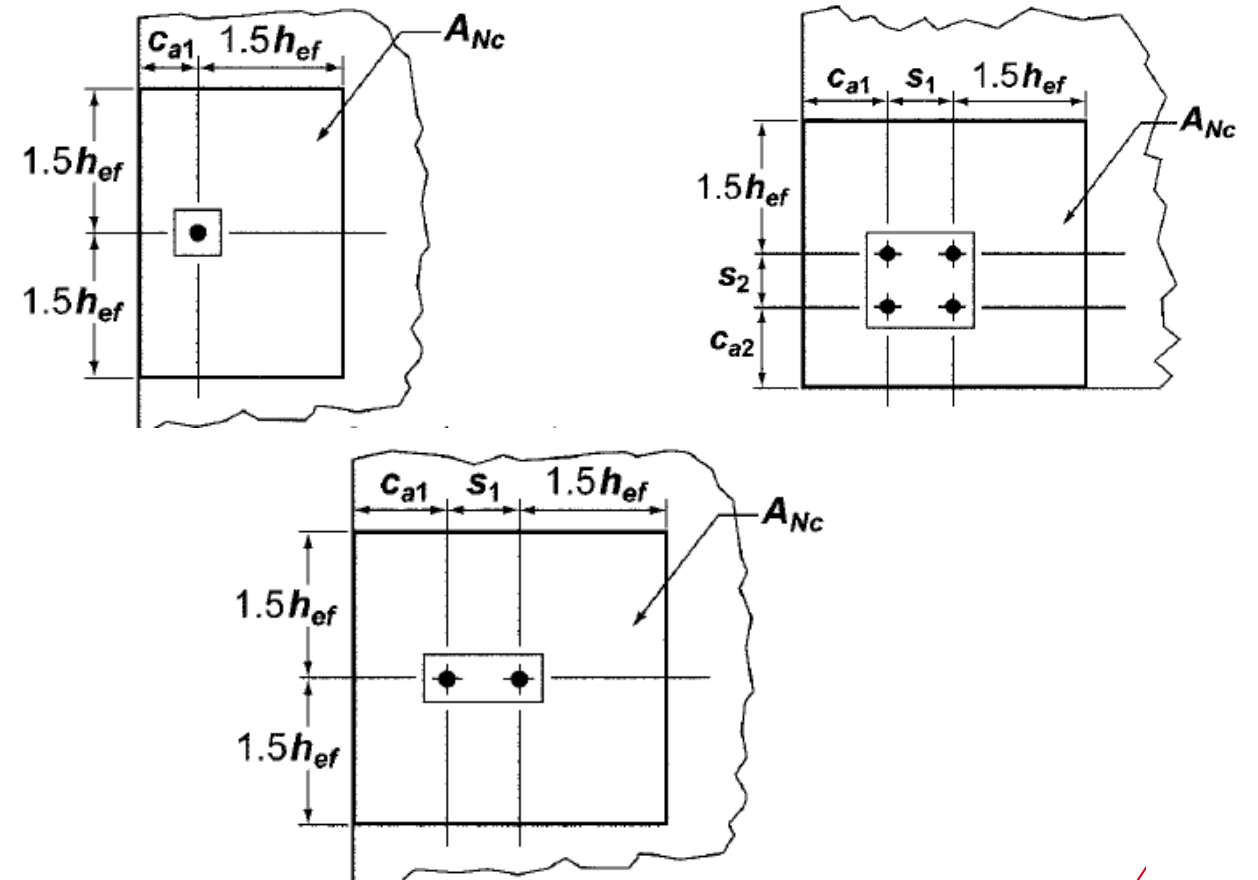
$\psi_{c,N} = 1.25$ for anchors in uncracked concrete

ADHESIVE ANCHOR AREA CALCULATIONS BASED ON EDGE DISTANCE

Projected influence area of a **single adhesive anchor without edge conditions**



Projected influence area for the **anchorage inclusive of edge and spacing conditions**



MODIFICATION FACTORS FOR DETERMINATION OF NOMINAL CONCRETE BREAKOUT STRENGTH

$$N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ec,N} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_b$$

A_{Nc}	Assumed area of influence for a given anchorage geometry	Area of influence including adjacent anchors and edge distances
A_{Nco}	Assumed area of influence for a single anchor	Area of influence for a single anchor without edge conditions
$\psi_{ec,N}$	Modification for eccentricity	Resultant tension force is eccentric with respect to anchor group
$\psi_{ed,N}$	Modification for edge effects	One or more edge distance is less than $1.5h_{ef}$
$\psi_{c,N}$	Modification for cracked or uncracked concrete conditions	= 1.0 for cracked concrete = 1.25 for uncracked concrete (cast-in)
$\psi_{cp,N}$	Modification for splitting	Increased edge distance for uncracked concrete (post-installed only)
N_b	Basic concrete breakout strength $= k_c \cdot \lambda_a \cdot \sqrt{f'_c} \cdot h_{ef}^{1.5}$	Concrete breakout strength for a single anchor without edge conditions

MODIFICATION FACTORS BASED ON CRITICAL EDGE DISTANCE

Eccentricity

$$\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)}$$

Edge Distance

$$\psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,min}}{1.5h_{ef}}$$

Splitting

$$\psi_{cp,N} = \left\{ \begin{array}{l} = 1.0 \text{ if } c_{a,min} \geq c_{ac} \\ = \frac{c_{a,min}}{c_{ac}} \text{ if } c_{a,min} < c_{ac} \end{array} \right\}$$

e'_N = distance between resultant tension load and anchors in tension

- only calculated for anchor groups

$c_{a,min}$ = smallest edge distance $< c_a$

$\underline{c_{ac}}$ = critical edge distance for splitting

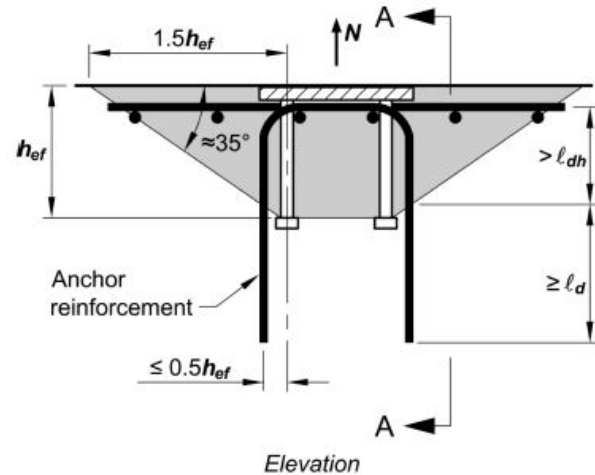
- [reference the anchor Evaluation Service Report](#)

no $\psi_{g,Na}$ modification factor

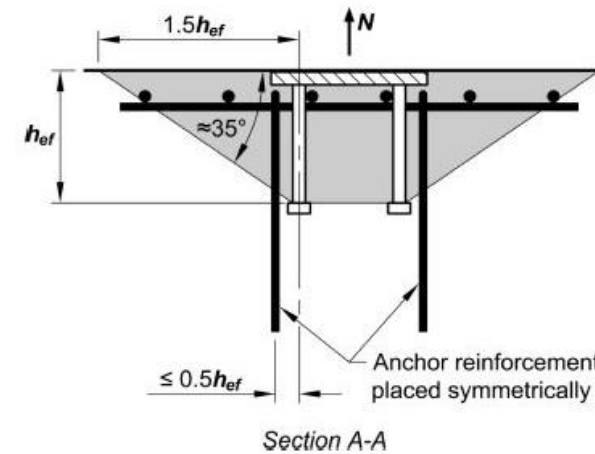
- required calculation in AC308

DETERMINATION OF NOMINAL CONCRETE BREAKOUT STRENGTH

Cast-In-Place Anchors ONLY



ACI 318-14 Fig R17.4.2.9

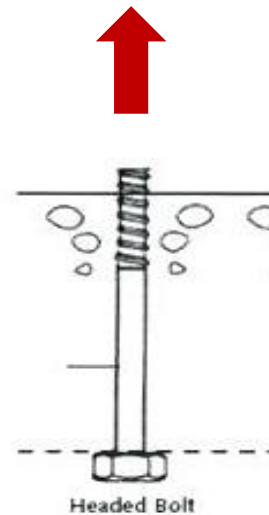
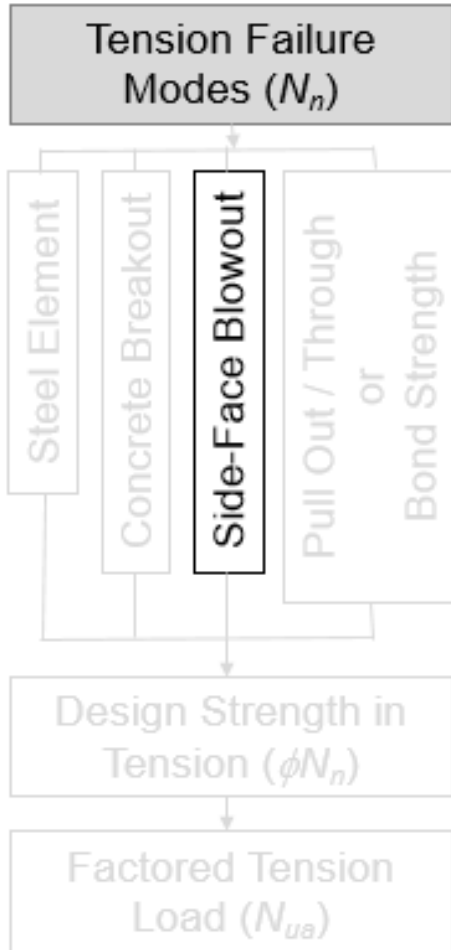


