ANCHOR SUITABILITY TO STATIC & SEISMIC CONDITIONS

[NSCP 7th Edition Chapter 417 Design Based]
28th July 2022 | 15.00-16.00

Welcome to today’s webinar! We will start shortly

OUR PRESENTER FOR THIS WEBINAR

MODERATOR

Richmond Olaya
MO Philippines
TM Marketing Manager

SPEAKER

Amol Singh
A2 Regional Eng’g
Marketing Manager
Structural

FEW REMINDERS…

Participate and Collaborate.
Type in your comments, questions and we will answer them in the Q/A section

We will have **Polls Questions** in between discussions to seek your perspectives

Session is **live** and will be **Recorded**

Tell us your experience and share your **feedback!**

ANCHOR SUITABILITY TO STATIC & SEISMIC CONDITIONS

[NSCP 7th Edition Chapter 417 Design Based]

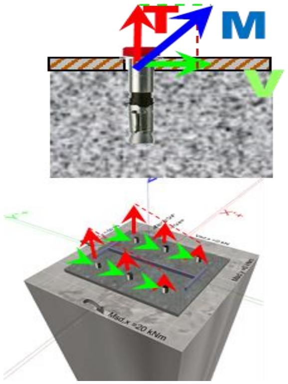
SESSION OVERVIEW

1. **Factors Influencing Anchor Performance**
2. Static Anchor Design
   a) Anchor Performance Assessment
   b) Design Calculations for Static
3. Influence of Seismic in Anchor Design
   a) Earthquake Influences in the Anchorage Resistance
   b) Suitability Testing and Anchor Design
4. Fastening Systems approved for Static and Seismic
5. Conclusion and Recommendation

FACTORS INFLUENCING ANCHOR PERFORMANCE

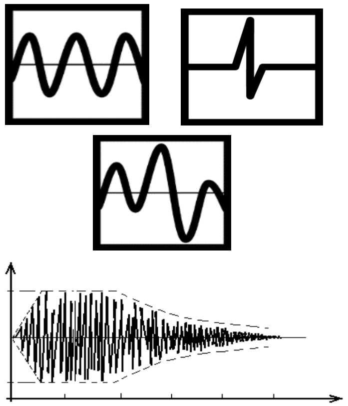
LOAD DIRECTION

- Tension
- Shear
- Moment



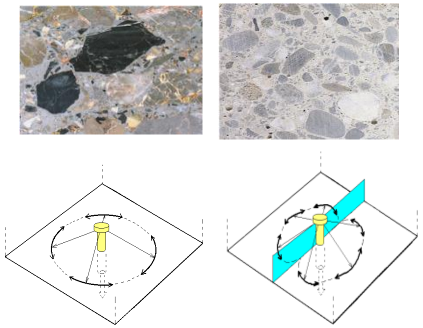
MODES OF LOADING

- Static Load
- Pulsating Load
- Alternating Load
- Dynamic Load
  - Fatigue
  - Shock
  - Seismic



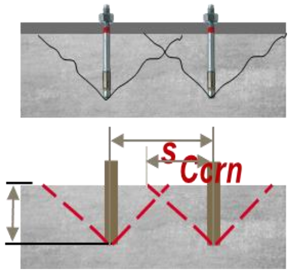
BASE MATERIAL

- Type of base material
- Cracked and Uncracked



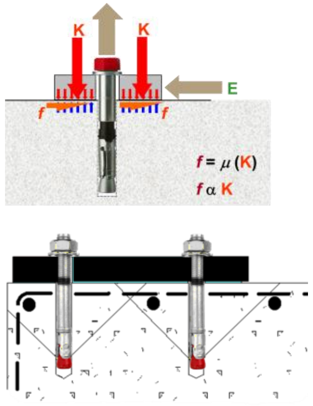
SPACING, EDGE AND EMBEDMENT

- Critical Edge Distance
- Minimum Spacing
- Typical & Minimum Embedment



TORQUE AND REINFORCEMENT

- Tightening Torque
- Effect of Reinforcement

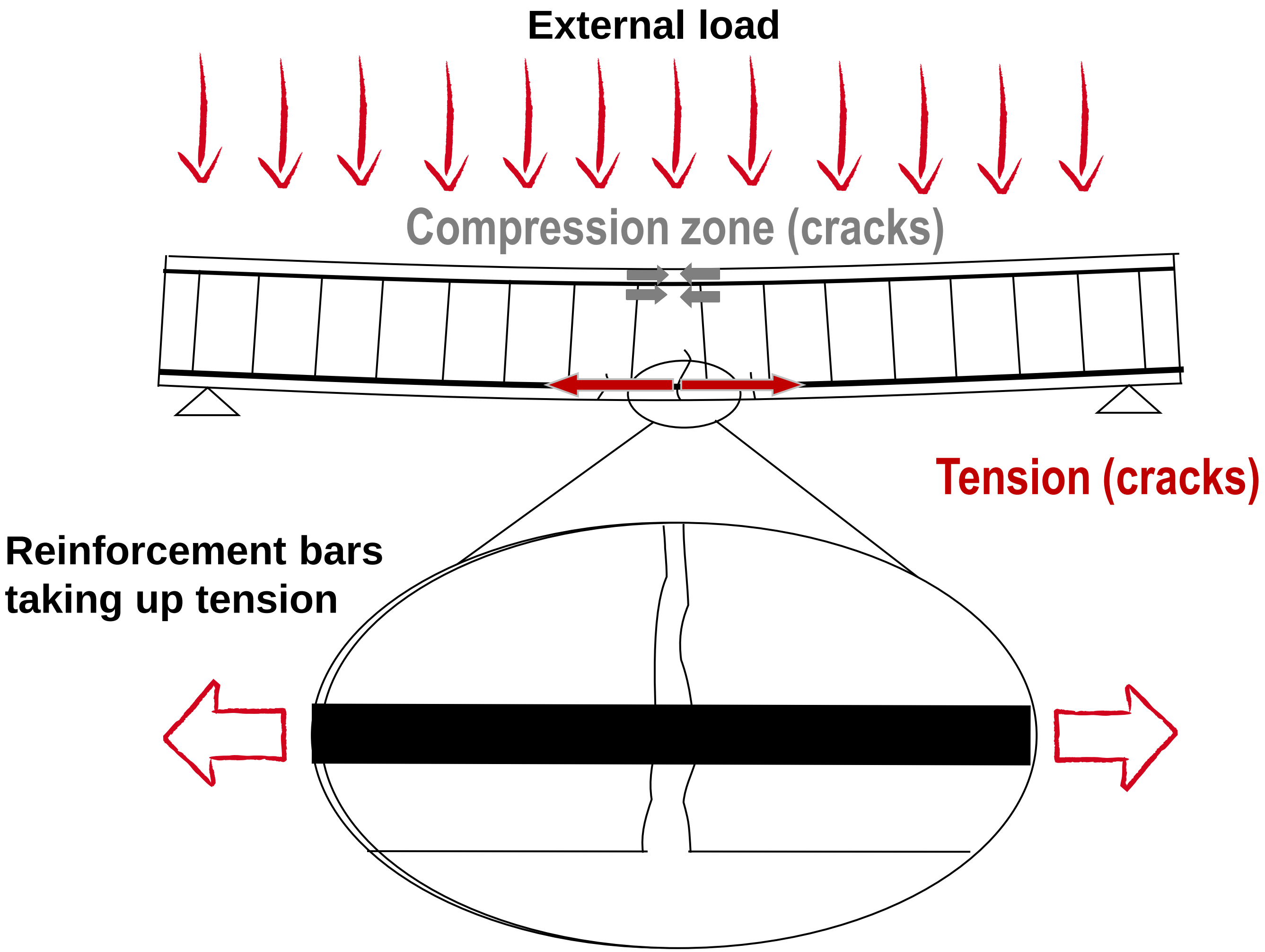


MATERIAL PROPERTY

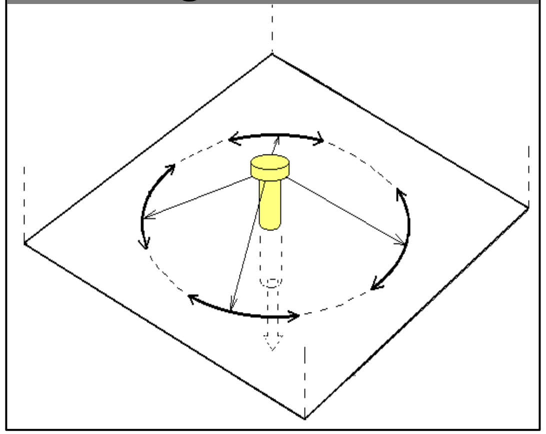
- Corrosion Resistance
- Steel grade/quality
- Toxicity

ANSI Accredited Program PERSONNEL CERTIFICATION

FACTORS INFLUENCING ANCHORING: BASE MATERIAL MODE

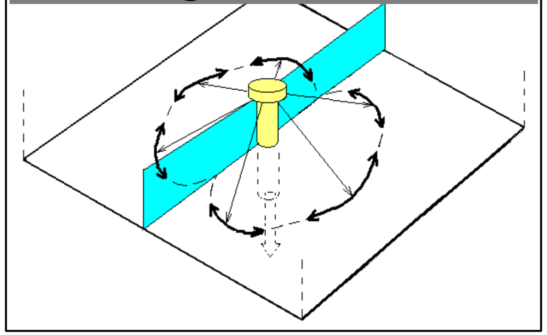


Before crack runs through the anchor



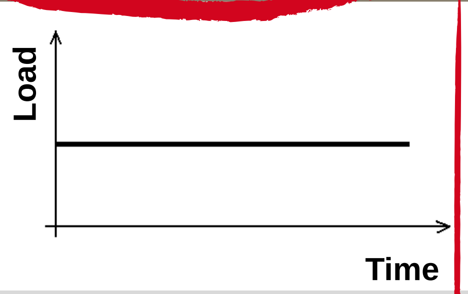
100% of anchor resistance

After crack runs through the anchor



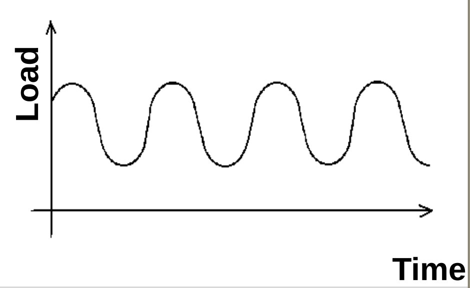
<100% of anchor resistance

FACTORS INFLUENCING ANCHORS: MODE OF LOADING



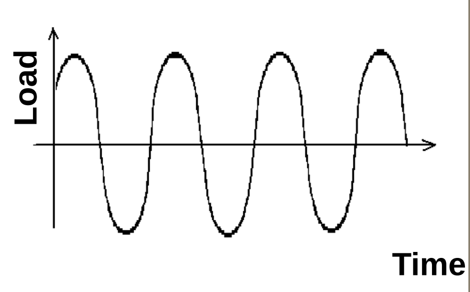
Static Load

- Dead weight
- Permanent actions
- Loads of non-bearing components



Pulsating Load

- Machine/ equipment vibrations

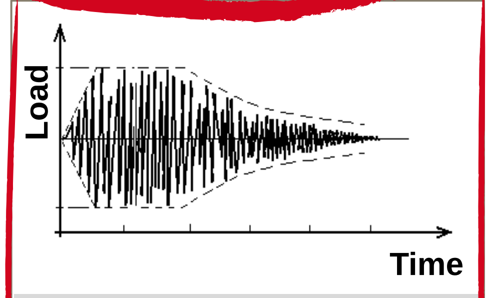


Alternating Load

- Live load
- Wind load

Shock Load

- Explosion
- Extraordinary traffic loads / collisions
- Hydraulic loads
- Sudden impact

