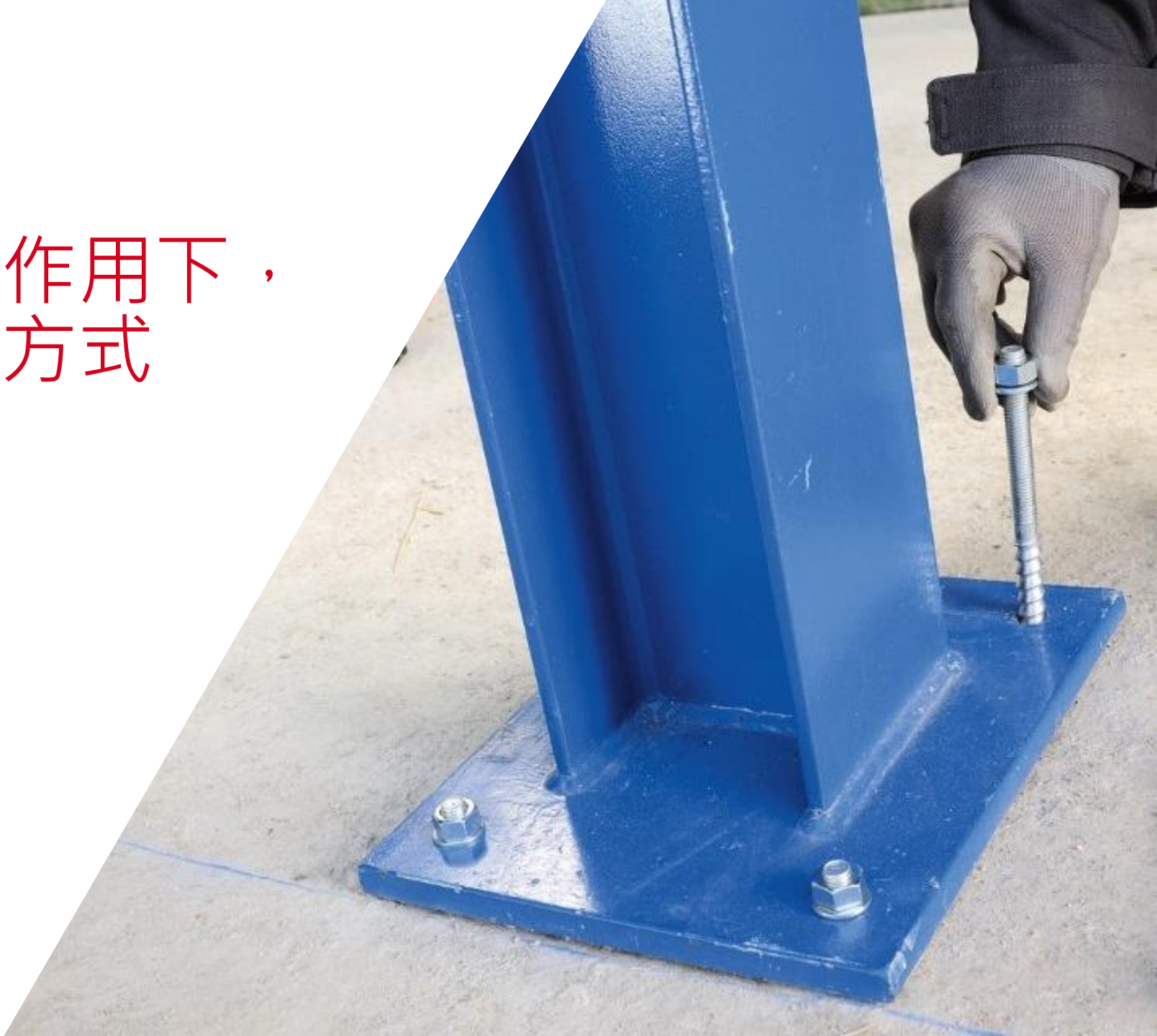
在靜荷載和地震力作用下，可靠的混凝土緊固方式

Michael Roessle
Hilti HQ

3rd November 2023

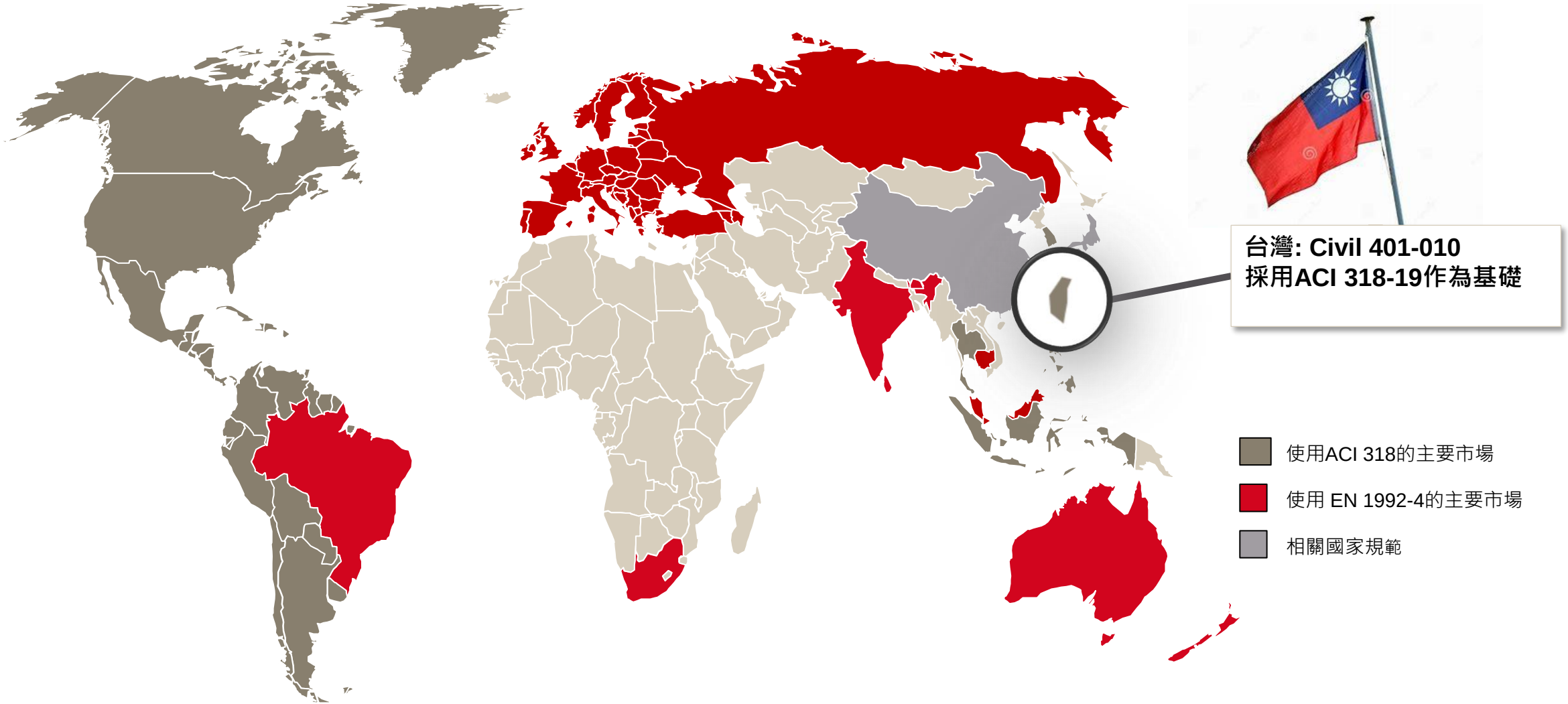


議程

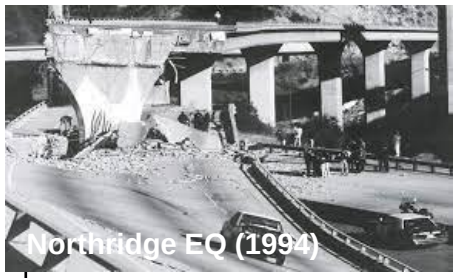
- **介紹**
- 最關鍵的影響?
- 產品認證
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