ACI 318-14 Fig R17.4.2.9

No concrete breakout calculation when anchor reinforcement is used

- Reinforcement must be developed on both sides of the concrete breakout surface
- Reference ACI 318 Anchoring to Concrete provisions
ACI 318-11 Appendix D (D.5.2.9) or ACI 318-14 Chapter 17 (Section 17.4.2.9)

DETERMINATION OF NOMINAL PULLOUT STRENGTH



Cast-In-Place Anchor

$$N_{pn} = \psi_{c,p} \cdot N_p$$

$$\psi_{c,p} = 1.0 \text{ (cracked concrete)}$$

$$\psi_{c,p} = 1.4 \text{ (uncracked concrete)}$$

$$N_p = 8A_{brg}f'_c$$

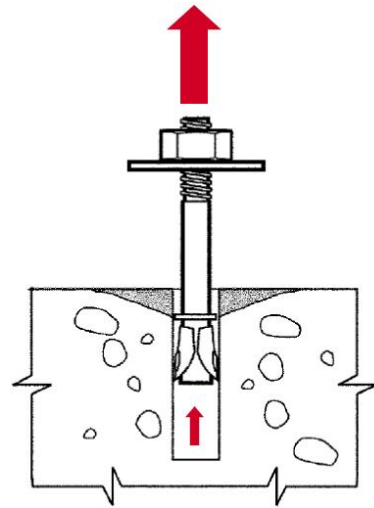
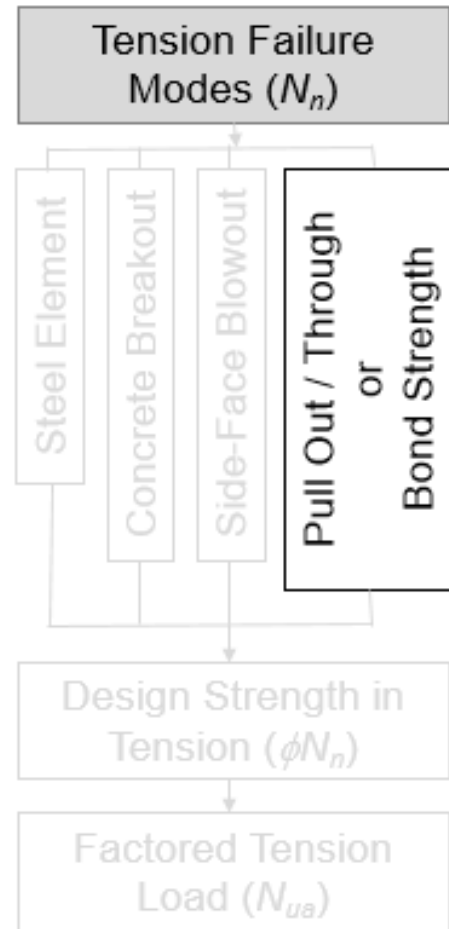
Check if:

$$\Phi_{concrete} \cdot N_{pn} \geq N_{ua,i}$$

Check the anchorage capacity with respect to pullout of the anchor element

DETERMINATION OF NOMINAL PULLOUT STRENGTH

Mechanical Anchor



$$N_{p,f'c} = \psi_{c,p} \cdot N_{p,cr(uncr)} \cdot \sqrt{\frac{f'c}{2500}}$$

$\psi_{c,p} = 1.0$ (cracked or uncracked concrete)

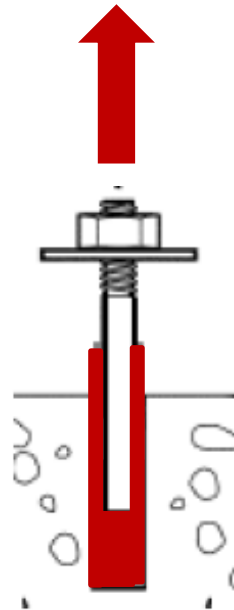
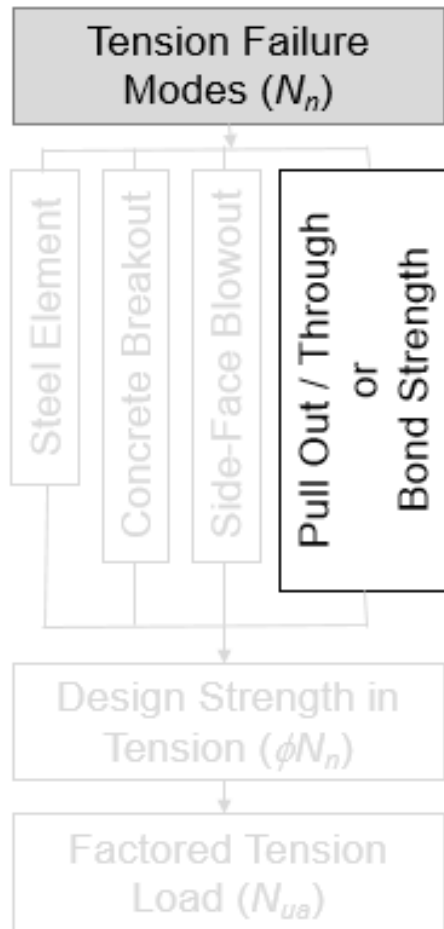
$N_{p,cr(uncr)}$ = can be found in the ICC – ES ESR

Check if:

$$\Phi_{concrete} \cdot N_{p,f'c} \geq N_{ua,i}$$

Check the anchorage capacity with respect to pullout of the anchor element

DETERMINATION OF NOMINAL BOND STRENGTH IN TENSION (PULLOUT)



Single Anchor

$$N_a = \frac{A_{Na}}{A_{Na0}} \cdot \psi_{ed,Na} \cdot \psi_{cp,Na} \cdot N_{ba}$$

Group of Anchors

$$N_{ag} = \frac{A_{Na}}{A_{Na0}} \cdot \psi_{ec,Na} \cdot \psi_{ed,Na} \cdot \psi_{cp,N} \cdot N_{ba}$$

Check if:

$$\phi_{bond} \cdot N_{a(g)} \geq N_{ua(g)}$$

Check the anchorage capacity with respect to the bond strength of the adhesive system

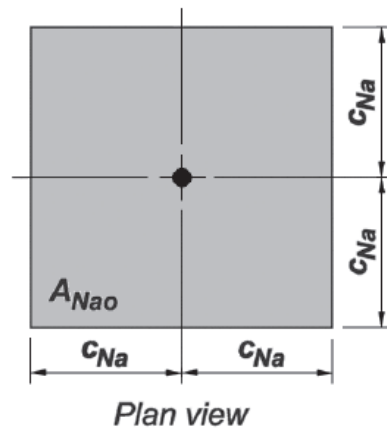
ADHESIVE ANCHOR AREA CALCULATIONS BASED ON EDGE DISTANCE

Projected Edge Distance

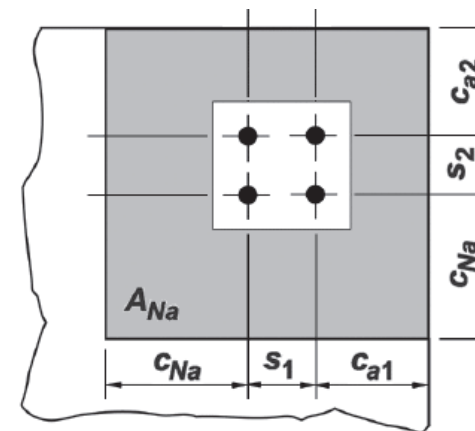
$$c_{Na} = 10d_a \sqrt{\frac{\tau_{uncr}}{7.6}} \quad (17.4.5.1d)$$

Source: Eligehausen et al. 2006

Projected influence area of a single adhesive anchor without edge conditions



Projected influence area for the anchorage inclusive of edge and spacing conditions