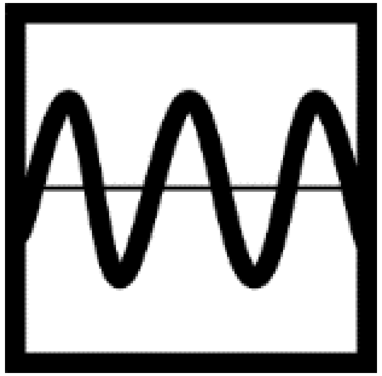


Seismic Load

- Structural member connections
- MEPF
- Architectural systems
- Curtain wall system

MODE OF LOADING: DYNAMIC LOADS

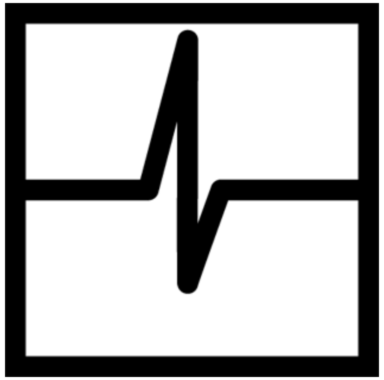
FATIGUE



- Steel failure due to large number of load cycles
- Approving bodies for dynamic loading (DIBt)

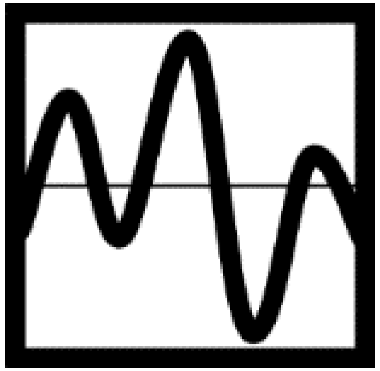
Deutsches Institut für Bautechnik DIBt

SHOCK



- Sudden load increase in milliseconds
- Approving bodies for shock loading - BZS (Swiss authority for Civil Defense)

SEISMIC



- Loading capacity reduced considerably after an earthquake
- Approving bodies for seismic loading (ICC – ES)

ICC ES

POLL #1

WHICH FACTORS AFFECT ANCHOR PERFORMANCE?

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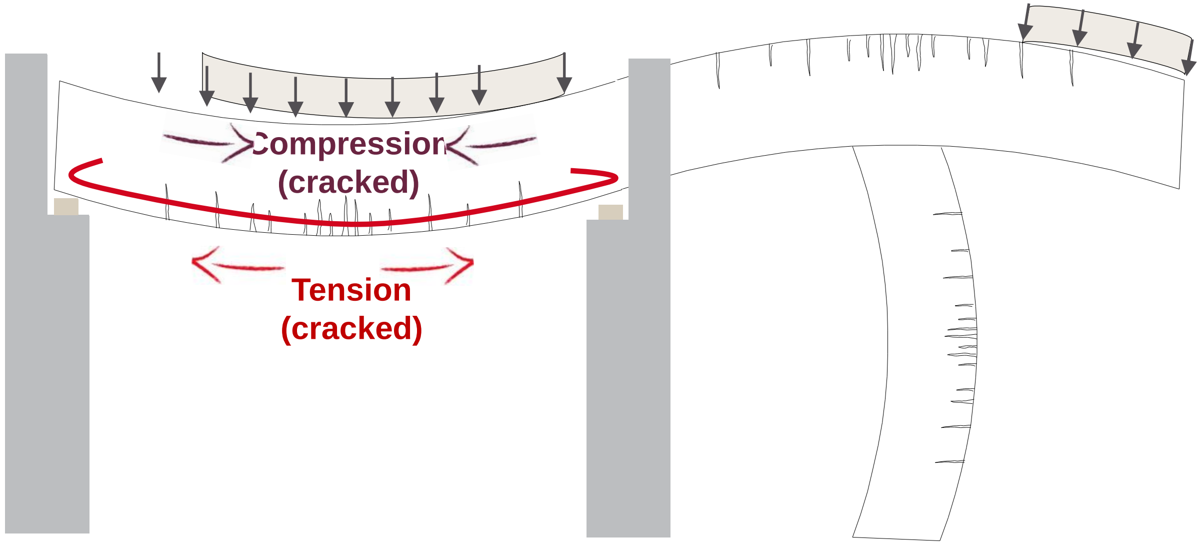
CONCRETE’S TENSILE CAPACITY IS ROUGHLY ~10% OF ITS COMPRESSIVE CAPACITY

- Concrete is not designed to resist **direct tension loads and** will crack when subject to tension stresses.
- Rebar carries the **full tension load** only when concrete cracks.

Reinforced concrete

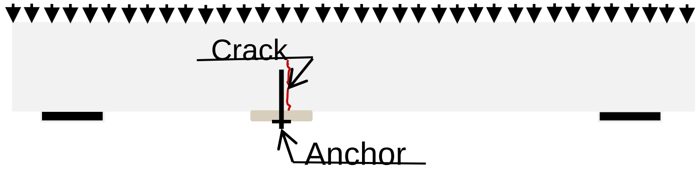
Rebar → **Tension**

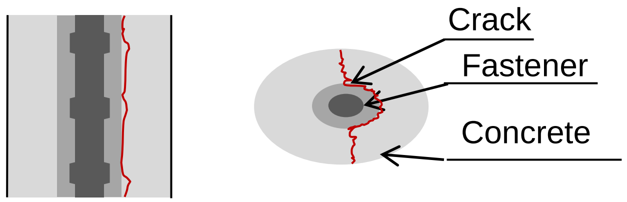
Concrete → **Compression**



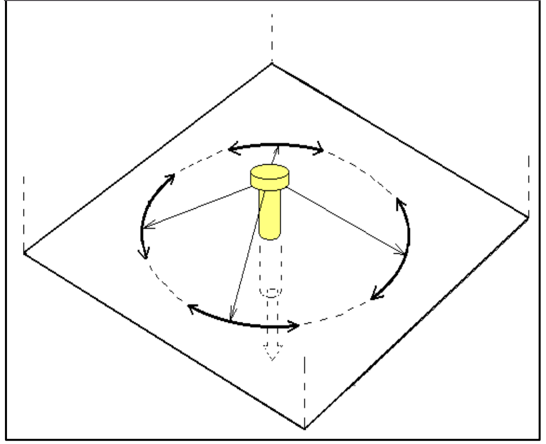
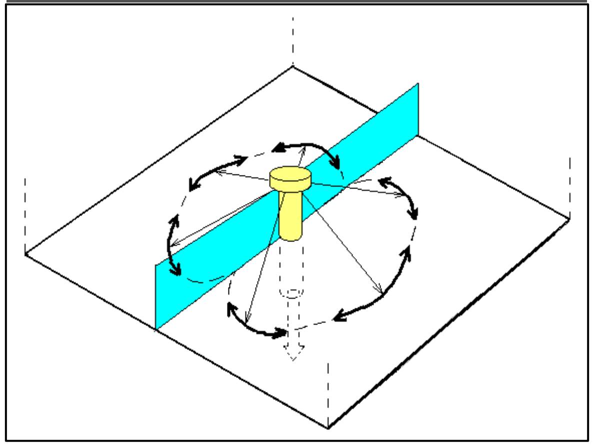
Concrete is reinforced due to prevent large cracks (>0.3mm) in concrete members

WHY DO CRACKS MATTER FOR FASTENINGS?





Once concrete cracks, anchor performance reduces and displacement increases.

Before crack runs through the anchor	After crack runs through the anchor
	
100% of anchor resistance	**<100% of anchor resistance**

Cracks intersecting the anchor position reduce its capacity

TESTS MUST BE CONDUCTED WITH A CONCRETE SLAB WITH CERTAIN CRACK WIDTH UNDER ACI 355.2

Table A.1 Test program

N°	Purpose of test	Concrete	Crack width	Size	d_{cut}	n_{min}	rqd. α	Required for	Section
Resistance to steel failure under tension load									
N1	Steel capacity	-	0	All	-	5	-	All	2.2.1.1
N2	Maximum torque moment	C50/60	0	All					2.2.1.2
N3	Hydrogen induced embrittlement	C50/60	0	All					2.2.1.3
Basic tension tests									
A1		C20/25	0	All		5		Option 1-12	2.2.2.1
A2	Reference tension tests	C50/60	0	All		5		CS: all options as reference for N3 All other: Option 7, 9, 11 [1)]	
A3		C20/25	0,30	All	$d_{cut,m}$	5	-	Option 1-6	
A4		C50/60	0,30	All		5		Option 1, 3, 5 [1)]	
Resistance to pull-out failure									
F1	Maximum crack width and large hole diameter	C20/25	0	s/m/l	$d_{cut,max}$	$5^{3)}$	0,80	Option 7-12	2.2.2.2
			0,50	All				Option 1-6	
F2	Maximum crack width and small hole diameter	C50/60	0	s/m/l	$d_{cut,min}$	$5^{3)}$	1,00	Option 7-12	2.2.2.3
			0,50	All			0,80	Option 1-6	
F3	crack cycling under load	C20/25	0,10-0,30	All	$d_{cut,max}$	$5^{3)}$	0,90	Option 1-6	2.2.2.4
					$d_{cut,m}$			UC, CS Option 1-6	
F4	repeated loads	C20/25	0	m	$d_{cut,m}$	3	1,00	DC, TC, UC Option 1-12	2.2.2.5
		C20/25		All		5		CS Option 1-12	
		C50/60		m		3		DC, TC, Option 7-12	
F5	Robustness of sleeve down type fasteners	C20/25	0	All	$d_{cut,m}$	5	0,80	DC	2.2.2.6
			0,50						
F6	Torqueing in low strength concrete	C20/25	0	All	$d_{cut,max}$	10		CS	2.2.2.7
F7	Torqueing in high strength concrete	C50/60	0	All	$d_{cut,min}$	10		CS	2.2.2.8
F8	Impact screw driver	C20/25	0	All	$d_{cut,max}$	15		CS	2.2.2.9
F9	Robustness to variation in use conditions	C20/25	0	s/m/l	$d_{cut,m}$	$5^{3)}$	0,95	Option 7-12	2.2.4.1
		C20/25	0,30	All			0,80	UC, DC, CS Option 1-6	
		C50/60					0,70	TC Option 1-6	
F10	Robustness to contact with reinforcement	C20/25	0,30	s/m [2)]	$d_{cut,m}$	$5^{3)}$	0,85 0,70 0,60	Option 1-6 UC, CS	2.2.4.2

Crack width

Same tests conducted as with uncracked concrete

- **Basic tension reference tests (0.3mm)**
- **Resistance to pull-out failure (for variable conditions)**
  - When borehole diameter is slightly smaller or bigger. (0.5mm)
  - Robustness of sleeve down type sleeves. (0.5mm)
  - Robustness to variation in use conditions

SPECIAL TESTS

- **Resistance to pull-out failure (for variable conditions)**
  Crack cyclic tests (0.1~0.3mm)
  Robustness to contact with reinforcement (0.3mm)