過去的事故告訴我們，在提高緊固件的安全方面還有進步空間

為了提高緊固件的安全性，歐洲和美國制定了設計規範，並得到廣泛的應用



美國的錨固規範是在過去 50 年不斷研究的基礎上制定的



ICBO, BOCA, SBC merge to form ICC

區域建築規範 NBC (BOCA), UBC (ICBO), SBC (SBCCI)

統一建築規範 (UBC) 變更為 **國際建築規範 (IBC)**

1975 1980 1990 1995 2000 2005 2010 2015 2020 2025

TVA 設計規範

ASTM E488

ICBO-ES AC01 後置式錨栓

ACI 349 附錄. B 45-度 椎體

ASTM E1512

AC58 化學錨栓

ACI 349-01 App. B w/CCD

AC01 機械錨栓

ACI 318-02 App. D w/CCD

ICC-ES AC193 混凝土中的機械錨栓

ACI 355.2-01 機械錨栓

ICC-ES AC308 混凝土中的化學錨栓

ACI 318-11 添加化學錨栓

ACI 355.4-11 化學錨栓

ACI 318-14 錨栓至規範主體 (Ch.17)

AC308 添加了後置式加固

ACI 318-19 添加剪力吊耳和螺旋錨栓

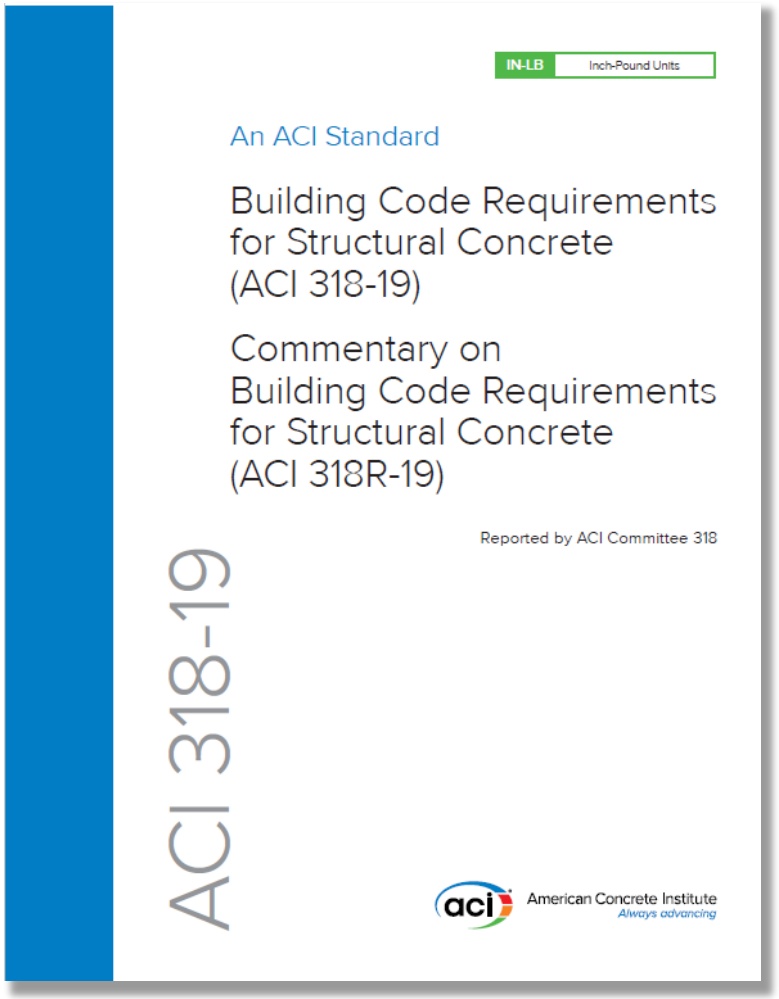
AC58/AC0 大更新

ACI 355.2 和 355.4 更新

AC308 防火

ACI 318-25 下一版更新:

ACI 318 包含了基於混凝土的錨固並引用 ACI 355.2 和ACI 355.4中的測試和評定



Chapter 17 Anchoring to Concrete

Chapter 25 Reinforcement Details

議程

- 介紹
- **最關鍵的影響?**
- 產品認證
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

對工程師來說最重要的是什麼？
實現安全可靠的完整解決方案

設計規則

ACI 318 第 17 章或第 25 章等標準規定了特定應用的規則

產品認證

由 ICC-ES 或 IAPMO 等機構發佈的評估報告顯示了根據 ACI 355.2 或 ACI 355.4 測試和評估的產品性能

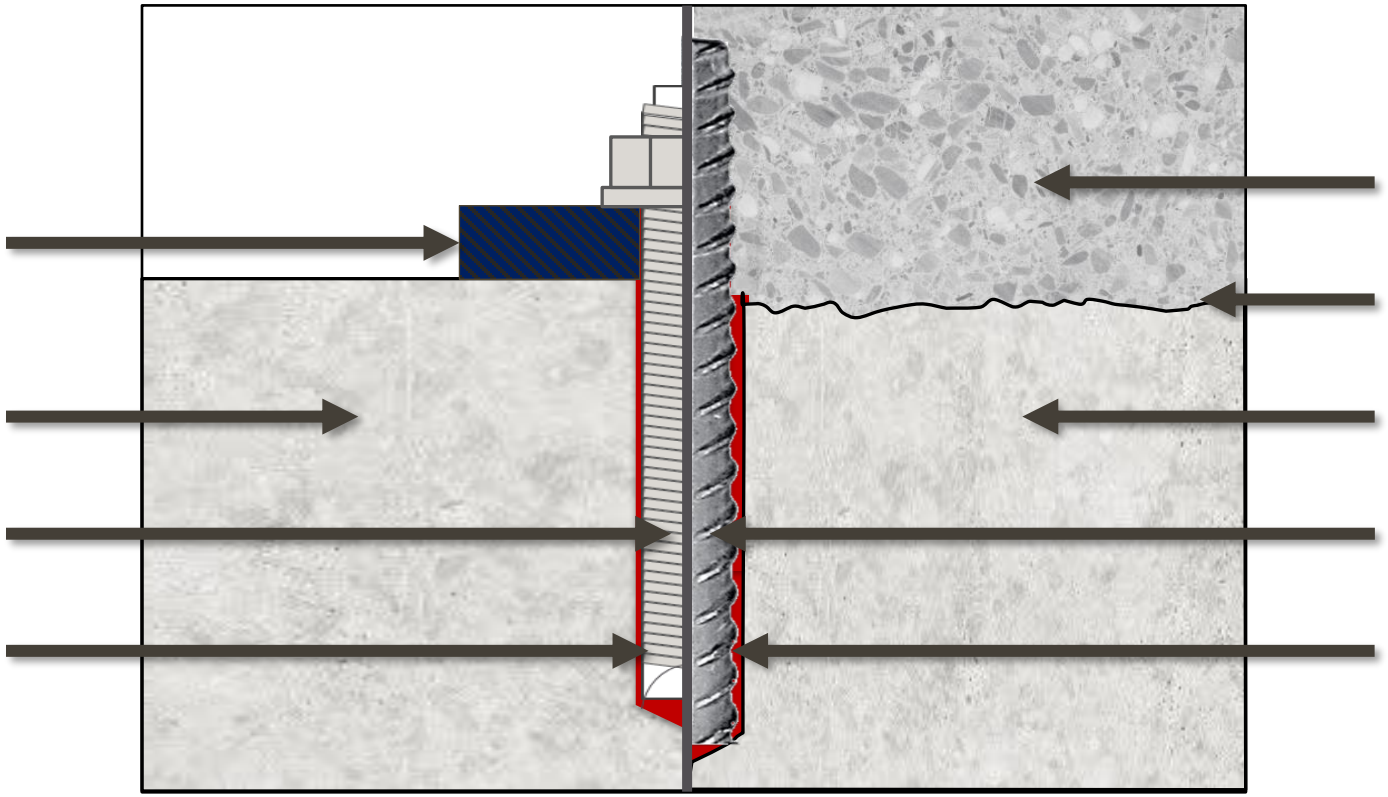
安裝品質

通過理論和實踐培訓，確保按照製造商的使用說明進行正確安裝和檢查，並進行現場測試。

對不同的應用採用不同的規則

後置錨栓連接

後置植筋連接



鋼與混凝土

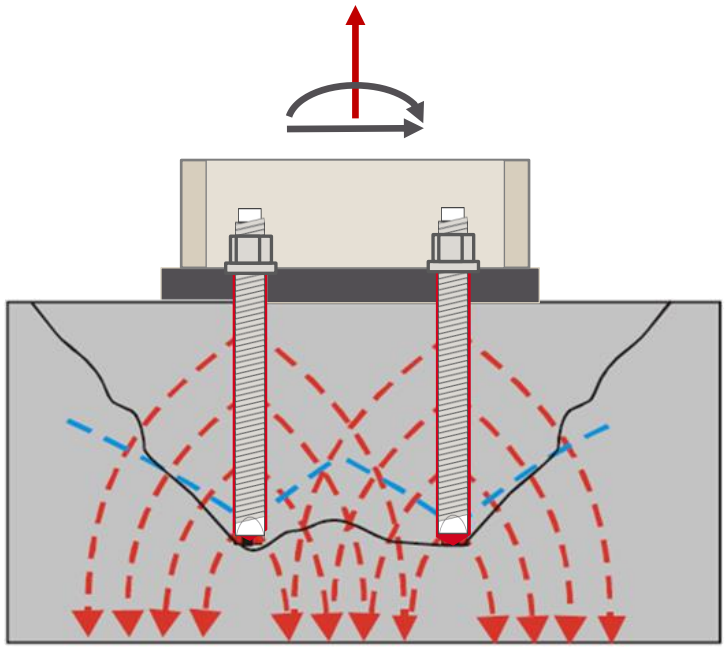
將鋼底板固定在混凝土上

新舊混凝土接合

擴展現有混凝土構件

對於不同的應用，適用不同的規則

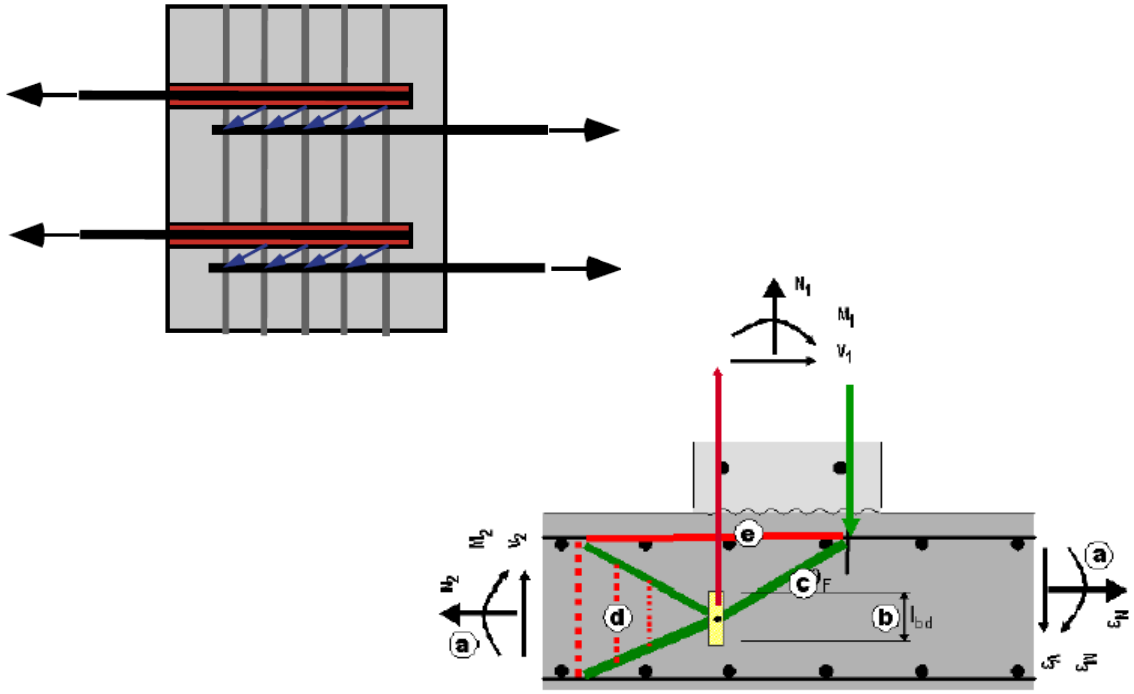
後置錨栓連接



根據 ACI 318 第 17 章進行設計

(混凝土錐狀乘載力)

後置植筋連接

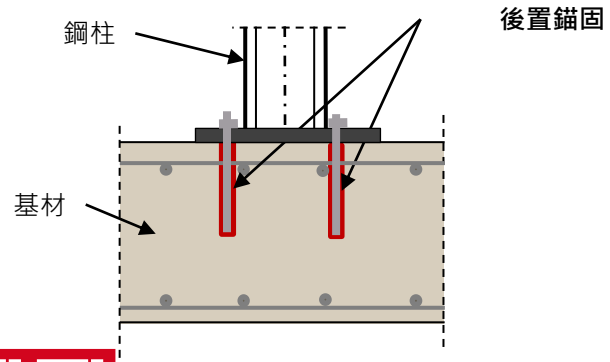


根據 ACI 318 第 25 章進行設計

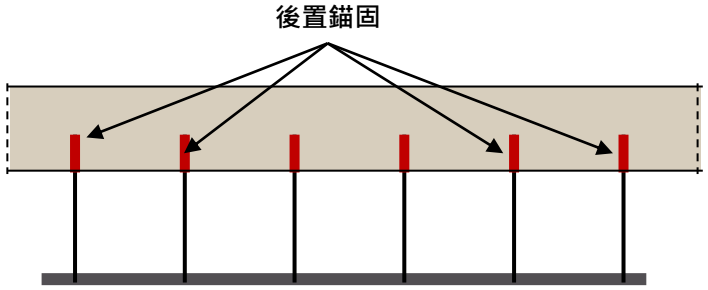
(搭接、端部錨固)