MODIFICATION FACTORS FOR DETERMINATION OF NOMINAL BOND STRENGTH

$$N_{ag} = \frac{A_{Na}}{A_{Na0}} \cdot \psi_{ec,Na} \cdot \psi_{ed,Na} \cdot \psi_{cp,N} \cdot N_{ba}$$

A_{Na}	Assumed area of influence for a given anchorage geometry	Area of influence including adjacent anchors and edge distances
A_{Na0}	Assumed area of influence for a single anchor	Area of influence for a single anchor without edge conditions
$\psi_{ec,Na}$	Modification for eccentricity	Resultant tension force is eccentric with respect to anchor group
$\psi_{ed,Na}$	Modification for edge effects	One or more edge distance is less than c_{Na}
$\psi_{cp,Na}$	Modification for splitting	Increased edge distance for uncracked concrete (post-installed only)
N_{ba}	Basic bond strength	Bond strength for a single anchor without edge conditions

MODIFICATION FACTORS BASED ON CRITICAL EDGE DISTANCE

Eccentricity

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

Edge Distance

$$\psi_{ed,Na} = 0.7 + 0.3 \frac{c_{a,min}}{c_{Na}}$$

Splitting

$$\psi_{cp,Na} = \max \left\{ \frac{c_{a,min}}{c_{ac}} ; \frac{c_{Na}}{c_{ac}} \right\}$$

e'_N = distance between resultant tension load and anchors in tension

- only calculated for anchor groups

$c_{a,min}$ = smallest edge distance $< c_{an}$

\underline{c}_{ac} = critical edge distance for splitting

- [reference the anchor Evaluation Service Report](#)

no $\psi_{g,Na}$ modification factor

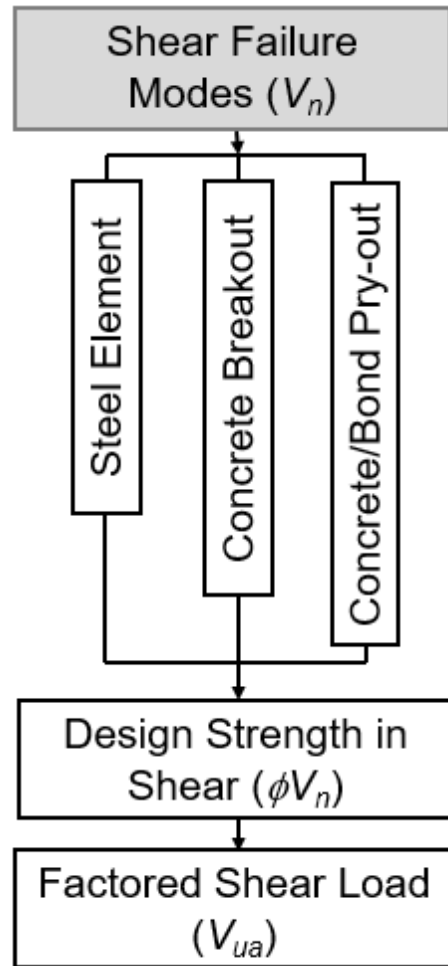
- required calculation in AC308

HILTI

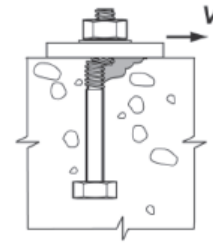
POLL QUESTION NO.2

NOMINAL SHEAR STRENGTHS CALCULATION

SHEAR PARAMETERS FOR DETERMINING SHEAR FAILURE MODES

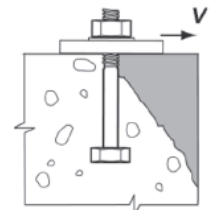


Determining the capacity of the anchor system through different shear failure modes



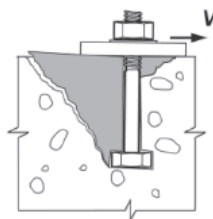
Steel Element

$$V_{ua,i} \leq \phi_{steel} V_{sa}$$



Concrete Breakout Strength

$$V_{ua(g)} \leq \phi_{concrete} V_{cb(g)}$$



Concrete Pryout

$$V_{ua,(g)} \leq \phi_{concrete} V_{cp(g)}$$

**Images are taken from ACI 318-14 Chapter 17*

NOMINAL SHEAR STRENGTHS FOR ANCHORING TO CONCRETE DESIGN

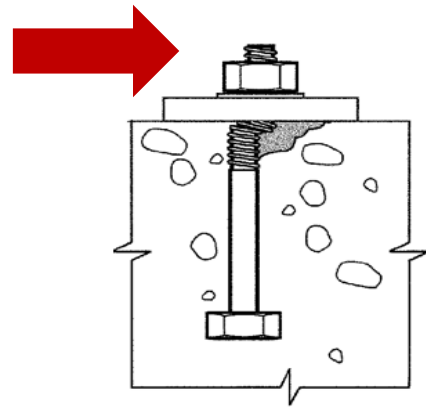
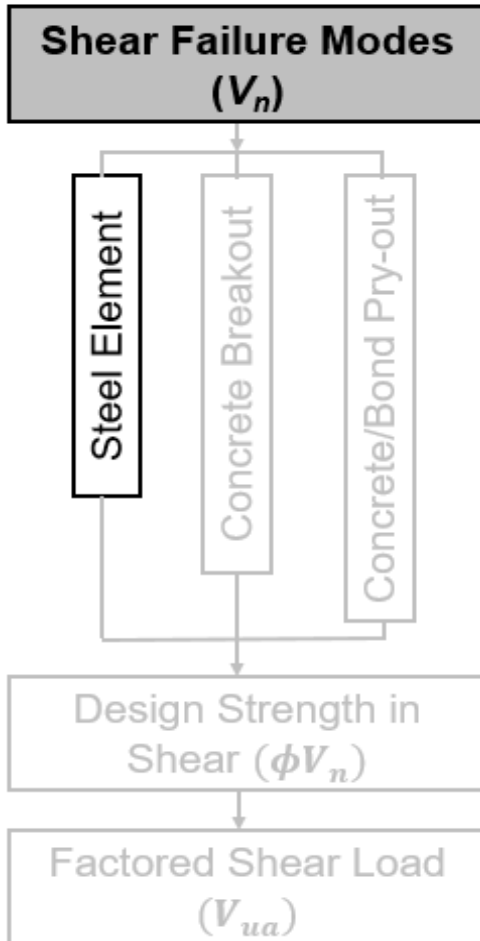
SHEAR FAILURE MODE

		CAST-IN	MECHANICAL	ADHESIVE
Steel Element Nominal steel strength for a single anchor only	V_{sa}	✓	✓	✓
Concrete Breakout Strength Nominal concrete breakout strength for a single anchor	V_{cb}	✓	✓	✓
Nominal concrete breakout strength for group of anchors	V_{cbg}	✓	✓	✓
Concrete Pryout Nominal pryout strength for a single anchor	V_{cp}	✓	✓	✓
Nominal pryout strength for group of anchors	V_{cpg}	✓	✓	✓

STRENGTH REDUCTION FACTORS FOR NOMINAL SHEAR STRENGTH CALCULATION

SHEAR FAILURE MODE		CAST-IN	MECHANICAL	ADHESIVE
Steel Element Strength reduction factor for steel in tension	ϕ_s	ACI 318-14 Chapter 17 Section 17.3.3 Strength reduction factors	ACI 318-14 ICC ESR Table - Design information table	ACI 318-14 ESR Table 1-Design Table Index: Steel design information table
Concrete Breakout Strength Strength reduction factor for concrete in tension	ϕ_c	ACI 318-14 Chapter 17 Section 17.3.3 Strength reduction factors	ACI 318-14 ICC ESR Table - Design information table	ACI 318-14 ESR Table 1-Design Table Index: Concrete breakout design information table
Concrete Pryout Strength reduction factor for concrete in tension	ϕ_c	ACI 318-14 Chapter 17 Section 17.3.3 Strength reduction factors	ACI 318-14 ICC ESR Table - Design information table	ACI 318-14 ESR Table 1-Design Table Index: Concrete breakout design information table

DETERMINATION OF NOMINAL STEEL STRENGTH IN SHEAR



Cast-in headed studs

$$V_{sa} = A_{se,v} \cdot f_{uta}$$

Cast-in headed studs / Hooked bolts

$$V_{sa} = 0.6 \cdot A_{se,v} \cdot f_{uta}$$

Check if:

$$\phi_{steel} \cdot V_{sa} \geq V_{ua,i}$$

Check the anchorage capacity with respect to the steel strength of the anchor element

DETERMINATION OF NOMINAL STEEL STRENGTH IN SHEAR

Post-Installed Anchor (adhesive and mechanical)