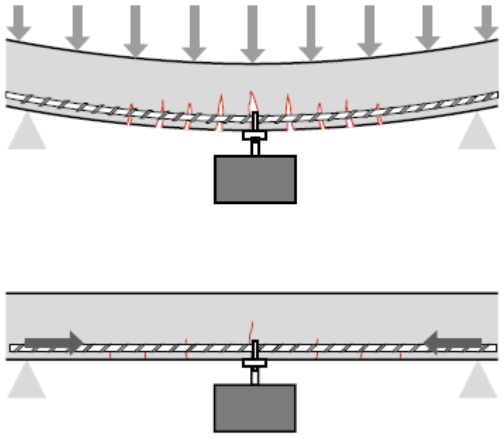
CRACK CYCLIC TEST IS THE MOST CRITICAL TEST AMONG ALL CRACKED CONCRETE RELEVANT TESTS

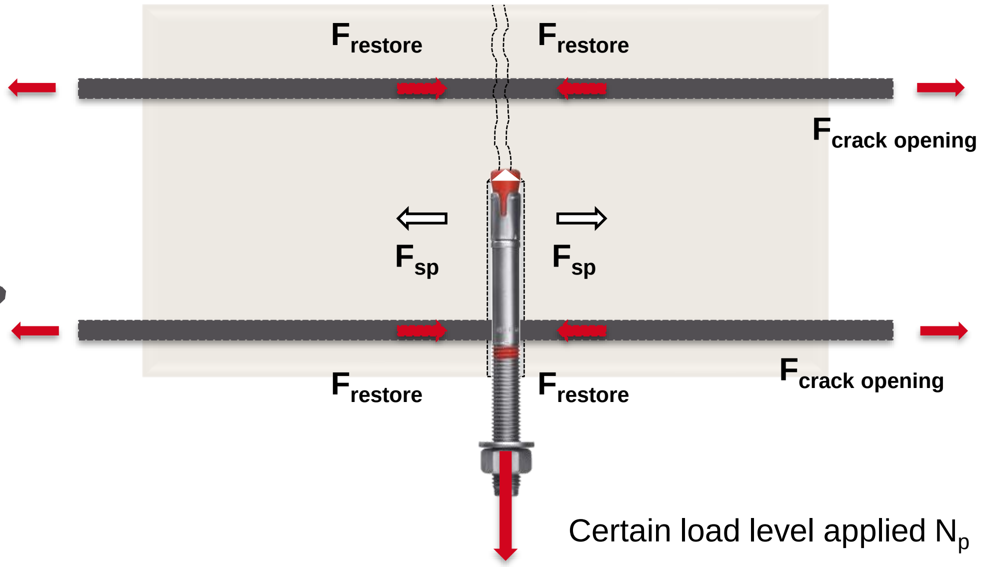
Live loads cause changes in crack width during the service life of the structure

Crack cycling tests

Crack open when live load applied to the base material

Crack close when live load is removed



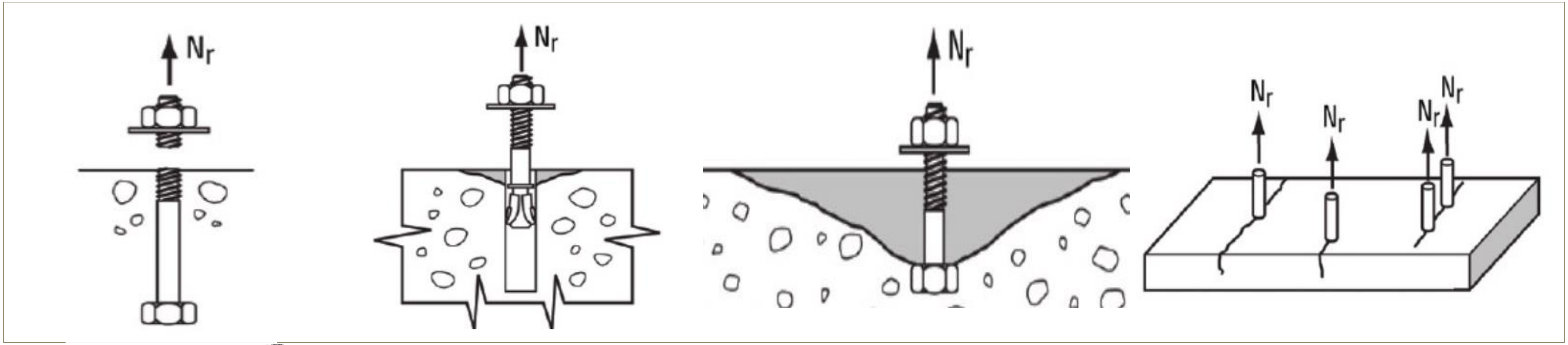


TYPICAL APPLICATIONS WHERE CRACK WIDTH MAY REDUCE BELOW 0.3mm

ON PLAIN CONCRETE	FASTENING ON PRE-STRESSED CONCRETE ELEMENTS		
			
Fastening on a plain concrete pavement	Pre-stressed concrete lining of tunnel	Pre-stressed pile/slab of bridge	Pre-stressed water tank
Unreinforced (Allowable Stress Design, no consideration of cracks)	**Crack width ≤ 0.3mm**		

FAILURES DUE TENSILE LOADING

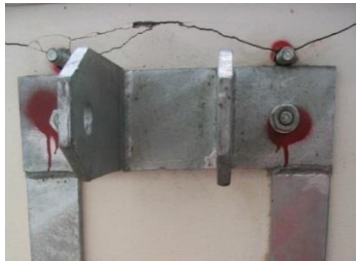
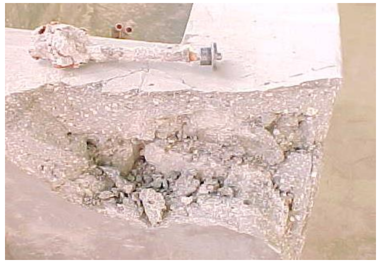
TENSILE LOADING



Steel Failure	Pull-out	Concrete Breakout	Splitting Failure



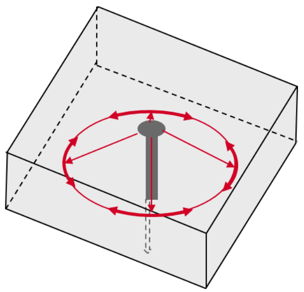


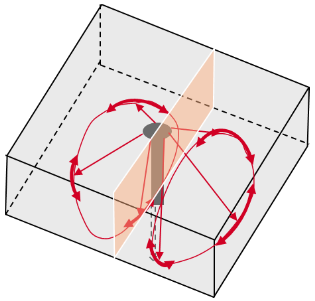
CONCRETE RELEVANT FAILURE MODES WILL HAVE DIFFERENT RESISTANCE IN CRACKED CONCRETE

CONCRETE CONE FAILURE

Before cracks



After cracks



Concrete relevant failure mode will have lower resistance in cracked concrete.

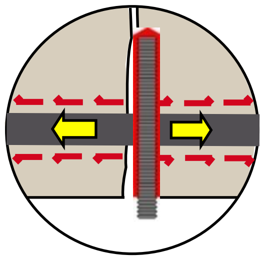
e.g., Concrete cone failure: $N_b = \mathbf{k_c} \cdot \sqrt{f_c'} \cdot h_{ef}^{1.5}$

30% reduction!

k_c before cracks	10.0
k_c after cracks	**7.0**

PULL-OUT FAILURE

Bonded fastener

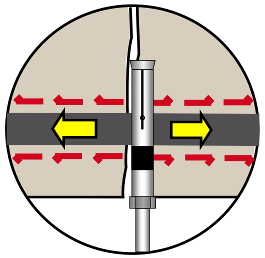


Bond resistance will be reduced.

Example:
RE500V3+M24 HAS-U

- $T_{Rk,uncracked}$ = 13.8 *MPa*
- $\mathbf{T_{Rk,cracked}}$ **= 8.5 *MPa***

Mechanical fastener

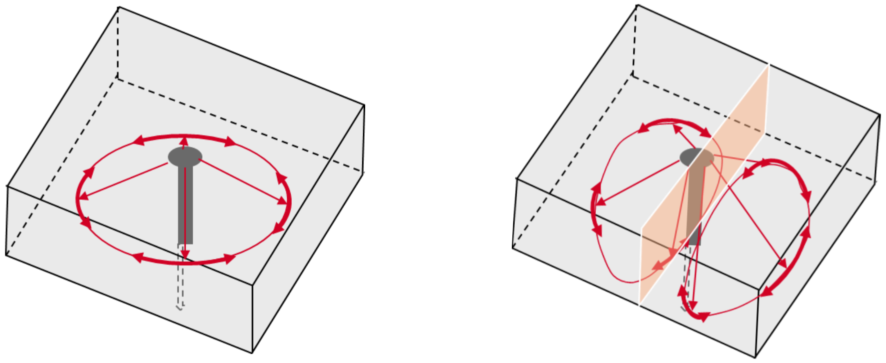


Undercut/headed anchor: the bearing area will be reduced.

Expansion anchor:
Expansion force will be lost, unless follow-up expansion occurs immediately afterwards

CONCRETE CONE BREAKOUT MODE WILL HAVE 30% LESS STRENGTH BY DEFAULT

17.4.2.2 Basic concrete breakout strength of a single anchor in tension in cracked concrete, N_b shall not exceed



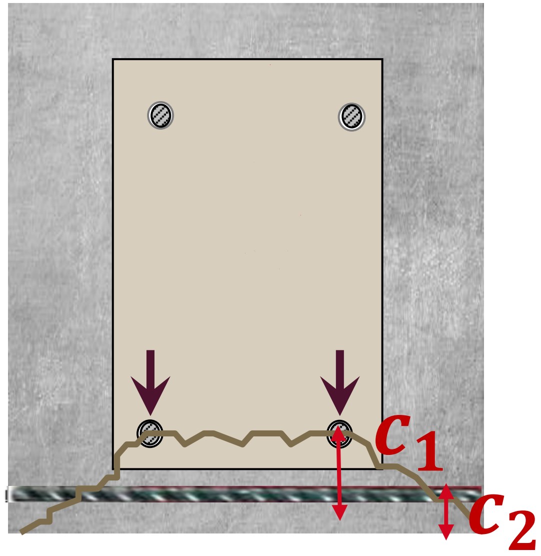
Uncracked **Cracked**

$$N_b = k_c \lambda_a \sqrt{f'_c} h_{ef}^{1.5} \qquad (17.4.2.2a)$$

k_c = 10 for cast-in anchors and **7 for post-installed** anchors.