為什麼需要後置錨固的連接？

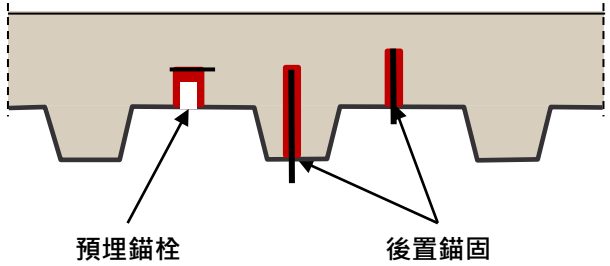
底板應用



多冗性緊固



其他 ： 金屬甲板 及 空心板



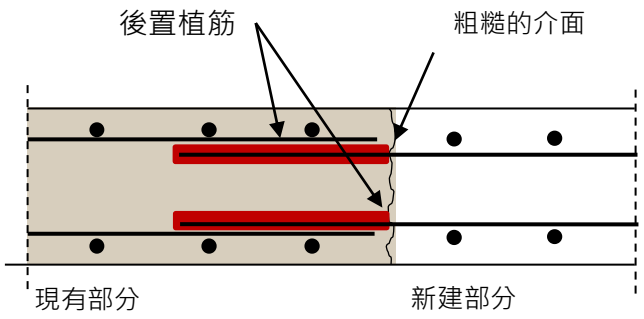
為什麼需要後置植筋的連接？

擴建現有建築

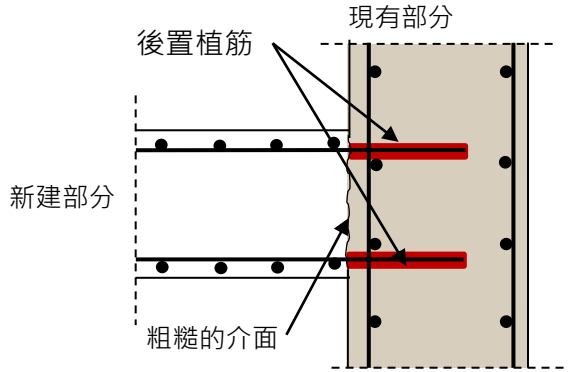
提高施工現場的生產率

強化結構

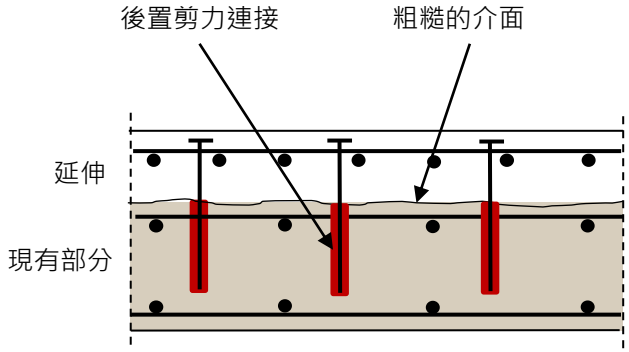
搭接



末端錨固



混凝土增厚



設計和選擇適合應用的緊固件最重要的因素是什麼？

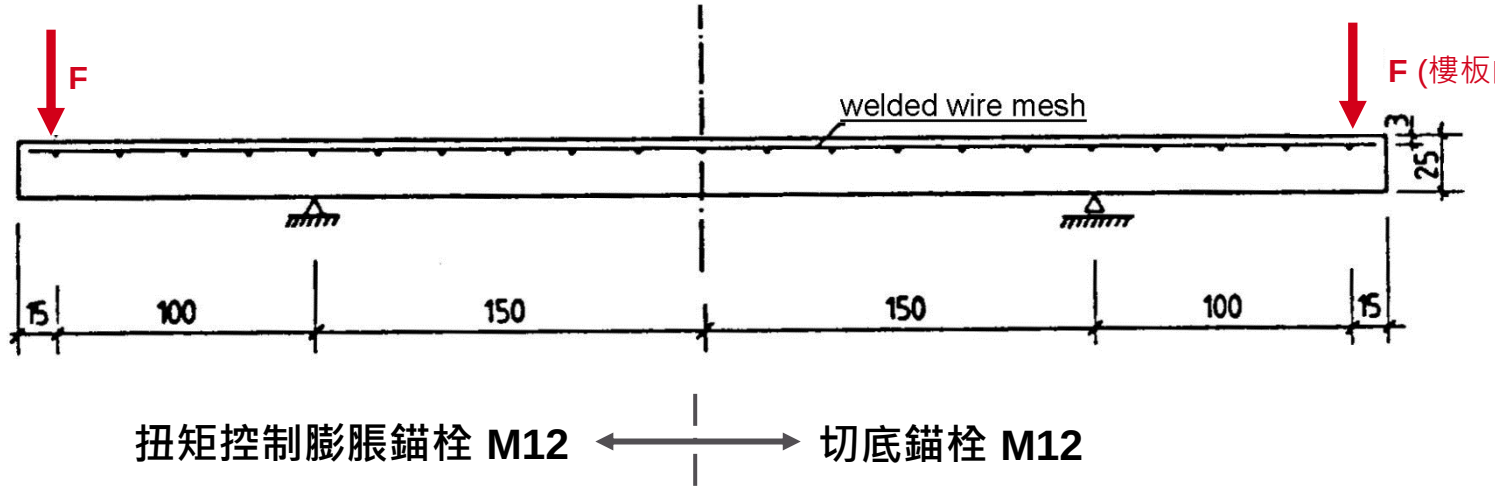
裝載
- 載荷方向
- 靜態和準靜態載荷
- 地震荷載
- 火災
- 疲勞

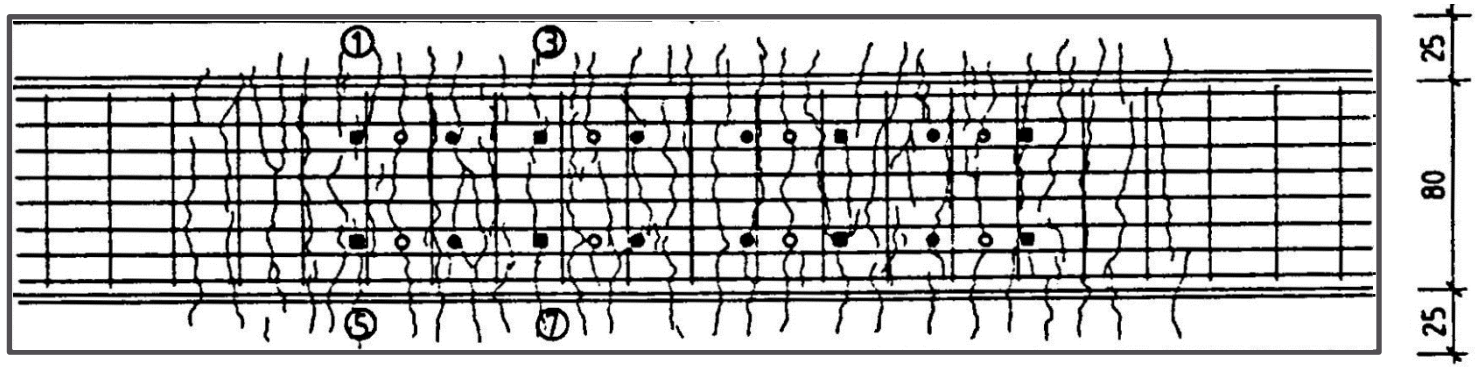
應用條件
錨固佈局
灌漿或隔離
邊緣距離和間距
構件厚度
鑽孔方法、鑽頭
孔清理
乾孔、飽和孔或浸水孔
安裝溫度
安裝方向
使用溫度
環境暴露

緊固件
需要針對具體應用進行測試、評估和鑒定！（例如， 參照ESR）

基礎材料
- 普通/輕質混凝土
- 實心、空心或混凝土外加金屬甲板
- 混凝土強度等級
- 開裂/未開裂混凝土...