Use ICC-ES ESR to determine nominal steel strength for post-installed anchors

- 1 Locate the 'Steel Design' Table in the ESR
- 2 Find the type of steel element you are using on the left hand side
- 3 Find the appropriate diameter along the top line
- 4 This intersection is the nominal steel strength, V_{sa}
- 5 The reduction factor $\alpha_{V,seis}$ is specific to adhesive anchor elements when the design is for seismic conditions
- 6 The strength reduction factor, ϕ , is listed below the nominal steel strength

Check if:

$$\phi_{steel} \cdot V_{sa} \geq V_{ua,i}$$

ESR-3814 | Most Widely Accepted and Trusted Page 13 of 45



1 Fractional Threaded Rod and Reinforcing Bars **Steel Strength**

TABLE 6—STEEL DESIGN INFORMATION FOR FRACTIONAL THREADED ROD AND REINFORCING BARS

DESIGN INFORMATION	Symbol	Units	Nominal rod diameter (in.)					
			#3	#4	#5	#6	#7	#8
Root O.D.	d	in.	0.375	0.5	0.625	0.75	1	1.25
Root effective cross-sectional area	A_{se}	in. ²	0.0715	0.1419	0.2260	0.3345	0.4817	0.6691
		mm ²	(50)	(92)	(148)	(238)	(391)	(625)
Nominal strength as governed by steel strength	N_{sa}	lb	6,620	10,290	16,388	23,470	43,910	70,260
		(kN)	(29.3)	(45.8)	(72.9)	(104.9)	(195.3)	(312.5)
Reduction for seismic shear	$\alpha_{V,seis}$	-	0.65	0.65	0.65	0.65	0.65	0.65
Strength reduction factor for tension ¹	ϕ	-	0.75	0.75	0.75	0.75	0.75	0.75
Strength reduction factor for shear ²	ϕ	-	0.65	0.65	0.65	0.65	0.65	0.65

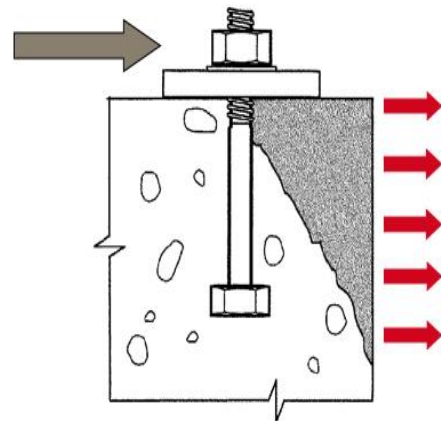
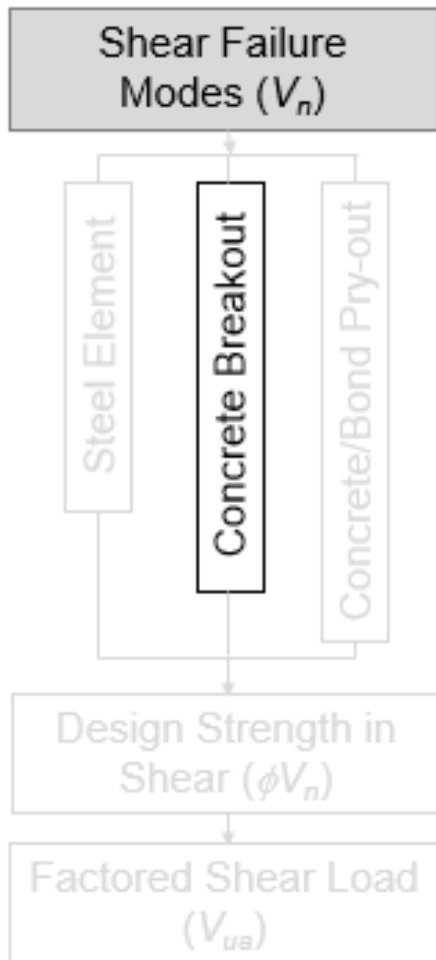
DESIGN INFORMATION	Symbol	Units	Nominal Reinforcing bar size (Rebar)					
			#3	#4	#5	#6	#7	#8
Nominal bar diameter	d	in.	0.375	0.5	0.625	0.75	1	1.25
Bar effective cross-sectional area	A_{se}	in. ²	0.0715	0.1419	0.2260	0.3345	0.4817	0.6691
		mm ²	(50)	(92)	(148)	(238)	(391)	(625)
Nominal strength as governed by steel strength	N_{sa}	lb	6,620	10,290	16,388	23,470	43,910	70,260
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Reduction for seismic shear	$\alpha_{V,seis}$	-	0.65	0.65	0.65	0.65	0.65	0.65
Strength reduction factor for tension ¹	ϕ	-	0.75	0.75	0.75	0.75	0.75	0.75
Strength reduction factor for shear ²	ϕ	-	0.65	0.65	0.65	0.65	0.65	0.65

For #1: 1 inch = 25.4 mm, 1 lbf = 4.448 N. For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf

¹ Values provided for common rod material types are based on specified strengths and calculated in accordance with ACI 318-14 Eq. (17.4.1.2) and Eq. (17.5.1.2b) or ACI 318-11 Eq. (D-2) and Eq. (D-2b), as applicable. Nuts and washers must be appropriate for the rod.
² For use with the load combinations of IBC Section 1605.2, ACI 318-14 S.3 or ACI 318-11 S.2, as applicable, as set forth in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.3. Values correspond to a brittle steel element.
³ For use with the load combinations of IBC Section 1605.2, ACI 318-14 S.3 or ACI 318-11 S.2, as applicable, as set forth in ACI 318-14 17.3.3 or ACI 318-11 D.4.3, as applicable. If the load combinations of ACI 318-11 Appendix C are used, the appropriate value of ϕ must be determined in accordance with ACI 318-11 D.4.3. Values correspond to a ductile steel element.

Check the anchorage capacity with respect to the steel strength of the anchor element

DETERMINATION OF CONCRETE BREAKOUT STRENGTH IN SHEAR



Single Anchor

$$V_{cb} = \frac{A_{Vc}}{A_{Vco}} \cdot \psi_{ed,V} \cdot \psi_{c,V} \cdot \psi_{h,V} \cdot V_b$$

Group of Anchors

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \cdot \psi_{ec,V} \cdot \psi_{ed,V} \cdot \psi_{c,V} \cdot \psi_{h,V} \cdot V_b$$

- V_b is dependent on the anchor type
- Always calculated for cracked concrete conditions

Check if:

$$\phi_{concrete} \cdot V_{cb(g)} \geq V_{ua(g)}$$

Check the anchorage capacity with respect to concrete breakout

DETERMINATION OF CONCRETE BREAKOUT STRENGTH IN SHEAR

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \cdot \psi_{ec,V} \cdot \psi_{ed,V} \cdot \psi_{c,V} \cdot \psi_{h,V} \cdot V_b$$

A_{Vc}	Assumed area of influence for a given anchorage geometry	Area of influence including adjacent anchors and edge distances
A_{Vco}	Assumed area of influence for a single anchor	Area of influence for a single anchor without edge conditions
$\psi_{ec,V}$	Modification for eccentricity	Resultant shear force is eccentric with respect to anchor group
$\psi_{ed,V}$	Modification for edge effects	One or more edge distance is less than $1.5c_{a1}$
$\psi_{c,V}$	Modification for cracked or uncracked concrete conditions	Increase if supplementary reinforcement or uncracked concrete assumed
$\psi_{h,V}$	Modification for slab thickness	Increase permitted for large edge distance and thin slab
V_b	Basic concrete breakout strength	Concrete breakout strength for a single anchor without edge conditions

MODIFICATION FACTORS BASED ON CRITICAL EDGE DISTANCE AND BASE MATERIAL THICKNESS

Eccentricity

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

Edge Distance

$$\psi_{ed,v} = \begin{cases} 1.0 & \text{if } c_{a2} \geq 1.5c_{a1} \\ 0.7 + 0.3 \frac{c_{a2}}{1.5c_a} & \text{if } c_{a2} < 1.5c_{a1} \end{cases}$$

Concrete Condition

$$\psi_{c,v} = \begin{cases} 1.0 \\ 1.2 \\ 1.4 \end{cases}$$

Base Material Thickness

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

where $h_a < 1.5c_{a1}$

DETERMINATION OF CONCRETE BREAKOUT STRENGTH IN SHEAR

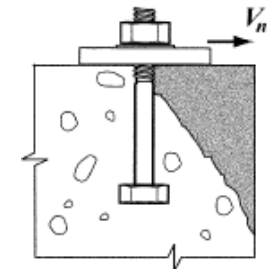
Basic Concrete Breakout Strength

$$V_b = \left(0.6 \left(\frac{l_e}{d_a} \right)^{0.2} \sqrt{d_a} \right) \lambda \sqrt{f'_c} (c_{a1})^{1.5}$$