- k_c for PI anchors may exceed 7 based on product-specific tests in ACI 355.2 or 355.4 (e.g., 7.1 for RE 500 V3)
- k_c upper limit = 10

EDGE FAILURE RESISTANCE REDUCES BY ~40%, BUT SUFFICIENT REINFORCEMENT NEGATES THIS DROP



$$V_{cbg} = \frac{A_{Vc}}{A_{Vc0}} \cdot \psi_{ec,V} \cdot \psi_{ed,V} \cdot \boldsymbol{\psi_{c,V}} \cdot \psi_{h,V} \cdot \boldsymbol{V_b} \qquad (17.5.2.1a)$$

$$\boldsymbol{V_b} = \left(0.6\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right)\lambda_a\sqrt{f_c'}(c_{a1})^{1.5}$$ → for cracked concrete

- $\boldsymbol{\psi_{c,V}} = 1.0$ for anchors without supplementary reinforcement or with edge reinforcement smaller than 13mm
- $\boldsymbol{\psi_{c,V}} = 1.2$ for anchors with edge reinforcement of 13mm or larger between the anchor and edge
- $\boldsymbol{\psi_{c,V}} = 1.4$ for anchors with edge reinforcement of 13mm or larger between the anchor enclosed by stirrups spaced at ≤100mm

ANCHOR SUITABILITY FOR STATIC & SEISMIC CONDITIONS CAN BE FOUND IN ITS EVALUATION REPORT

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DIVISION: 03 00 00—CONCRETE
SECTION: 03 16 00—CONCRETE ANCHORS
DIVISION: 05 00 00—METALS
SECTION: 05 05 19—POST-INSTALLED CONCRETE ANCHORS

REPORT HOLDER:

HILTI, INC.

7250 DALLAS PARKWAY, SUITE 1000
PLANO, TEXAS 75024

EVALUATION SUBJECT:

HILTI HIT-RE 500 V3 ADHESIVE ANCHORS AND POST-INSTALLED REINFORCING BAR CONNECTIONS IN CRACKED AND UNCRACKED CONCRETE

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Reissued 01/2017
This report is subject to renewal 01/2019.

Under 2.0 USES, it shall mention that the system can be used for both anchor design and rebar design.

2.0 USES

The Hilti HIT-RE 500 V3 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are used to resist static, wind and earthquake (Seismic Design Categories A through F) tension and shear loads in cracked and uncracked normal-weight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa) [minimum of 24 MPa is required under ADIBC Appendix L, Section 5.1.1].

PULL-OUT / BOND FAILURE RESISTANCE DEPENDS ON AN INDIVIDUAL FASTENER'S PERFORMANCE

Mechanical Anchor (e.g., HSL4)

Design parameter	Symbol	Units	Nominal anchor diameter					
			M8	M10	M12	M16	M20	M24
Anchor O.D.	d_a	mm in.	12 (0.47)	15 (0.59)	18 (0.71)	24 (0.94)	28 (1.10)	32 (1.26)
Effective min. embedment depth[1]	$h_{ef,min}$	mm in.	60 (2.36)	70 (2.76)	80 (3.15)	100 (3.94)	125 (4.92)	150 (5.91)
Anchor category[2]	1,2 or 3	-	1	1	1	1	1	1
Strength reduction factor for tension, steel failure modes[3]	ϕ	-	0.75					
Strength reduction factor for shear, steel failure modes[3]	ϕ	-	0.65					
Strength reduction factor for tension, concrete failure modes[3]	ϕ	Cond.A	0.75					
		Cond.B	0.65					
Strength reduction factor for shear, concrete failure modes[3]	ϕ	Cond.A	0.75					
		Cond.B	0.70					
Yield strength of anchor steel	f_{ya}	lb/in² (N/mm²)	92,800 (640.0)					
Ultimate strength of anchor steel	f_{uta}	lb/in² (N/mm²)	116,000 (800.0)					
Tensile stress area	$A_{se,N}$	in² (mm²)	0.057 (36.6)	0.090 (58.0)	0.131 (84.3)	0.243 (157.0)	0.380 (245.0)	0.547 (353.0)
Steel strength in tension	N_{sa}	lb (kN)	6,612 (29.4)	10,440 (46.4)	15,196 (67.6)	28,188 (125.4)	44,080 (196.1)	63,452 (282.2)
Effectiveness factor uncracked concrete	k_{uncr}	- (SI)	24 (10)	24 (10)	24 (10)	24 (10)	24 (10)	24 (10)
Effectiveness factor cracked concrete[4]	k_{cr}	- (SI)	17 (7.1)	24 (10)	24 (10)	24 (10)	24 (10)	24 (10)
Modification factor for cracked and uncracked concrete[5]	$\psi_{c,N}$	-	1.00	1.00	1.00	1.00	1.00	1.00
Pullout strength uncracked concrete[6]	$N_{p,uncr}$	lb (kN)	4,204 (18.7)	N/A	N/A	N/A	N/A	N/A
Pullout strength cracked concrete[6]	$N_{p,cr}$	lb (kN)	2,810 (12.5)	4,496 (20.0)	N/A	N/A	N/A	N/A
Steel strength in shear HSL4,-B,-SK	V_{sa}	lb (kN)	7,239 (32.2)	10,229 (45.5)	14,725 (65.5)	26,707 (118.8)	39,521 (175.8)	45,951 (204.4)
Steel strength in shear HSL4-G		lb (kN)	6,070 (27.0)	8,385 (37.3)	12,162 (54.1)	22,683 (100.9)	33,159 (147.5)	43,169 (192.0)
Coefficient for pryout strength	k_{cp}	-	1.0	2.0				
Load bearing length of anchor in shear	ℓ_e	mm (in.)	24 (0.94)	30 (1.18)	36 (1.42)	48 (1.89)	56 (2.20)	64 (2.52)
Tension pullout strength seismic[7] HSL4,-B,-SK	$N_{p,eq}$	lb (kN)	2,810 (12.5)	4,496 (20.0)	N/A	N/A	N/A	14,320 (63.7)
Tension pullout strength seismic[7] HSL4-G		lb (kN)	2,810 (12.5)	4,496 (20.0)	N/A	N/A	N/A	N/A
Steel strength in shear, seismic[7] HSL4,-B,-SK	$V_{sa,eq}$	lb (kN)	4,609 (20.5)	8,453 (37.6)	11,892 (52.9)	24,796 (110.3)	29,135 (129.6)	38,173 (169.8)
Steel strength in shear, seismic[7] HSL4-G		lb (kN)	3,777 (16.8)	6,924 (30.8)	9,824 (43.7)	21,065 (93.7)	24,459 (108.8)	N/A

Adhesive Anchor (e.g., RE 500 V3)

TABLE 19—BOND STRENGTH DESIGN INFORMATION FOR METRIC THREADED RODS IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT (OR HILTI HOLLOW CARBIDE DRILL BIT)[1]

DESIGN INFORMATION			Symbol	Units	Nominal rod diameter (mm)							
					8	10	12	16	20	24	27	30
Minimum Embedment			$h_{ef,min}$	mm (in.)	60 (2.4)	60 (2.4)	70 (2.8)	80 (3.1)	90 (3.5)	100 (3.9)	110 (4.3)	120 (4.7)
Maximum Embedment			$h_{ef,max}$	mm (in.)	160 (6.3)	200 (7.9)	240 (9.4)	320 (12.6)	400 (15.7)	480 (18.9)	540 (21.4)	600 (23.7)
Dry and Water Saturated Concrete	Temperature range A[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	MPa (psi)	8.8 (1,280)	8.8 (1,280)	8.8 (1,270)	8.7 (1,260)	8.6 (1,250)	8.5 (1,240)	8.5 (1,230)	8.4 (1,220)
		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	MPa (psi)	16.7 (2,420)	16.3 (2,370)	16.0 (2,320)	15.2 (2,210)	14.5 (2,100)	13.8 (2,000)	13.2 (1,920)	12.7 (1,840)
	Temperature range B[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	MPa (psi)	6.1 (890)	6.1 (880)	6.0 (880)	6.0 (870)	5.9 (860)	5.9 (860)	5.9 (850)	5.8 (840)
		Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	MPa (psi)	11.5 (1,670)	11.3 (1,630)	11.0 (1,600)	10.5 (1,520)	10.0 (1,450)	9.5 (1,380)	9.1 (1,320)	8.7 (1,270)
	Anchor Category		-	-	1	1	1	1	1	1	1	1
	Strength Reduction factor		ϕ_d, ϕ_{ws}	-	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Reduction for seismic tension			$\alpha_{N,seis}$	-	1	0.92	0.93	0.95	1	1	1	1

Different anchors will have different data!

CRACKS ARE EXPECTED TO ARISE AND PROPAGATE IN SEISMIC SCENARIOS

Seismic Case

Structural response to earthquake may lead to cracks in almost every concrete element

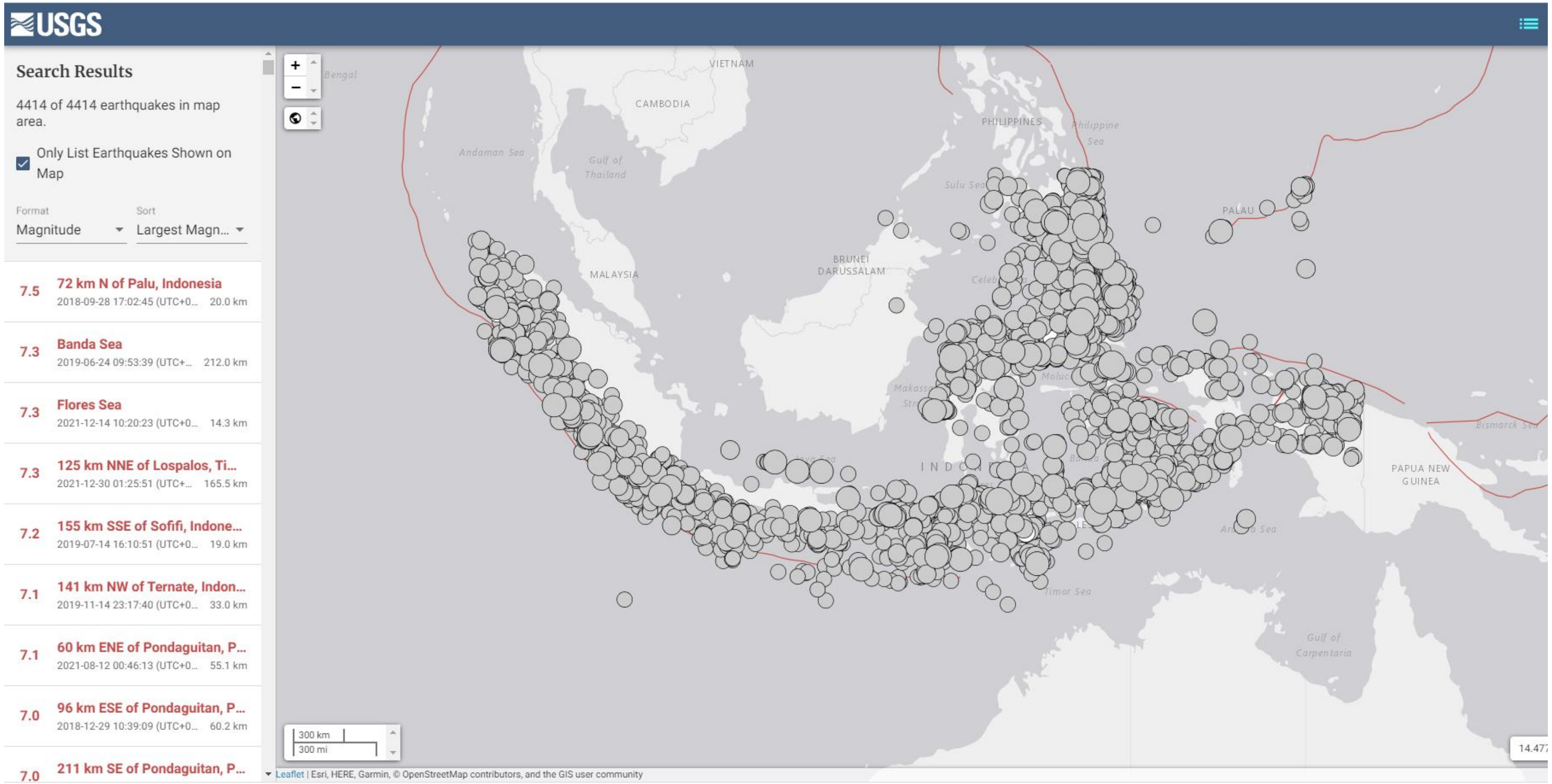
17.2.3.3 Post-installed anchors shall be qualified for earthquake loading in accordance with ACI 355.2 or ACI 355.4. The pullout strength N_p and steel strength in shear V_{sa} of expansion and undercut anchors shall be based on the results of the ACI 355.2 Simulated Seismic Tests. For adhesive anchors, the steel strength in shear, V_{sa}, and the characteristic bond stresses, τ_{uncr} and τ_{cr}, shall be based on results of the ACI 355.4 Simulated Seismic Tests.