開裂混凝土 - 緊固件會因 “缺口 ”效應而產生裂縫

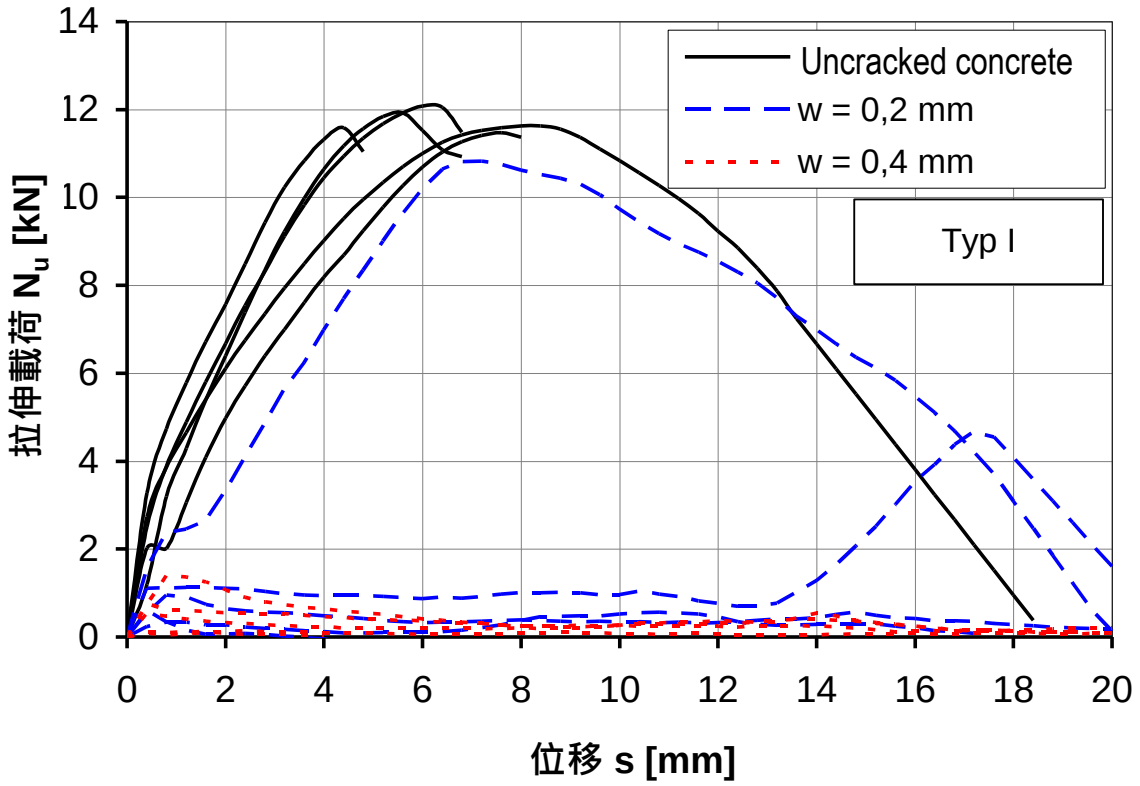


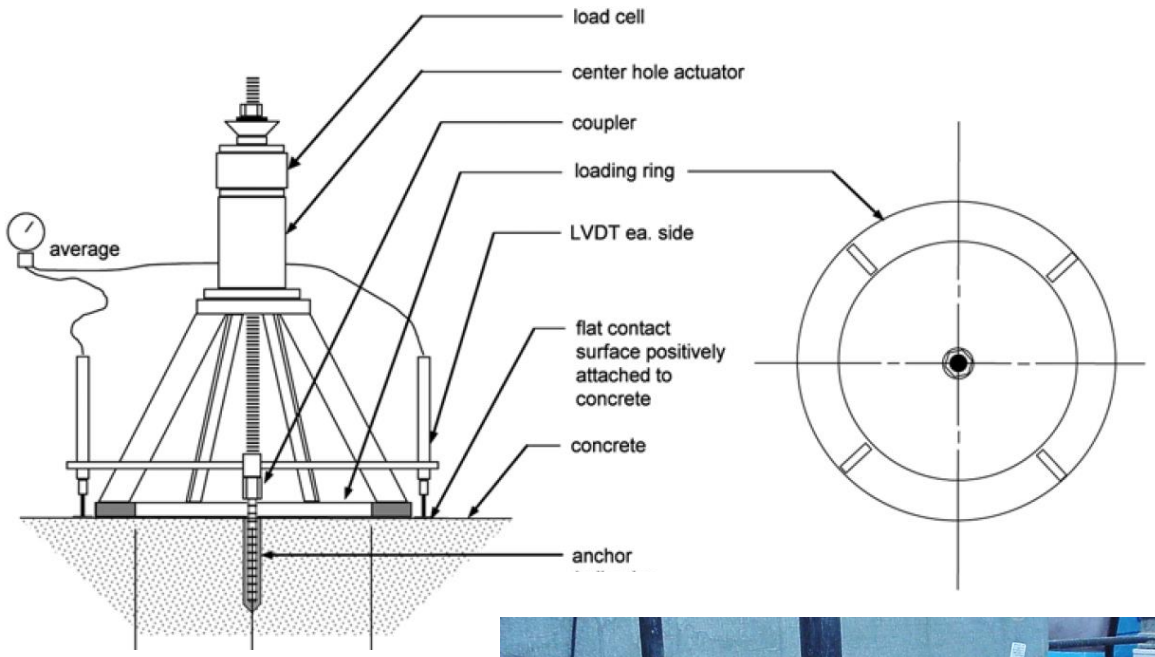


- ■ 受力錨栓
- ● 預應力錨固但未受力
- ○ 鑽孔

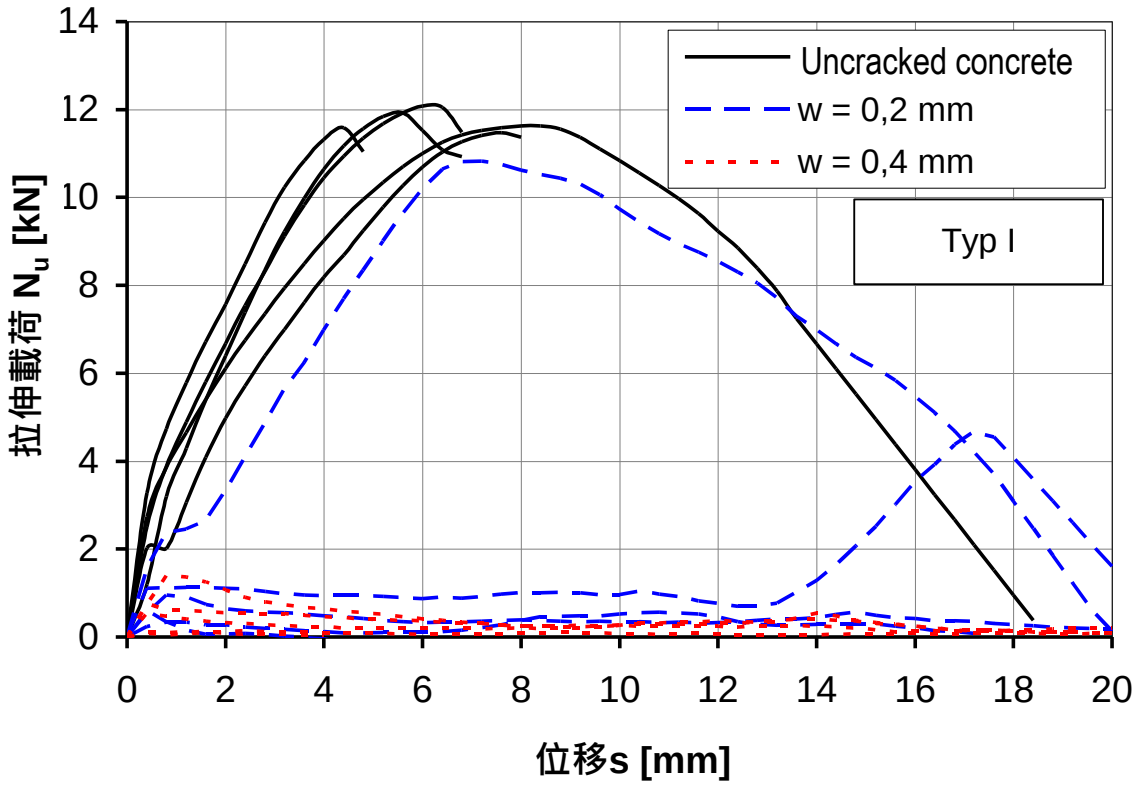
Source: Lotze D. (1987)