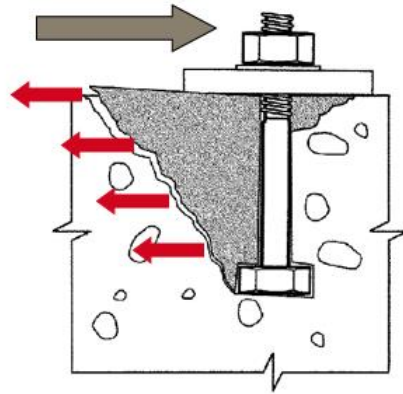
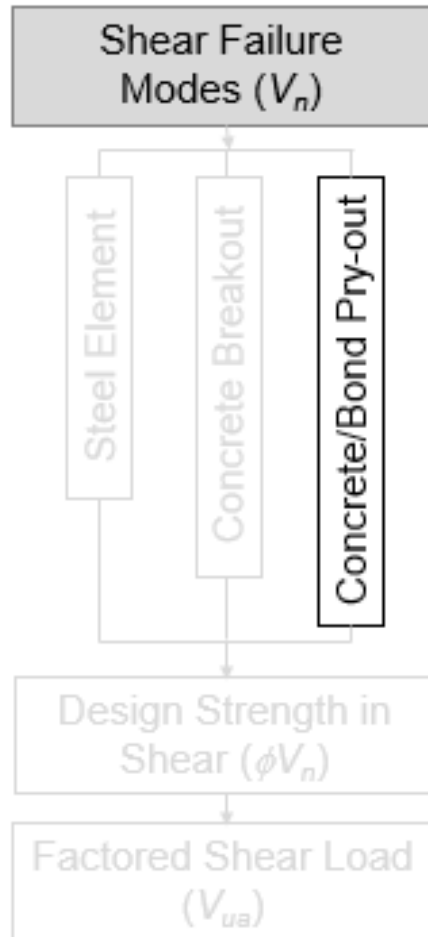
$$V_b = 3.7 \sqrt{f'_c} (c_{a1})^{1.5}$$

Use the smaller V_b value from this check to calculate V_{cb} or V_{cbg}

- l_e = load bearing length of anchor for shear
MINIMUM {hef : 8da} for anchors with constant stiffness
2da for anchors that do not have a constant stiffness (e.g. HSL-3 anchors)



DETERMINATION OF CONCRETE PRY-OUT STRENGTH IN SHEAR



k_{cp} = pryout coefficient

$k_{cp} = 1.0$ if $h_{ef} < 2.5''$

$k_{cp} = 2.0$ if $h_{ef} \geq 2.5''$

Cast-in Place and Mechanical Anchors

Single Anchor

$$V_{cp} = k_{cp} \cdot N_{cb}$$

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_b$$

Group of Anchors

$$V_{cp(g)} = k_{cp} \cdot N_{cb(g)}$$

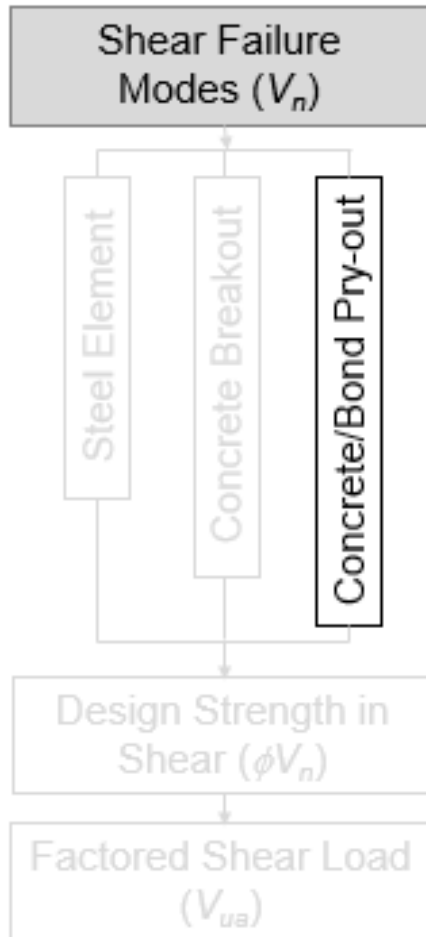
$$N_{cb(g)} = \frac{A_{Nc}}{A_{Nco}} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_{b(g)}$$

Check if:

$$\phi_{concrete} \cdot V_{cp(g)} \geq V_{ua(g)}$$

Check the anchorage capacity with respect to concrete breakout

DETERMINATION OF CONCRETE PRY-OUT STRENGTH IN SHEAR



Adhesive Anchors

Single Anchor

$$V_{cp} = \min\{k_{cp}N_a; k_{cp}N_{cb}\}$$

Group of Anchors

$$V_{cpg} = \min\{k_{cp}N_{ag}; k_{cp}N_{cbg}\}$$

$$N_a = \frac{A_{Na}}{A_{Na0}} \cdot \psi_{ed,Na} \cdot \psi_{cp,Na} \cdot N_{ba}$$

$$N_{cb} = \frac{A_{Nc}}{A_{Nc0}} \cdot \psi_{ed,N} \cdot \psi_{c,N} \cdot \psi_{cp,N} \cdot N_b$$

Check if:

$$\phi_{concrete} \cdot V_{cp(g)} \geq V_{ua(g)}$$

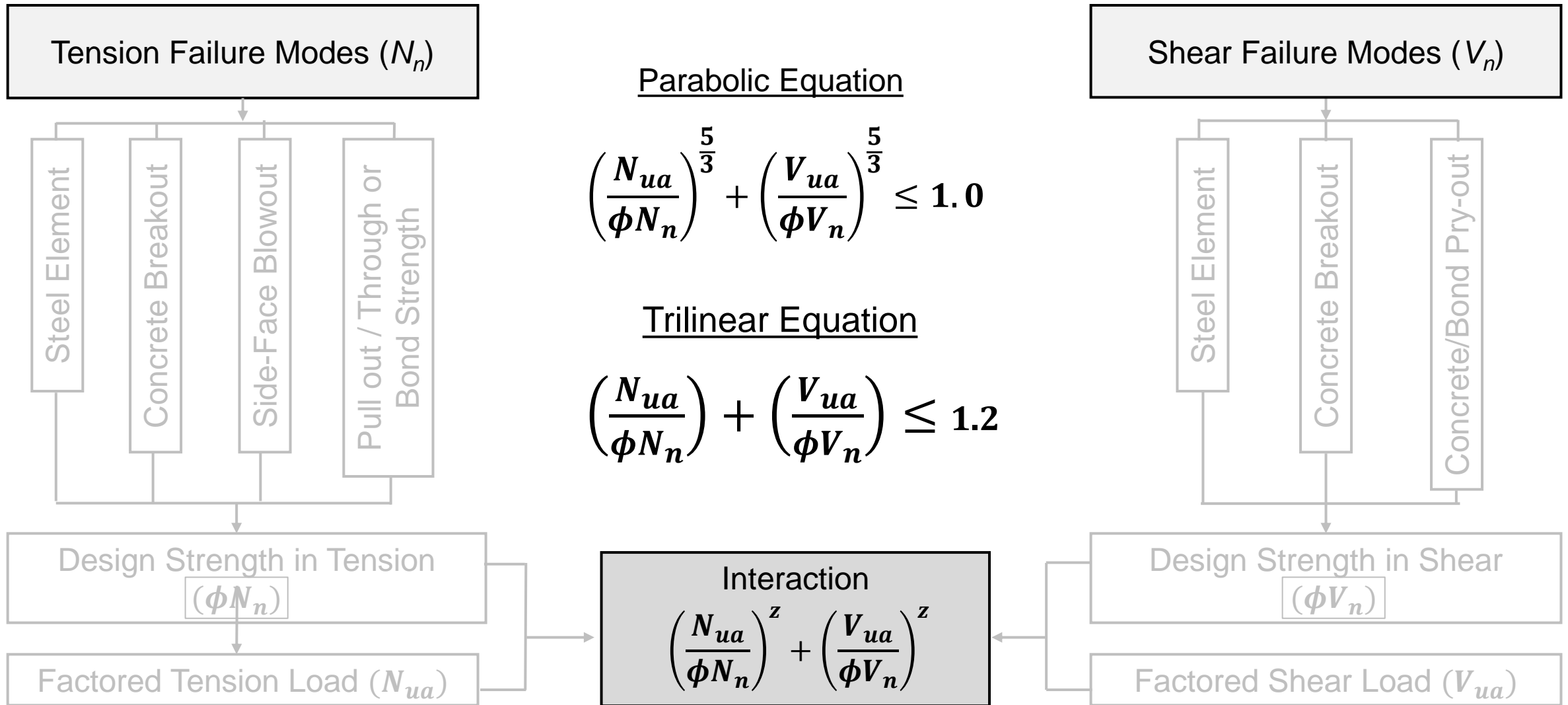
Check the anchorage capacity with respect to concrete breakout