POLL #2

DO YOU CONSIDER SEISMIC FORCES IN YOUR DESIGN?

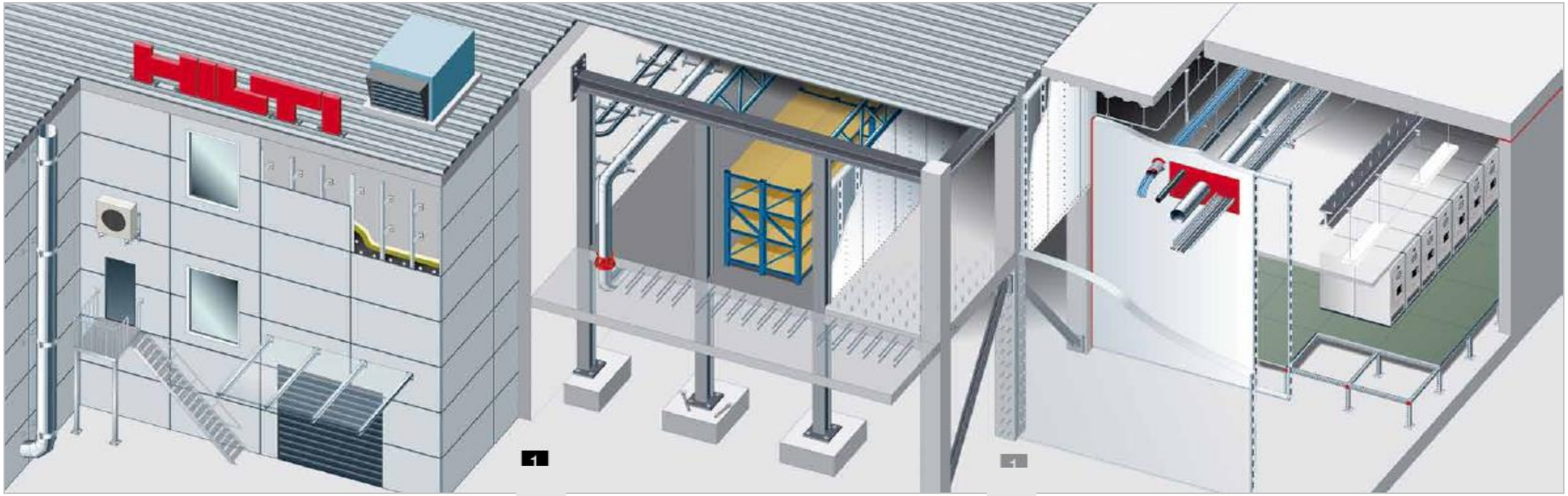
SESSION OVERVIEW

WHY SEISMIC IS IMPORTANT TO DESIGNERS?



WHY SEISMIC IS IMPORTANT TO DESIGNERS?

Seismic strength checks are required for connections involving both structural and non-structural elements.
Structural connections are vital to ensure structural stability and robustness



Seismic-relevant connections within the majority of building types

STRUCTURAL ELEMENTS

Collapse of these elements may result to failure of a part of OR the whole structure.

STRUCTURAL SUPPORT SYSTEMS

Beams

Columns

Truss support

CURTAIN WALL ATTACHMENTS

Collapse of these attachments may result in loss of life and considerable economic, social, and environmental consequences.

NON-STRUCTURAL ELEMENTS

Collapse of these attachments may result in loss of life and considerable economic, social, and environmental consequences.

NON-STRUCTURAL SUPPORT SYSTEMS

Piping

Boilers

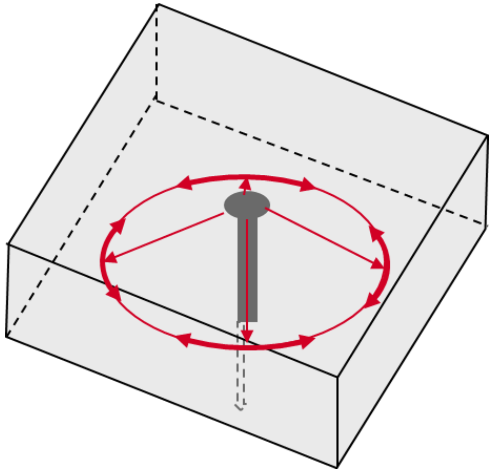
Storage tanks

HVAC

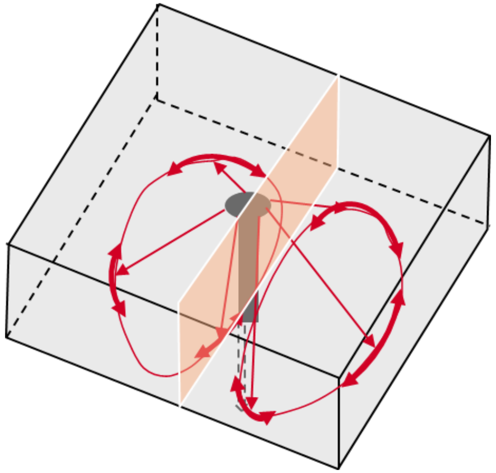
NON-STRUCTURAL ELEMENT FAILURE DURING AN EARTHQUAKE

CONCRETE CRACKS LEAD TO SIGNIFICANT CHANGES IN ANCHORING LOAD TRANSFER AND PERFORMANCE

As cracks intersect the anchor the load transfer will be changed due to an ***unsymmetrical distribution of the anchor loads.***



stress distribution in non-cracked concrete

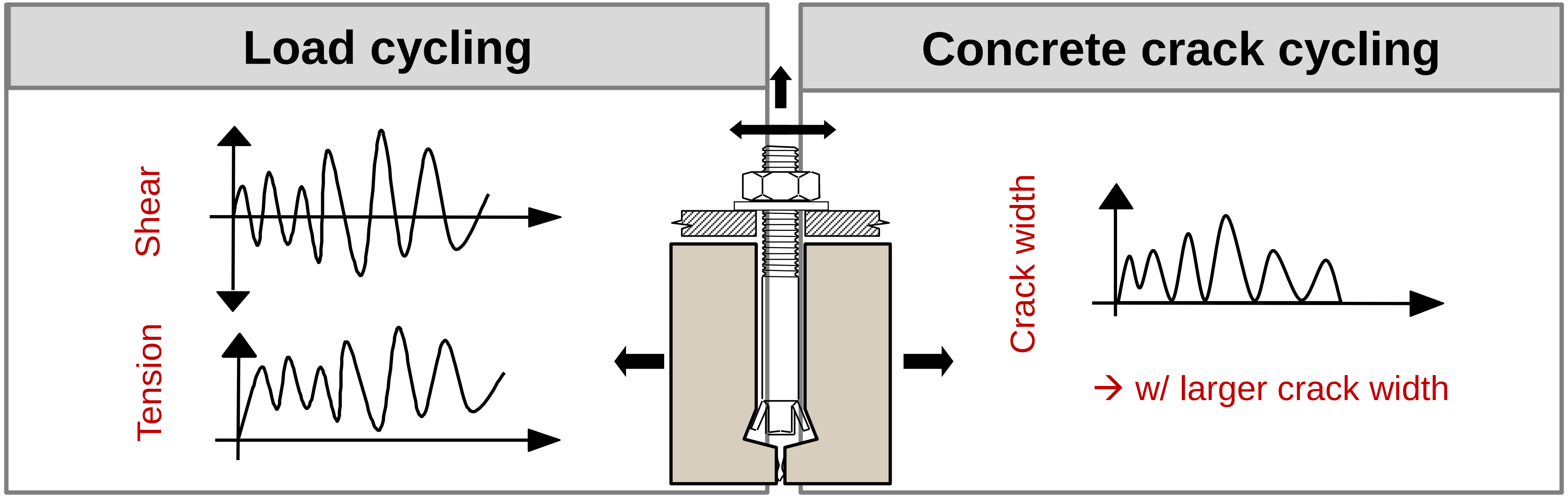


stress distribution in cracked concrete

Anchor's fitness in cracks is the starting point for assessing its seismic performance

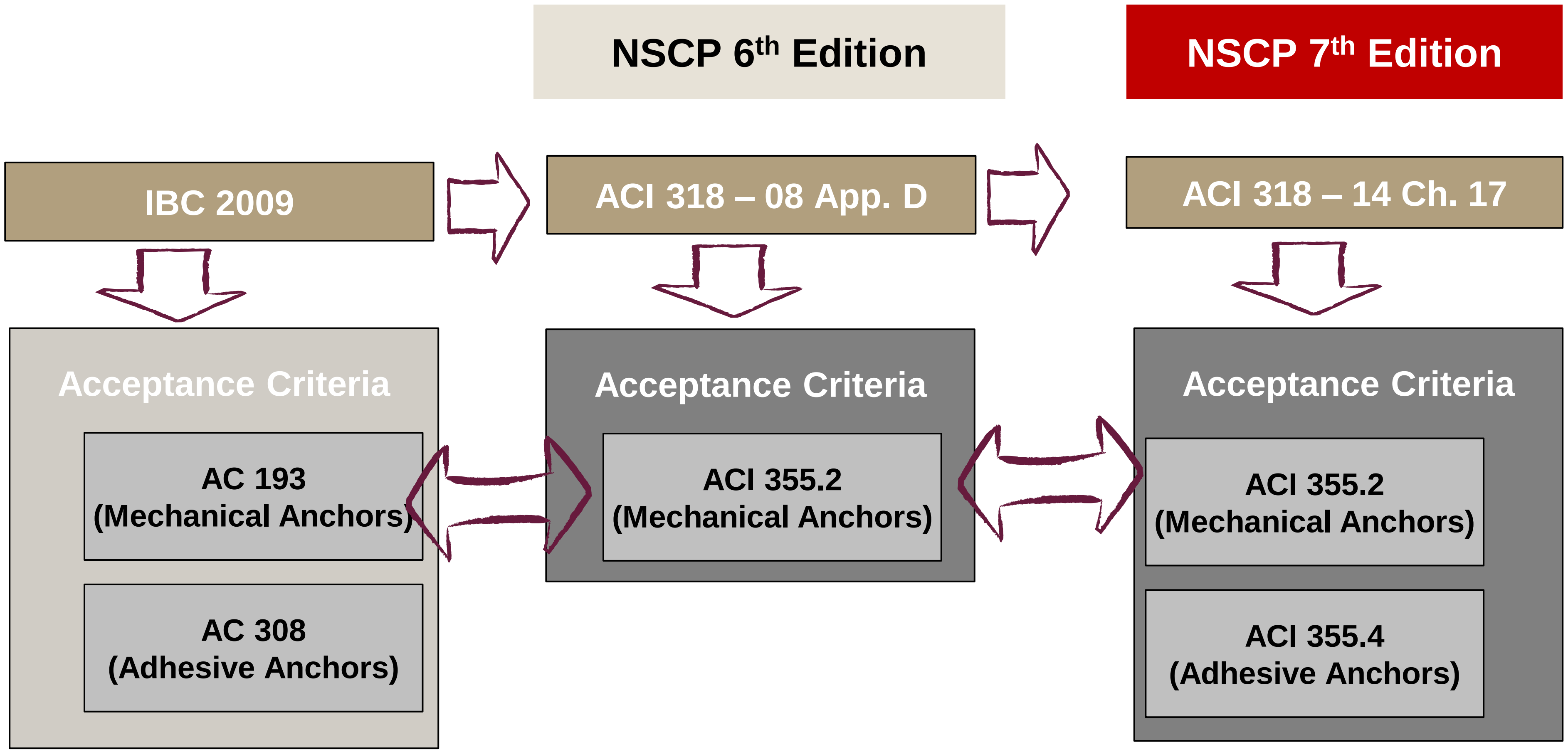
SEISMIC LOADING INDUCES EXTREME CONDITIONS IN THE FASTENINGS, MUCH ABOVE CONCRETE CRACKS