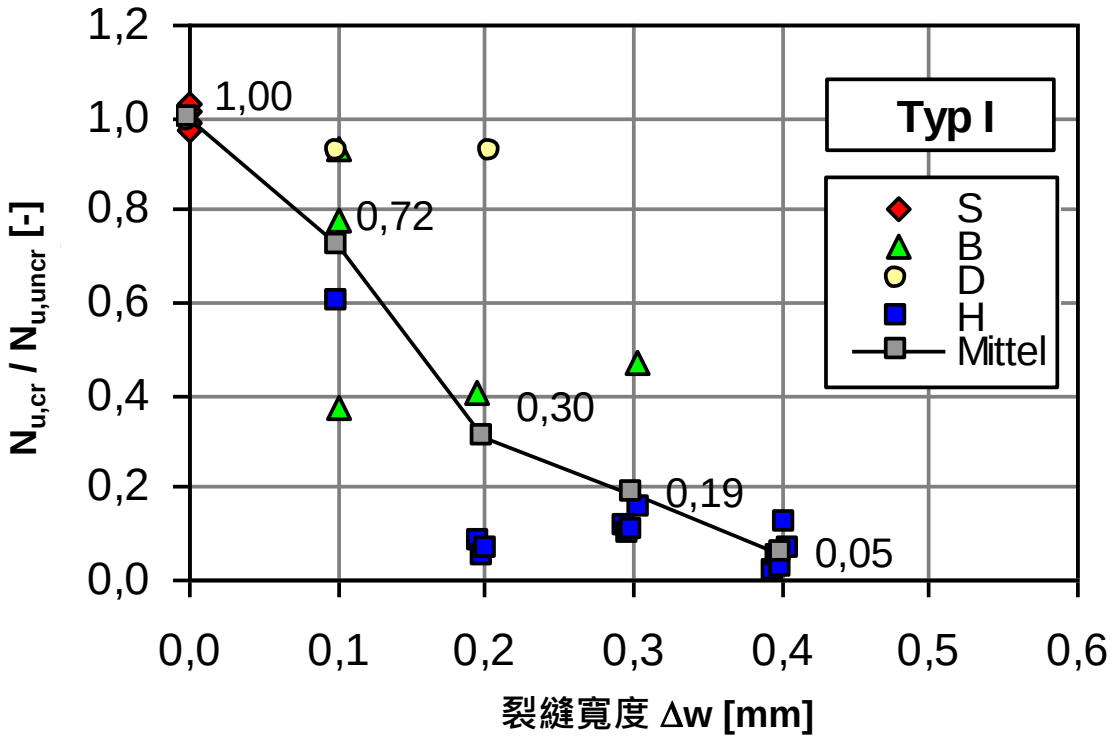
在未開裂混凝土中顯示正常功能的錨固件，在開裂混凝土中可能會提前失效



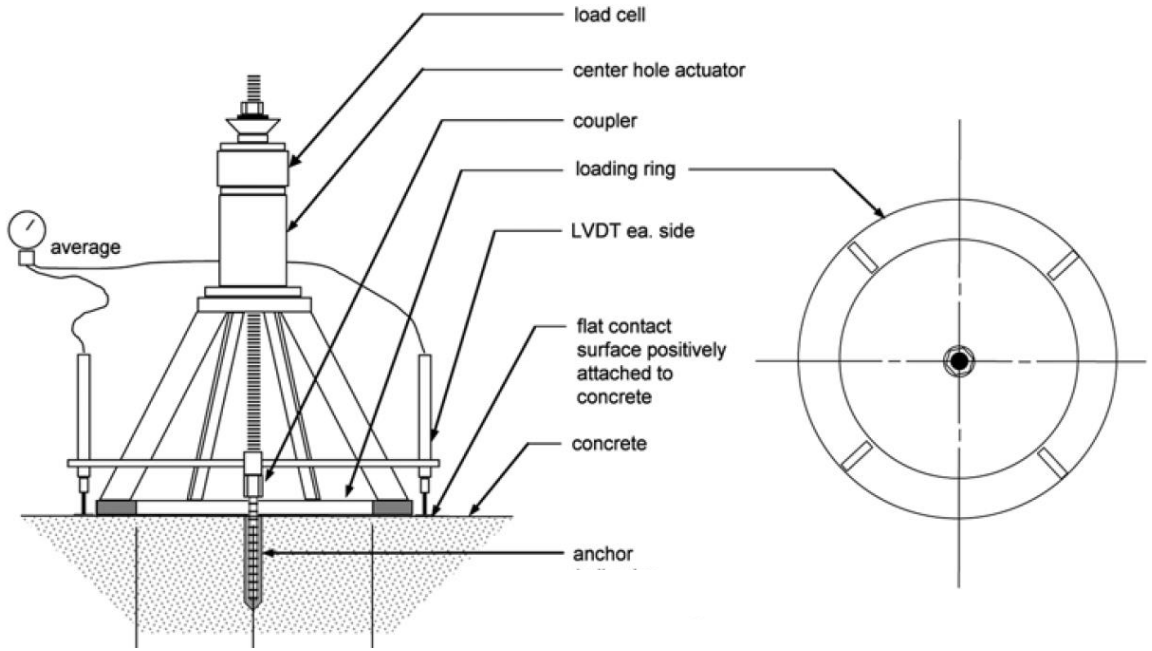


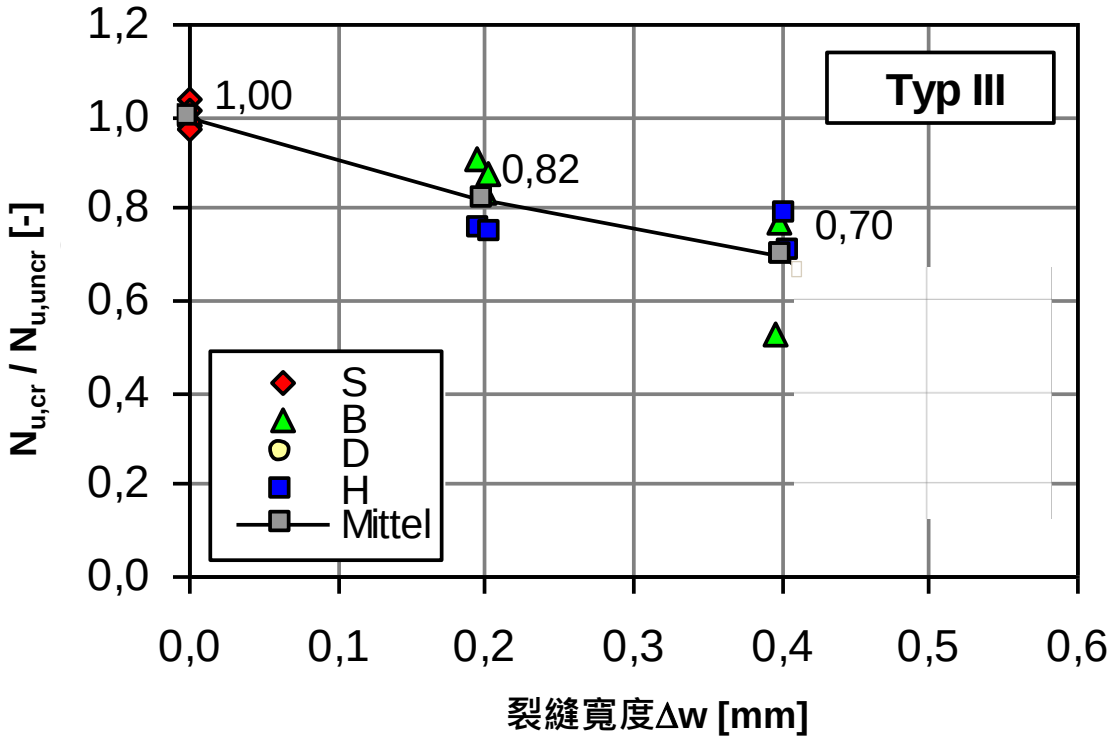
在未開裂混凝土中顯示正常功能的錨固件，在開裂混凝土中可能會提前失效





設計用於開裂混凝土並擁有認證的錨栓在開裂條件下顯示出適度的下降





議程

- 介紹
- 最關鍵的影響?
- **產品認證**