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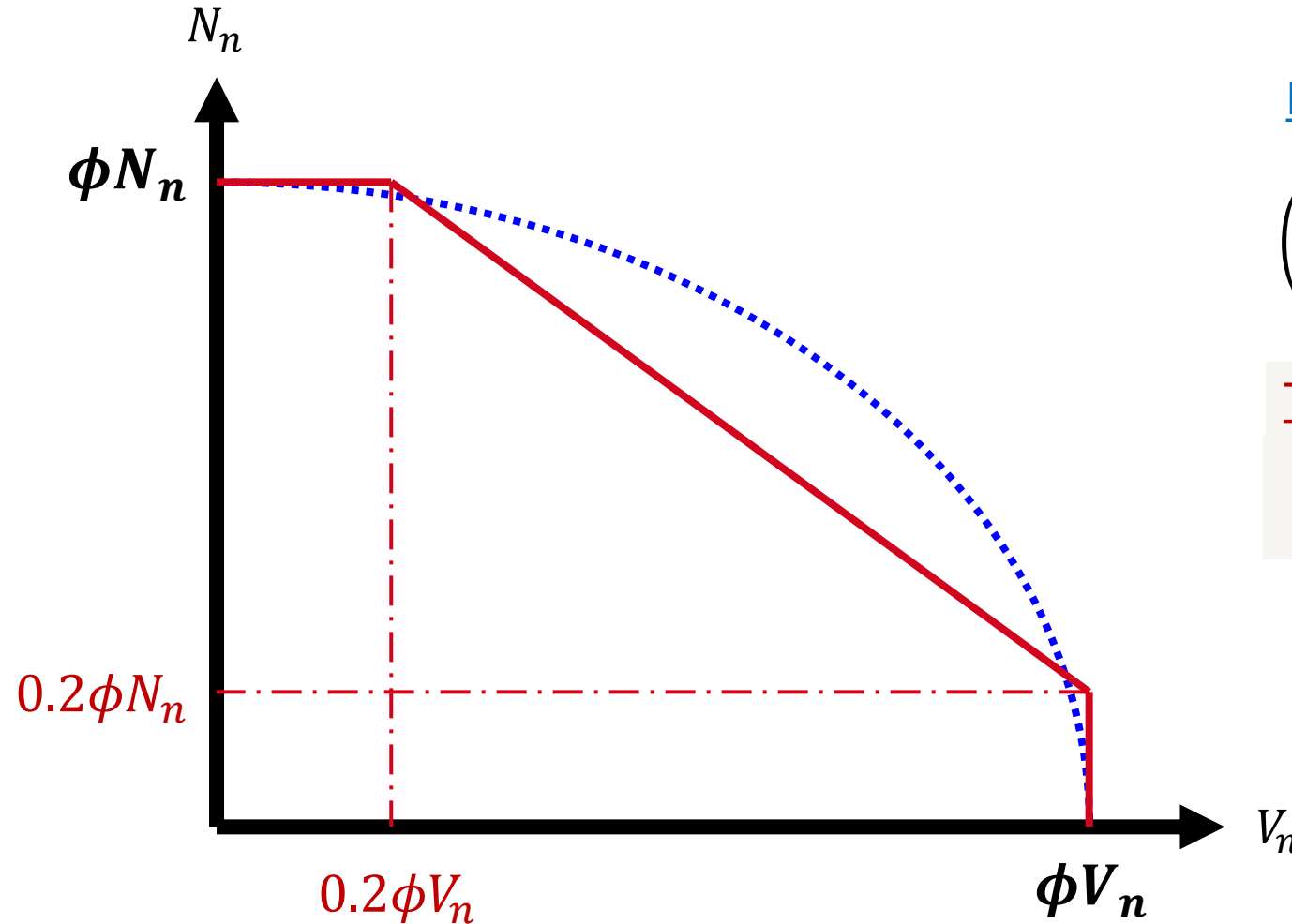
POLL QUESTION NO.3

INTERACTION EQUATION CALCULATION

DETERMINATION OF INTERACTION EQUATION



INTERACTION OF TENSILE AND SHEAR FORCES



Parabolic equation

$$\left(\frac{N_{ua}}{\phi N_n}\right)^{\frac{5}{3}} + \left(\frac{V_{ua}}{\phi V_n}\right)^{\frac{5}{3}} \leq 1.0$$

Trilinear equation

$$\left(\frac{N_{ua}}{\phi N_n}\right) + \left(\frac{V_{ua}}{\phi V_n}\right) \leq 1.2$$

PRESENTATION OUTLINE

- 1.0** Introduction to Post – Installed Anchor [Overview]
- 2.0** Qualification of Anchor Assembly – Code Landscape
- 3.0** Concrete Capacity Design Provisions
 - 2.1** Nominal Tension Strengths
 - 2.2** Nominal Shear Strengths
 - 2.3** Interaction Equation
- 4.0** Conclusions and Recommendations

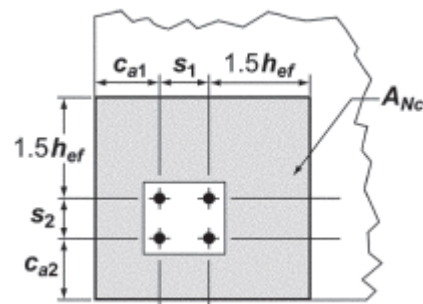
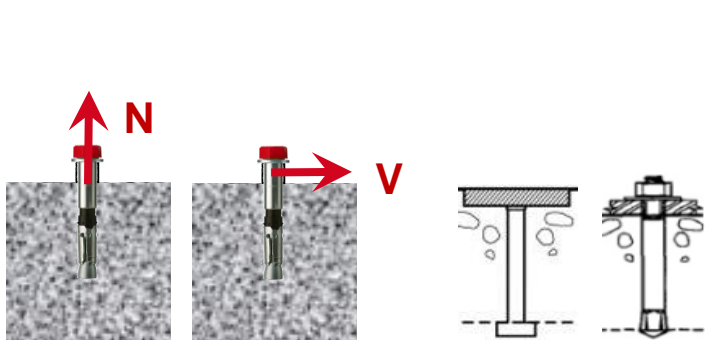


CCD DESIGN PROCESS

CCD METHOD DESIGN PROCEDURE



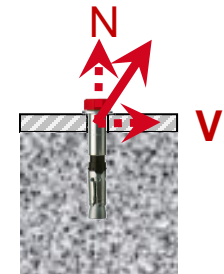
- Determine tension and shear loads for application
- Select anchor type and size
- Check: s_{min} (spacing), c_{min} (edge), h_{min} (embedment)
- Determine strength reduction factors
- Determination and comparison of nominal tension and shear resistance
- Combined load interaction



- ✓ ϕ Steel Strength
- ✓ ϕ Concrete Strength
 - Breakout
 - Pryout
 - Pullout
- ✓ ϕ Bond Strength

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







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



$$\left(\frac{N_{ua}}{\phi N_n} \right)^{\frac{5}{3}} + \left(\frac{V_{ua}}{\phi V_n} \right)^{\frac{5}{3}} \leq 1.0$$

PARAMETERS AFFECTING THE DESIGN RESISTANCE FOR DIFFERENT POSSIBLE FAILURE MODES

Resistance to possible failure modes

Resistance to parameter	Tension				Shear		
	Steel 	Concrete cone 	Pull-out 	Splitting 	Steel ^{b)} 	Concrete edge 	Pry-out 
h_{ef} : Effective anchorage depth	0	+	0/+ ^{a)}	+	0	+	+
s_1 : Spacing perpendicular to the edge	0	+	0 ^{a)}	+	0	0	+
s_2 : Spacing parallel to the edge	0	+	0 ^{a)}	+	0	+	+
n : Edge distance	0	+	0 ^{a)}	+	0	+	+
n : Number of anchors	+	+	+	+	+	+ ^{d)}	+
d : Element size/diameter	+	0	0/+ ^{a)}	0/+/-	+	+	0
Anchor material (strength class of steel)	+	0	0	0	+	0	0
(l , w) Length and width of the fixture	+ ^{c)}	+ ^{c)}	+ ^{c)}	+ ^{c)}	0	0	0
h : Thickness of base material	0	0	0	+	0	+	0
f_{cc} : Concrete compressive strength	0	+	0/+	+	0	+	+

- 0 changing the parameter has no effect on the resistance
- + by increasing the parameter the resistance also increases
- 0/+ depending on the anchor type