During an earthquake, the anchors will need to cope with:



Specific tests regulated by ACI 355.2 or 355.4 enable a proper assessment of the anchor

NEW ACI 318-14 ANCHORAGE TO CONCRETE DESIGN STANDARDS

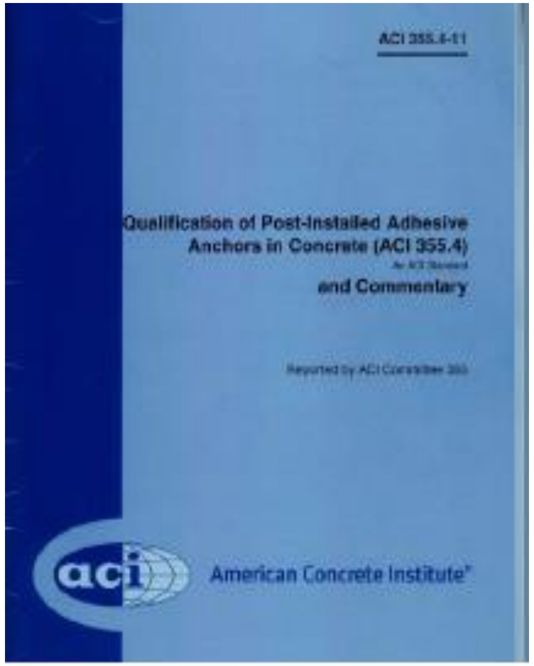


NSCP

ANCHOR SEISMIC DESIGN REQUIRES A SET OF TESTING, APPROVAL DOCUMENT AND DESIGN REGULATIONS

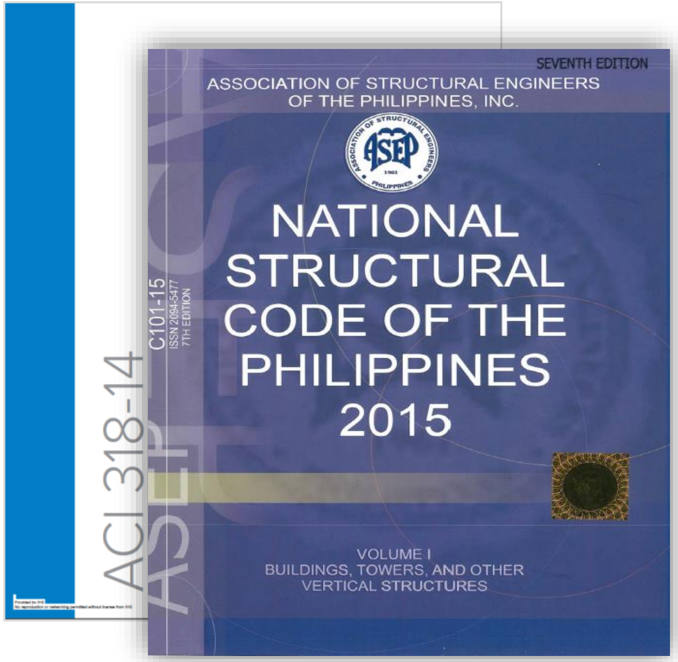
Seismic design for post-installed anchors are available in US/PH frameworks

Qualification	Technical data	Design method



ACI 355.4 with
ICC-ES AC193/AC308

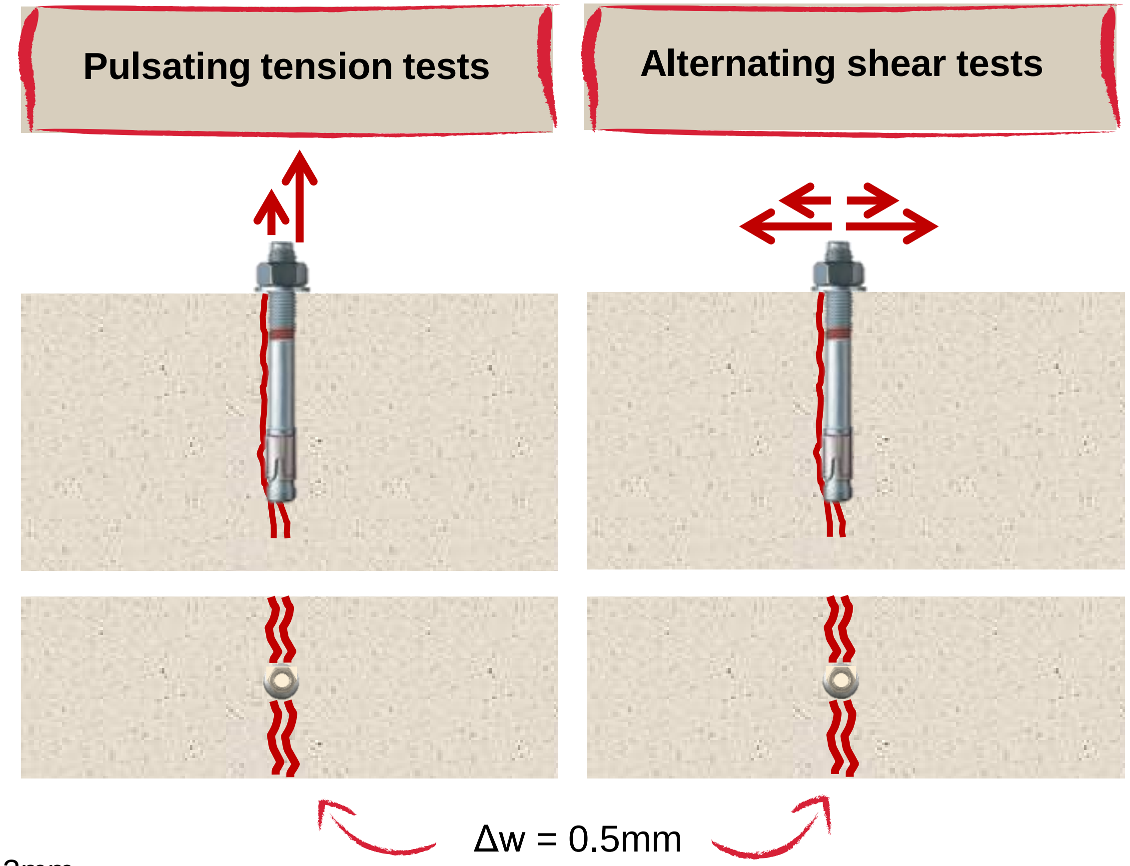
ICC-ES
Evaluation Service Report (ESR)



ACI 318-14
Chapter 17/**NSCP 7th Edition** Chapter 4
Sec. 417

ACI 355.2 & 355.4 CATEGORIES - TESTING PROCEDURES FOR POST-INSTALLED MECHANICAL & CHEMICAL ANCHOR

Seismic approval → simulate earthquake load cycling in 0.5mm stationary cracks



= Seismic Design Category

B, C, D, E, F

Note: For Static approval crack width 0.3mm

SEISMIC APPROVED ANCHORS ARE REQUIRED FOR SEISMIC DESIGN CATEGORIES C TO F

These are the provisions are presented in the ASCE7 → ASCE 7 is the regulation that defines the seismic loads

All elements (structural and non-structural)		
Seismic Design Category (SDC)	**Importance Class II or III**	**Importance Class IV**
A	No seismic requirements	
B		**ICC-ES seismic approved**
C - F	**ICC-ES seismic approved**	

Importance class IV as per ASCE 7: Buildings whose integrity is of vital importance for civil protection such as hospitals, fire stations, power plants, etc.

ANCHOR STRENGTH IS DERIVED FROM THE ICC-ESR'S VALUES AND CALCULATED VALUES FROM ACI 318

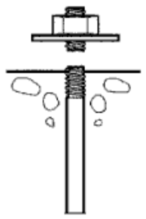
ACI 318-14 Chapter 17/**NSCP 7th Ed. Chapter 4 Sec 417 Strength Design**:

Tensile Loading

- **ϕN_{sa} = Design Steel Strength in Tension**

$$\phi_{\text{steel}}(n \cdot N_{sa}) \quad \phi_{\text{steel}} N_{sa}$$

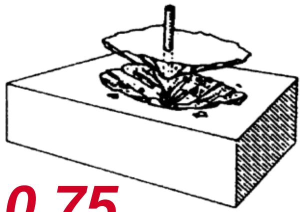
Given in the ESR relevant design table



- **ϕN_{cb}, ϕN_{cbg} = Design Concrete Cone Breakout Strength in Tension**

$$\phi_{\text{concrete}} N_{cbg} = \phi_{concrete} \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \times \phi_{seismic}$$

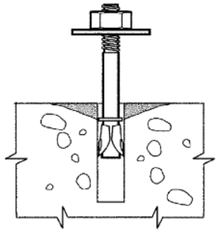
$\phi_{seismic}$ **= 0.75**



- **ϕN_a, ϕN_{ag} = Design pullout/bond strength in tension**

$$\phi_{\text{bond}} \cdot N_{ag} = \phi_{bond} \cdot \frac{A_{Na}}{A_{Na0}} \cdot \psi_{ed,Na} \cdot \psi_{g,Na} \cdot \psi_{ec,Na} \cdot \psi_{p,Na} \cdot N_{a0} \times \phi_{seismic}$$

$\phi_{seismic}$ **= 0.75**



*Images taken from ACI 318-14

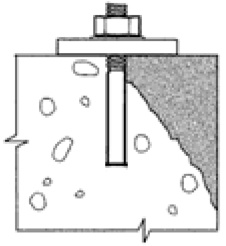
ANCHOR STRENGTH IS DERIVED FROM THE ICC-ESR'S VALUES AND CALCULATED VALUES FROM ACI 318

ACI 318-14 Chapter 17/**NSCP 7th Ed. Chapter 4 Sec 417**

Strength Design:

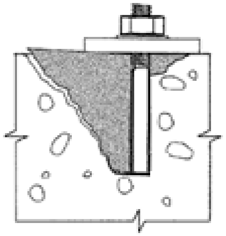
- **ϕV_{cb}, ϕV_{cbg} = Design concrete edge breakout strength in shear**

$$\phi_{concrete} V_{cbg} = \phi_{concrete} \frac{A_{Vc}}{A_{Vc0}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} V_b$$