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

如何評估後置錨栓的性能？同類產品是否具有相同的強度？

機械錨栓的強度

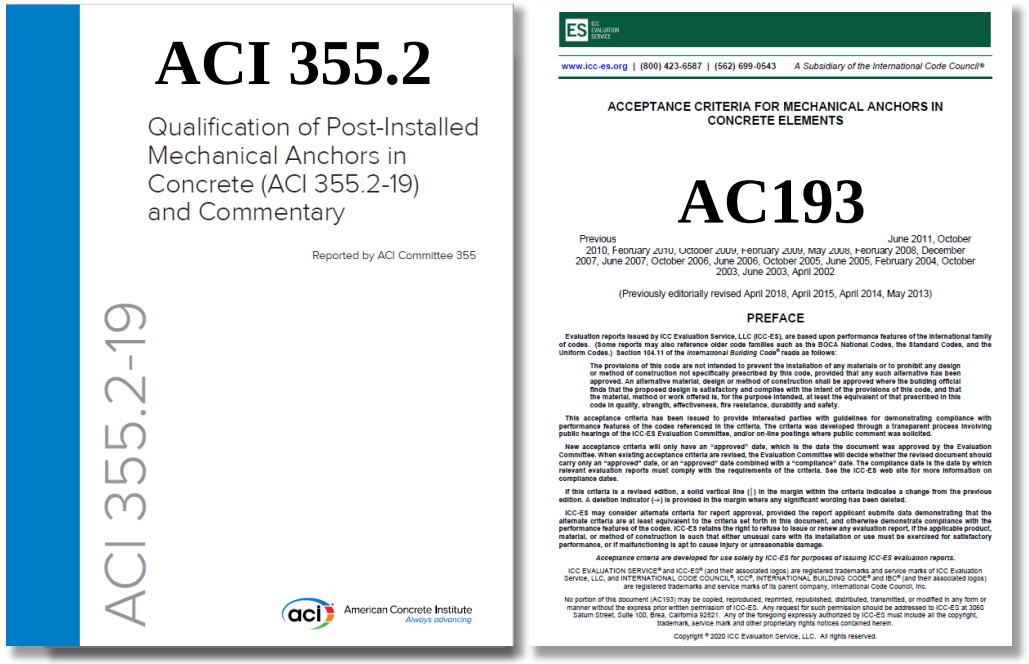
- 未開裂和開裂混凝土的**拉拔強度**
- 地震荷載下的**抗拉強度**
- 在拉力和剪力荷載下的**鋼材強度**

化學錨栓的強度

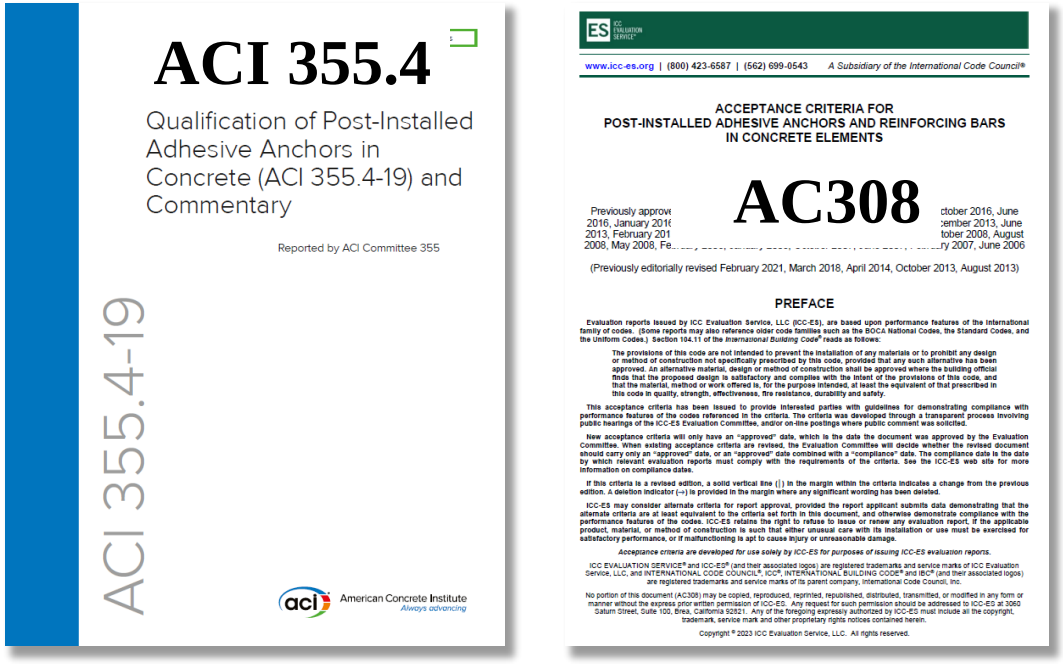
- 未開裂和開裂混凝土中的**粘結強度**
- 地震荷載下的**粘結強度**
- 高溫下的**粘結強度/潛變**，以及
- 使用壽命的**耐久性**