- +** Main parameter
- a) for bonded anchors: +
- b) with and without lever arm
- c) in case of tension forces due to bending, modifying the length and/or width of the fixture affects the lever arm and therefore the tension load acting on the anchors (the resistance is not affected)

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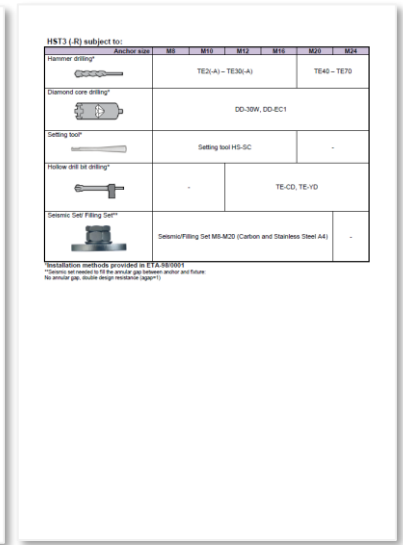
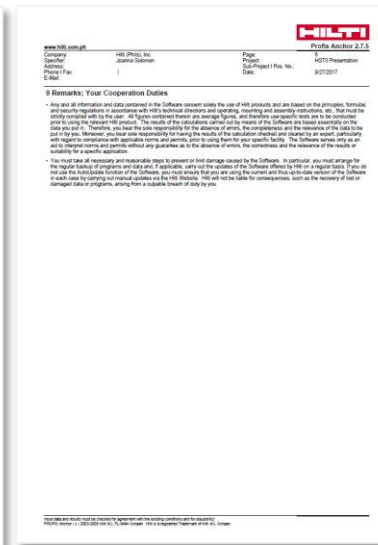
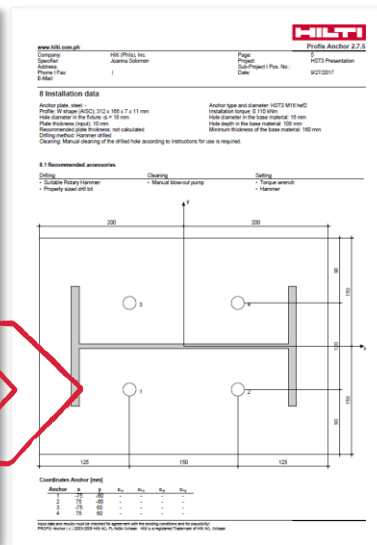
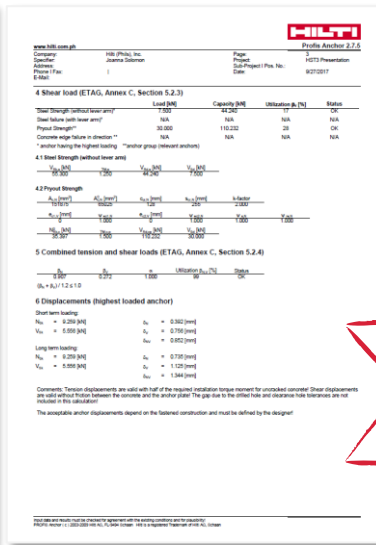
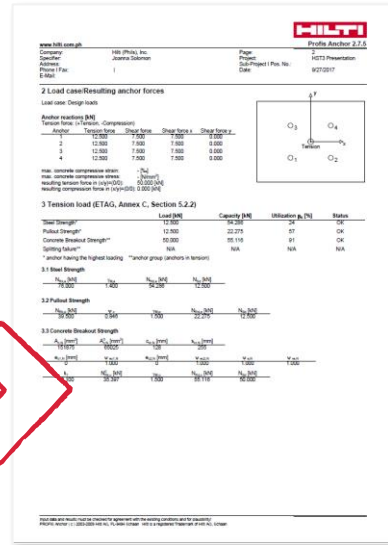
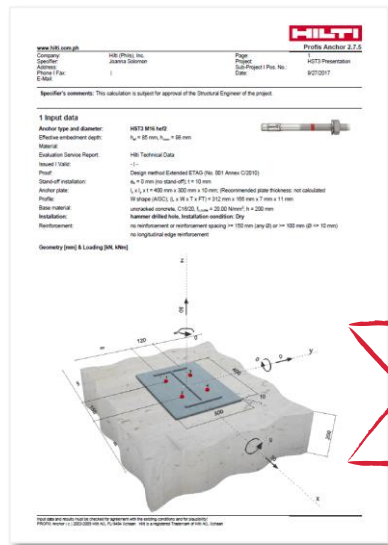
POLL QUESTION NO. 4

PROFIS ANCHOR DESIGN REPORT FEATURE SUMMARIZES YOUR CALCULATION IN PDF FORM

1 Design Requirement

2 Assembly & Performance Qualification

3 Connection Detail & Specs



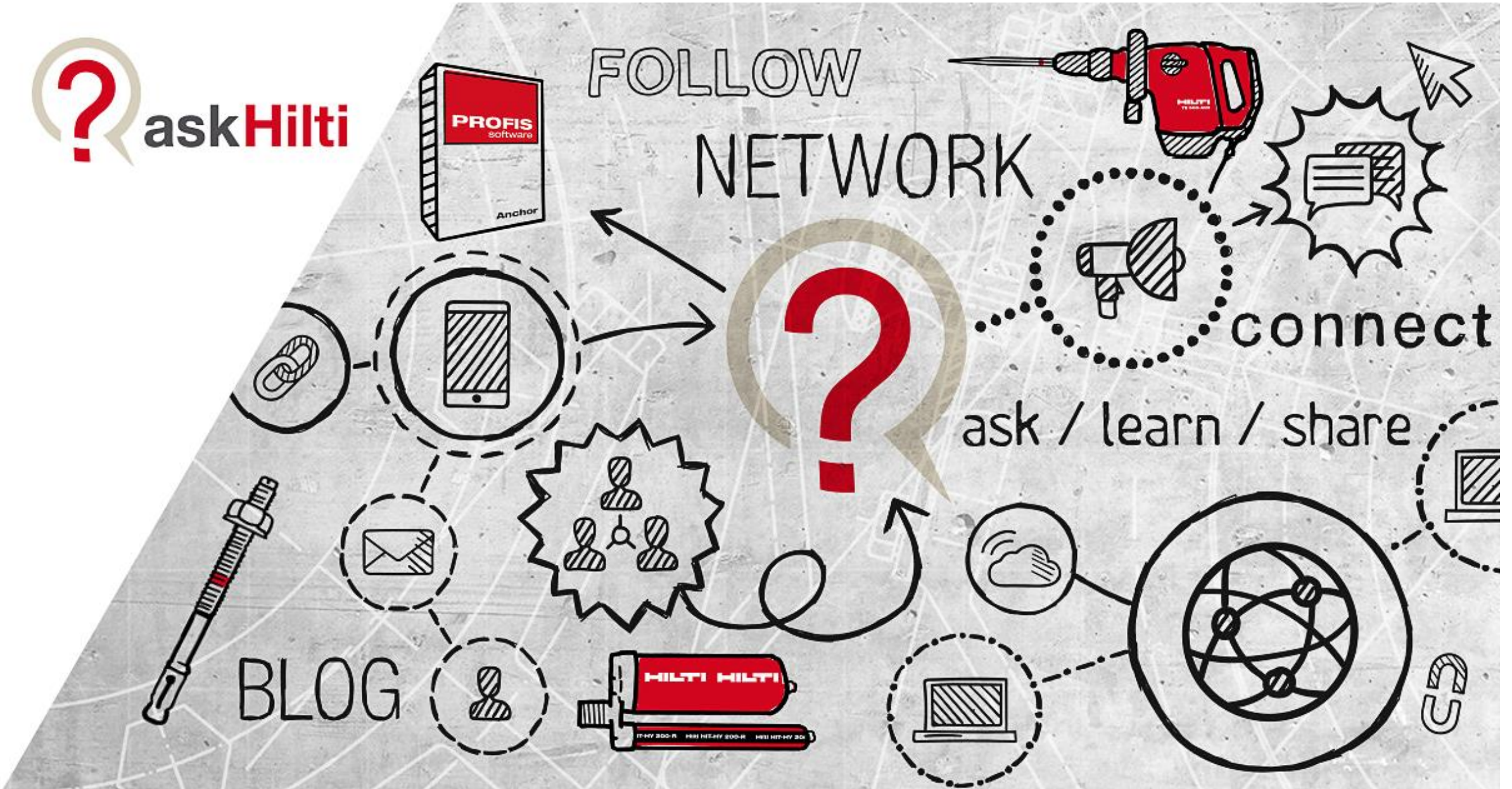
- Connection assembly (properties and installation)
- Design load requirement
- Design code and approval

- Installation and concrete condition factors applied in the solution based on approval used
- **Concrete capacity design calculation**

- Anchor layout to follow in the design plans and details [plan view]
- Calculation remarks specific to design parameters used and installation guidelines.