- **ϕV_{cp}, ϕV_{cpg} = Design pryout strength in shear**

$$\phi_{concrete} V_{cpg} \quad \textit{with} \quad V_{cpg} = \min \left| k_{cp} N_{ag} ; k_{cp} N_{cbg} \right|$$



*Images taken from ACI 318-17/NS

No specific reduction factor required for pry-out and concrete edge breakout

DESIGN CONSIDERATIONS FOR STATIC AND SEISMIC CONDITION S

STATIC LOADING	SEISMIC LOADING

- **Concrete Cone Failure**

✓ 30% Reduction in anchor resistance for cracked concrete

- **Edge failure**

✓ Reduced by 40%, but consideration of supplementary rebar permitted if present

- **Pull-out Failure**

- **Design Concrete Breakout Strength in Tension**

$$\phi_{\text{conc}} N_{cbg} = \varphi_{concrete} \frac{A_{Nc}}{A_{Nc0}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \;\; \boldsymbol{x} \;\; \phi_{seismic}$$

- **Design pullout/bond strength in tension**

$$\phi_{bond} \cdot N_{ag} = \varphi_{bond} \cdot \frac{A_{Na}}{A_{Na0}} \cdot \psi_{ed,Na} \cdot \psi_{g,Na} \cdot \psi_{ec,Na} \cdot \psi_{p,Na} \cdot N_{a0} \;\; \boldsymbol{x} \;\; \phi_{seismic}$$

$$\phi_{seismic} = 0.75$$

POLL #3

HOW DOES THE STRENGTH REDUCE IN SEISMIC SCENARIOS?

SESSION OVERVIEW

1. Factors Influencing Anchor Performance
2. Static Anchor Design
   a) Anchor Performance Assessment
   b) Design Calculations for Static
3. Influence of Seismic in Anchor Design
   a) Earthquake Influences in the Anchorage Resistance
   b) Suitability Testing and Anchor Design
4. **Fastening Systems approved for Static and Seismic**
5. Conclusion and Recommendation

SEISMIC APPROVED ANCHORS COMPLIANT WITH ACI 355 (CHEMICAL AND MECHANICAL ANCHORS)

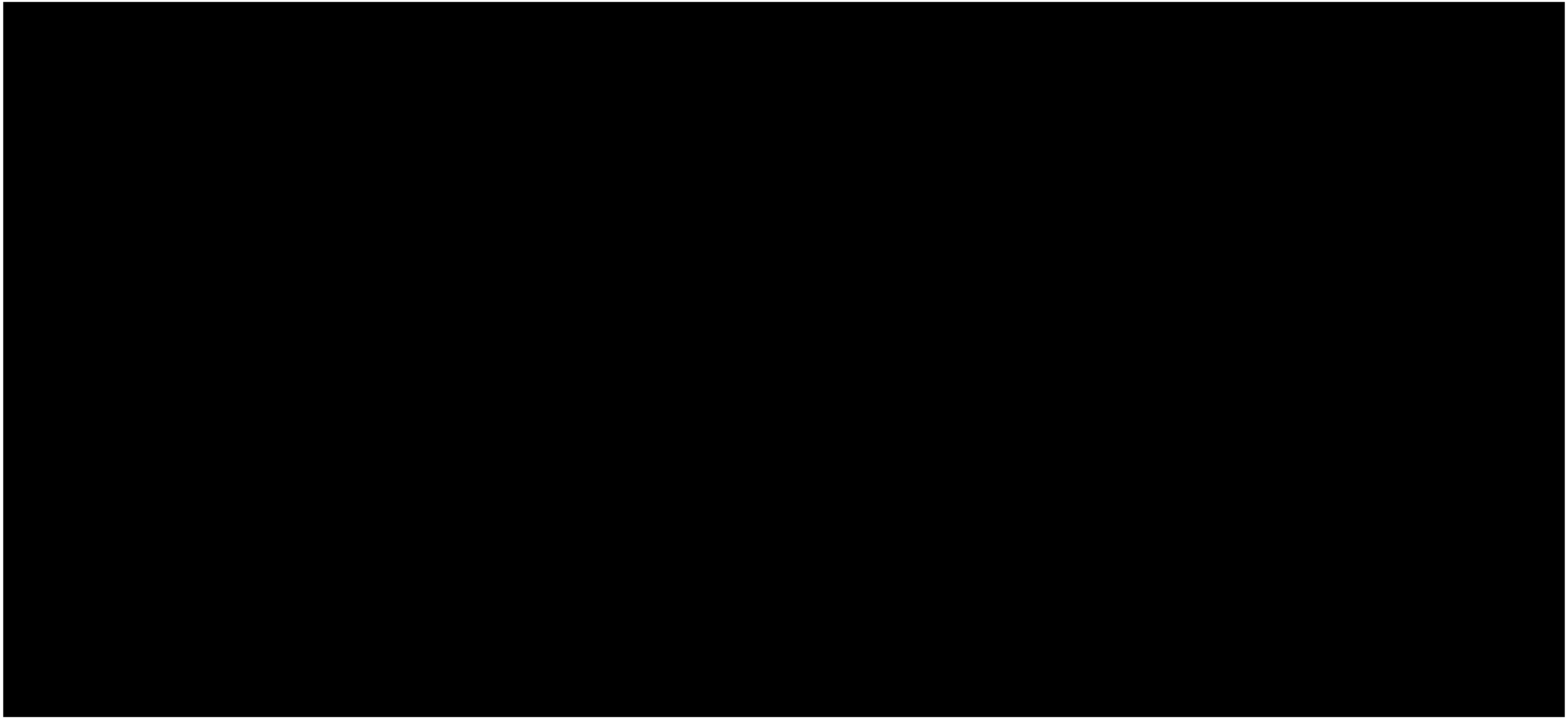






Product	HY 200-R V3 + HAS-U (NEW!)	RE 500 V3 + HAS-U	HVU2 + HAS-U	HSL4	HST3	HUS4 (NEW!)	RE 100 + HAS-U
Description	The high-performance Fast Cure anchor for different design needs. Non cleaning solution with HIT Z rod for extra peace of mind under SafeSet	The high-performance Slow Cure anchor that works for tough jobsite conditions (underwater, M30+ fasteners, oversized boreholes, diamond coring, …)	Pre-packed high performance Fast Cure anchor for easy installation with faster loading and without waste	High-performance product for larger jobs or when appearance combined with performance matters.	The high-performance product you are familiar with for different design needs and extra peace of mind under SafeSet and TraceFast	The productive and flexible solution when speed matters with flexibility in design.	A cost-effective Slow Cure anchor for a wide range of jobsite conditions
Type	Fast-Cure Hybrid Mortar	Slow-cure Epoxy Mortar	Adhesive Capsule	Heavy-duty Wedge Anchor	Expansion Anchor	Screw Anchor	Slow-cure Epoxy Mortar
Approval Test Reports	ICC, Cracked, **Seismic**, 100 yrs	ICC, Cracked, **Seismic**, 100 yrs	ICC, Cracked, **Seismic**	ICC, Cracked, Seismic	IAPMO approval with ACI Compliance (ACI 318), Cracked, Seismic	ETA, Cracked, Seismic	ICC, Cracked, Seismic
Base Material	Dry, Wet, Water-filled Concrete	Dry, Wet, Water-filled concrete	Dry, Wet Concrete	Dry Concrete	Dry Concrete	Dry Concrete	Dry, Wet Concrete
Working Time (30 °C)	6 min	15 min	-	-	-	-	12 min
Curing Time (30 °C)	1 hour	5 hours	5 min	-	-	-	8 hours

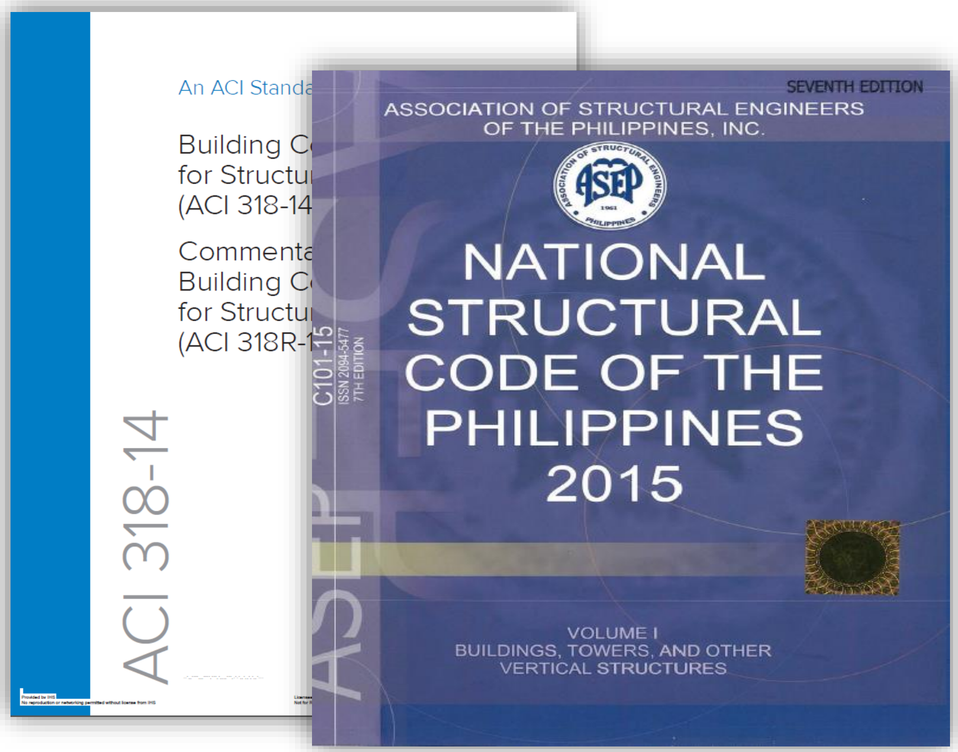
CRACK RETRACTION EFFECT → SEISMIC SOLUTION

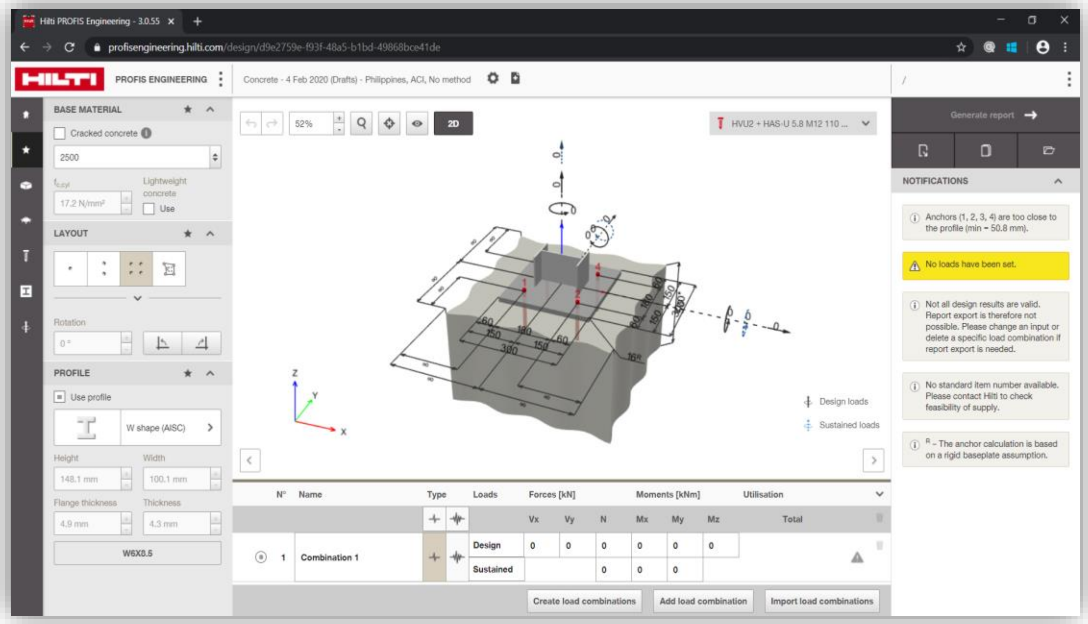


CONCLUSION AND RECOMMENDATIONS

- ACI 318 considers that cracks will occur in concrete.
- This is the starting point for assessing performance in seismic conditions.
- Anchors having an approval for seismic are suitable for static conditions too, but not the other way around.
- Considering the high seismicity of the Philippines and the anticipation of the “BIG ONE”, seismic strength design is vital not only for structural components but also for non-structural elements
  – Especially relevant for buildings whose integrity is of vital importance for civil protection.
- As world leader in fastening technology, Hilti offers you a mix of hardware, software, and services that enable you to design for static and seismic conditions to national and international standards.