CONCLUSIONS AND RECOMMENDATIONS

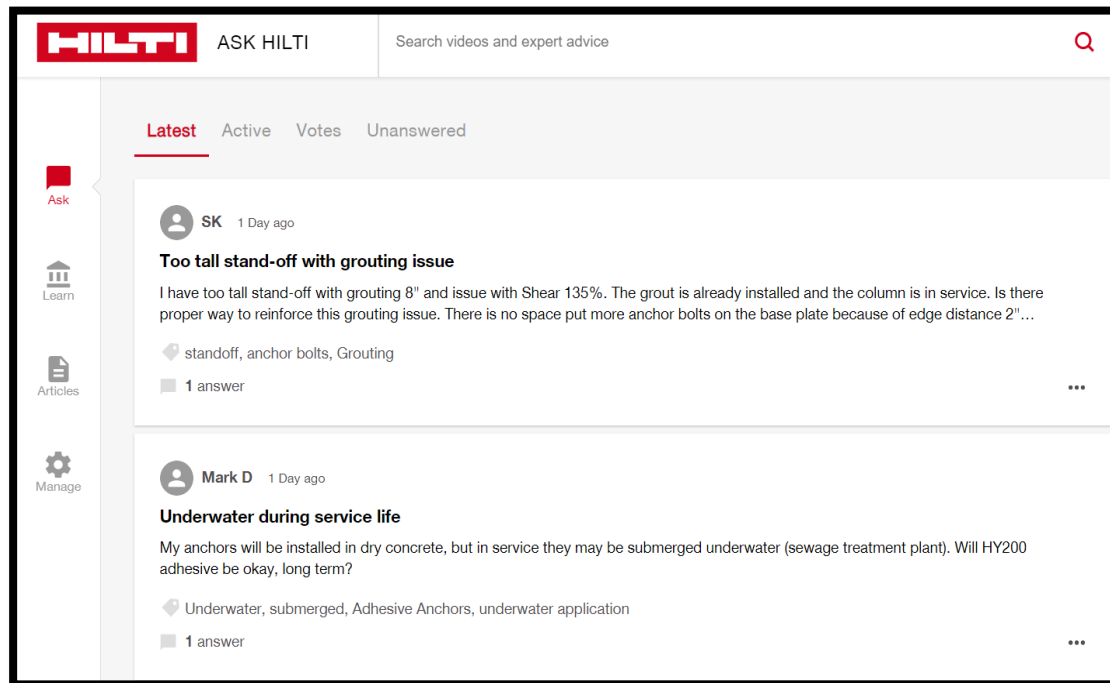
- ❑ The **Concrete Capacity Design Method** is used for the calculation of anchoring to concrete for both cast-in place and post-installed anchors.
- ❑ The local code, NSCP 2015, follows the American standard, ACI 318. Anchoring to Concrete is found at **ACI 318-14 Chapter 17**. It follows that for all post-installed anchor connections, products shall be qualified under ICC. Relevant product approval, **ICC-ESR product approval** shall be obtained before an anchor is used for any application.
- ❑ Hilti, as a global expert in fastening technology, guides and supports designers in ensuring codes and standards are met for all fastening applications.
- ❑ To help professionals in designing anchoring to concrete connections (post-installed anchors) that is more realistic and compliant to governing codes, Hilti developed **PROFIS Engineering** which is easy to use, and is able to generate comprehensive report for easy submittal and approval.



ASK HILTI IS AN ONLINE COMMUNITY THAT OFFERS EXPERT ADVICE AND CONTINUING EDUCATION

Expert Advice

question and answer forum

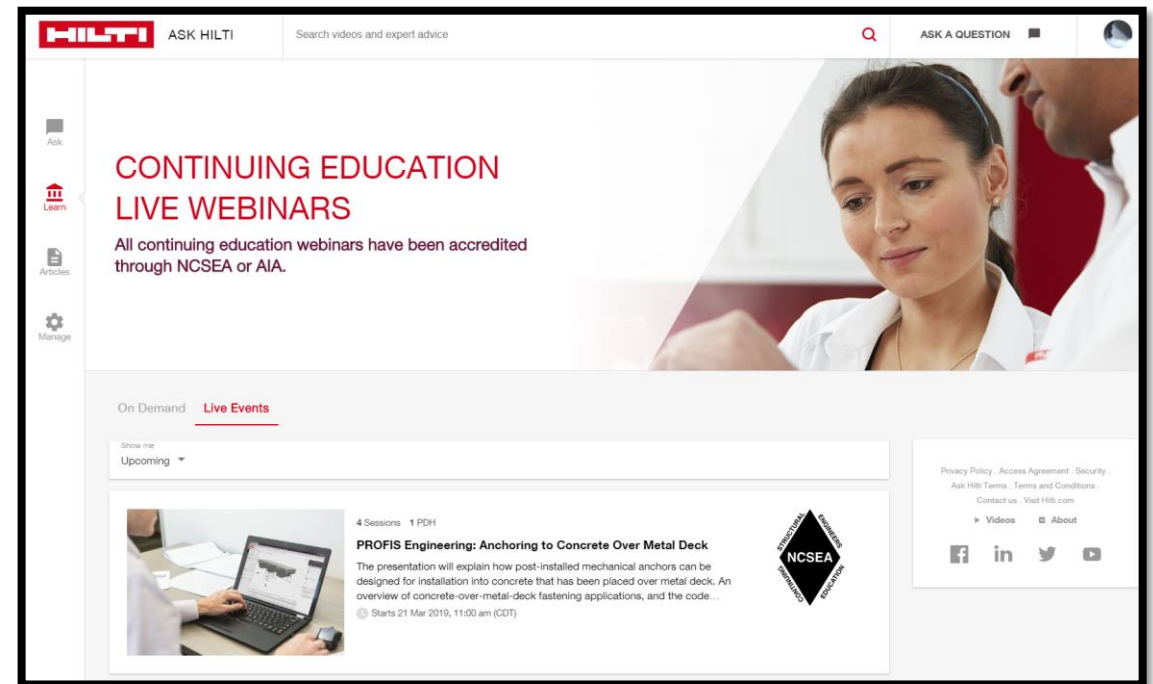


The screenshot shows the ASK HILTI forum interface. At the top, there is a search bar with the text "Search videos and expert advice". Below the search bar, there are tabs for "Latest", "Active", "Votes", and "Unanswered". The "Latest" tab is selected. On the left side, there is a navigation menu with icons for "Ask", "Learn", "Articles", and "Manage". The main content area displays two questions:

- Question 1:** User "SK" (1 Day ago) asks: "Too tall stand-off with grouting issue". The question text is: "I have too tall stand-off with grouting 8" and issue with Shear 135%. The grout is already installed and the column is in service. Is there proper way to reinforce this grouting issue. There is no space put more anchor bolts on the base plate because of edge distance 2"...". The tags are "standoff, anchor bolts, Grouting". There is 1 answer.
- Question 2:** User "Mark D" (1 Day ago) asks: "Underwater during service life". The question text is: "My anchors will be installed in dry concrete, but in service they may be submerged underwater (sewage treatment plant). Will HY200 adhesive be okay, long term?". The tags are "Underwater, submerged, Adhesive Anchors, underwater application". There is 1 answer.

Expert Learn

on demand video, live webinar and articles



The screenshot shows the ASK HILTI "Expert Learn" section. At the top, there is a search bar with the text "Search videos and expert advice". Below the search bar, there are tabs for "On Demand" and "Live Events". The "Live Events" tab is selected. The main content area features a large banner for "CONTINUING EDUCATION LIVE WEBINARS" with the text: "All continuing education webinars have been accredited through NCSEA or AIA." Below the banner, there is a section for "On Demand" with a dropdown menu set to "Upcoming". The main content area displays a webinar titled "PROFIS Engineering: Anchoring to Concrete Over Metal Deck". The webinar details are: "4 Sessions 1 PDH". The description is: "The presentation will explain how post-installed mechanical anchors can be designed for installation into concrete that has been placed over metal deck. An overview of concrete-over-metal-deck fastening applications, and the code...". The start time is "Starts 21 Mar 2019, 11:00 am (CDT)". There is a logo for "NCSEA" (National Concrete Steel Education Association) and a "Videos" icon. On the right side, there is a footer with links for "Privacy Policy", "Access Agreement", "Security", "Ask Hilti Terms", "Terms and Conditions", "Contact us", and "Visit Hilti.com". There are also social media icons for Facebook, LinkedIn, Twitter, and YouTube.

THANK YOU

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