ANCHOR DESIGN RESOURCES AVAILABLE





Hand Calculation using ACI 318-14 Chapter 17/**NSCP 7th Ed. Chapter 4 Sec 417**

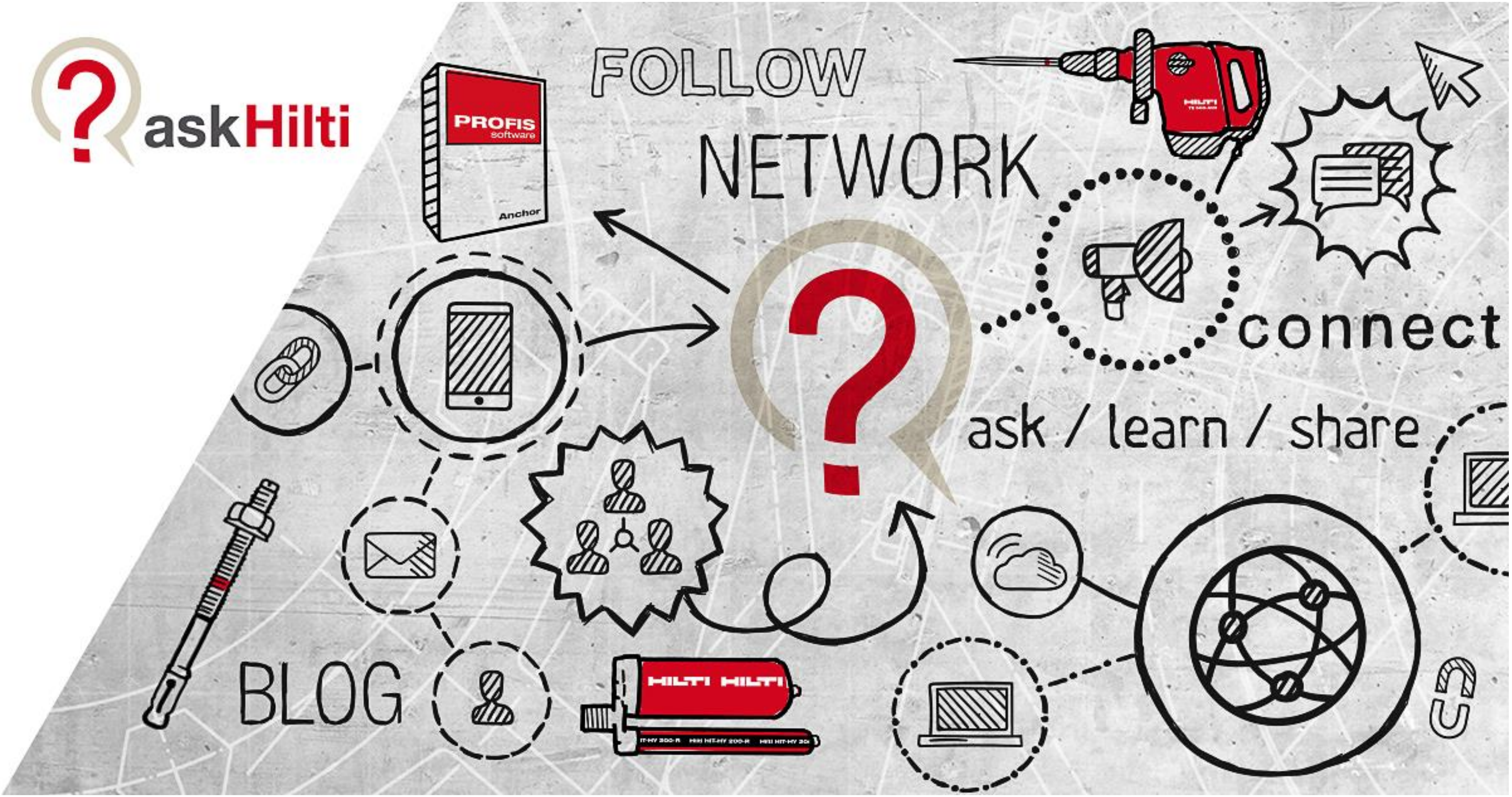
- Design of Anchor System Using ACI 318 /NSCP 2015 7th Edition (Philippines) Anchoring-to-Concrete Provisions

Hilti's PROFIS Engineering Software

- Design Software Utilizing ACI 318 Anchoring-to-Concrete Provisions

POLL #4

WOULD YOU LIKE TO KNOW MORE ON THIS TOPIC?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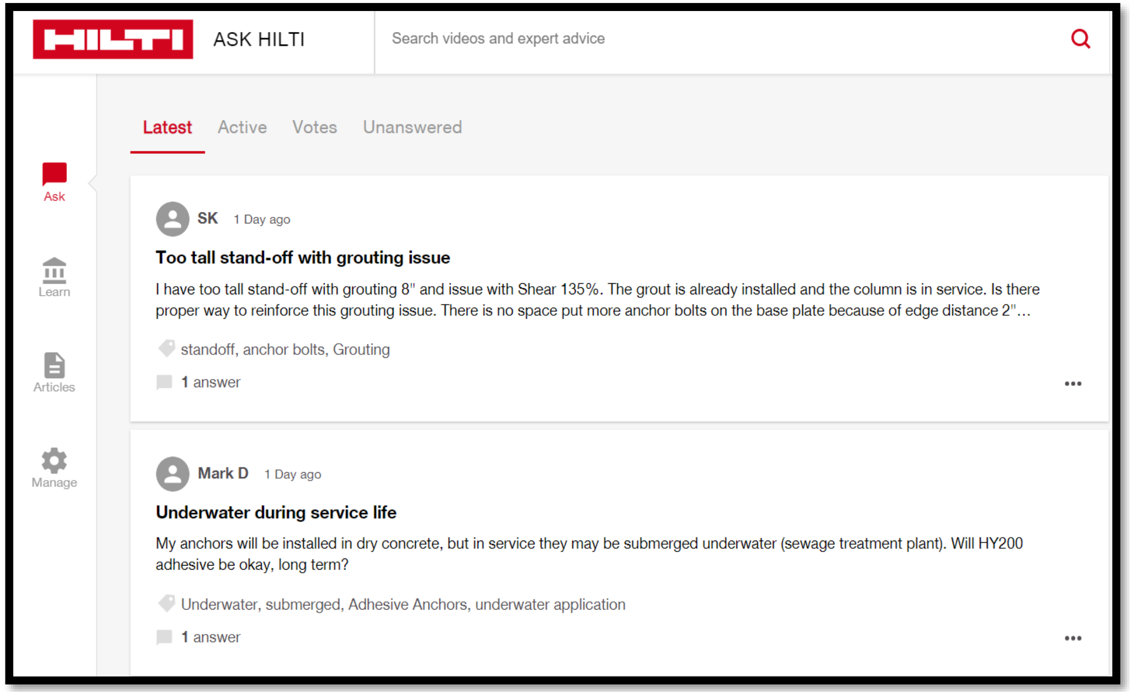
Expert Advice

question and answer forum



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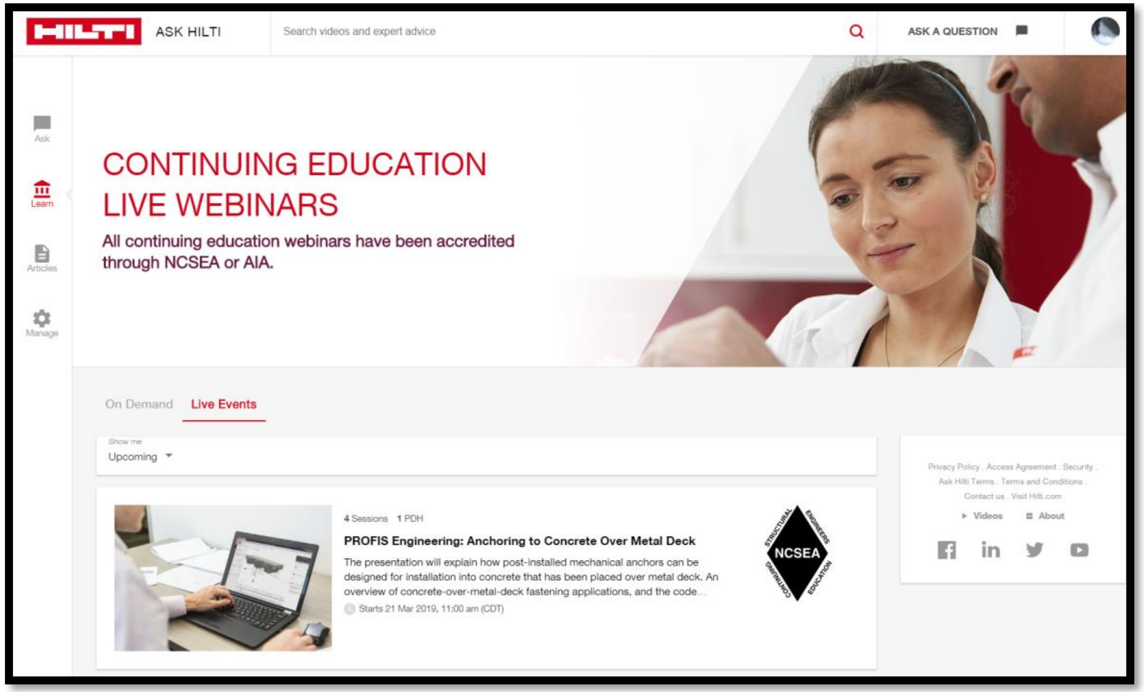

Q&A SESSION

THANK YOU

Engr. Richmond T. Olaya
Technical Marketing Manager

Amol Singh

9F Robinsons Cyberscape Beta
(bet) Ruby and Topaz Road
Ortigas Avenue, 1605 Pasig City

+632 784 7100 |
Richmond.Olaya@hilti.com
www.hilti.com.ph