錨栓品質評估建立於 ACI 355，ICC-ES AC 用於執行評估錨栓品質是否合格

機械錨栓



化學錨栓



- **參考試驗**：低強度和高強度混凝土
- **可靠性試驗**：測試對非理想條件（潮濕、溫度.....）的敏感性，以確定抗拉能力。
- **使用條件試驗**：用於確定臨界邊緣距離、間距、構件厚度等。

需要在各種條件下對錨栓進行產品測試 ...

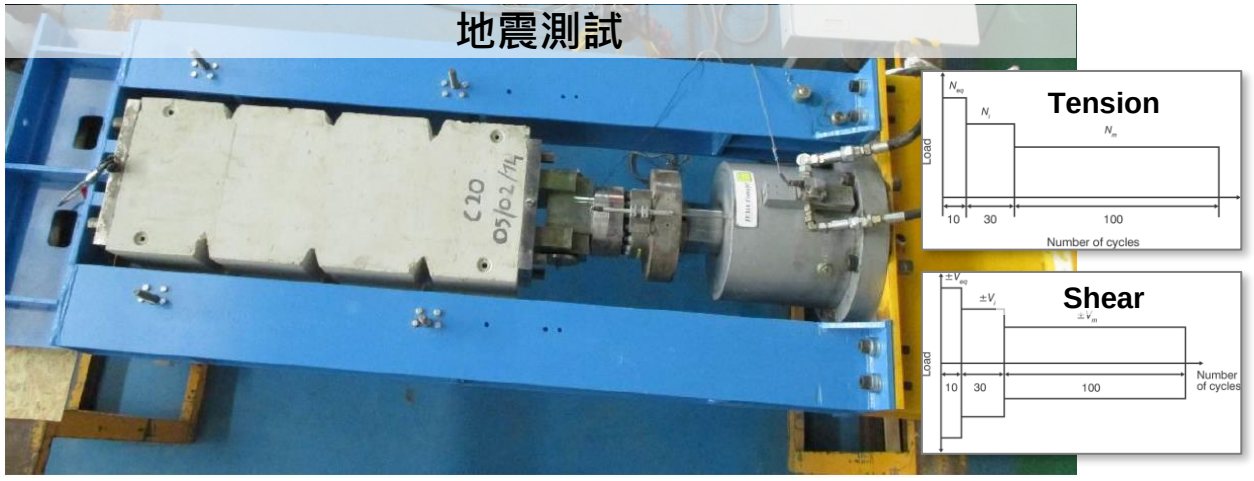
非受限拉力試驗

邊角測試

對清潔的敏感度

剪力試驗

地震測試



認證需要大量的測試計畫

ACI 355.2 是測試混凝土機械錨栓的主要標準，例如

切底錨栓

拉脹錨栓

螺紋錨栓(增加於 ACI 318-19 and ACI 355.2-19)

Test Number	Reference	Purpose	Description	Crack Opening Width, in (mm)	Concrete Strength	Member Thickness	Drill Bit Diameter	Minimum Sample Size*, *n*
			Reference tests					
1	7.2.1	Reference test in uncracked low-strength concrete	Tension-single anchor with no edge influence		Low	$\geq h_{min}$	d_m	5
2	7.2.1	Reference test in uncracked high-strength concrete	Tension-single anchor with no edge influence		High	$\geq h_{min}$	d_m	5
3	7.2.1	Reference test in cracked low-strength concrete	Tension-single anchor with no edge influence	0.012 (0.3)	Low	$\geq h_{min}$	d_m	5
4	7.2.1	Reference test in cracked high-strength concrete	Tension-single anchor with no edge influence		High	$\geq h_{min}$	d_m	5
5	7.2.2	Reference test for screw anchors - Confined test in uncracked high-strength concrete	Confined tension - single anchor away from edges	—	High	$\geq h_{min}$	d_m	5[a,b]
			Reliability tests					
6	8.2	Sensitivity to reduced installation effort	Tension-single anchor with no edge influence	0.012 (0.3)	Varies with anchor type	$\geq h_{min}$	d_m[†]	5
7	8.3	Sensitivity to crack width and large hole diameter	Tension-single anchor with no edge influence	0.020 (0.5)	Low	$\geq h_{min}$	d_{max}	5
8	8.4	Sensitivity to crack width and small hole diameter	Tension-single anchor with no edge influence	0.020 (0.5)	High	$\geq h_{min}$	d_{min}	5
9	8.6	Tests in cracks whose opening width is cycled	Sustained tension – single anchor with no edge influence	0.020 (0.5)	Low	$\geq h_{min}$	d_{max}[§]	5
10	8.5	Reliability of screw anchors under repeated load	Repeated tension – single anchor away from edges, residual capacity	—	Low	$\geq h_{min}$	d_m	5
11	8.7	Reliability of screw anchors against brittle failure	Method A Embrittlement test - single anchor away from edges	—	High	$\geq h_{min}$	d_m	5[a,b]
12	8.8.2	Reliability of screw anchors when set with impact screw driver	Setting test – single anchor away from edges	—	Low	$\geq h_{min}$	d_{max}	15
13	8.8.3	Reliability of screw anchors when set with a torque wrench in low-strength concrete	Setting test – single anchor away from edges	—	Low	$\geq h_{min}$	d_{max}	10
14	8.8.4	Reliability of screw anchors when set with a torque wrench in high-strength concrete	Setting test – single anchor away from edges	—	High	$\geq h_{min}$	d_{min}	10
			Service-condition tests					
15	9.2	Verification of full concrete capacity in corner with two edges located at $1.5h_{ef}$	Tension-single anchor with two edges located at $1.5h_{ef}$	—	Low	h_{min}	d_m	4
16	9.3	Minimum spacing and edge distance to preclude splitting on installation	High installation tension (torque or direct)-two anchors near edge	—	Low	h_{min}	d_m	5
17	9.4	Shear capacity of anchor steel‡	Shear-single anchor with no edge influence	0.012 (0.3)	Low	$\geq h_{min}$	d_m	5
18‖	9.5	Seismic tension	Pulsating tension, single anchor with no edge influence	0.020 (0.5)	Low	$\geq h_{min}$	d_m	5
19‖	9.6	Seismic shear	Alternating shear, single anchor, with no edge influence	0.020 (0.5)	Low	$\geq h_{min}$	d_m	5
20‖	9.7	Torque Test (Optional)	Effect of torque on anchor tension force	—	High	$\geq h_{min}$	d_m	5
21‖	9.8	Tension capacity in concrete fill on deck-soffit installation	Tension–single anchor away from edges	—	Low or high	h_{min}	d_m	5
22‖	9.9	Shear capacity in concrete fill on deck soffit installation	Shear toward nearest edge of flute–single anchor in lower flute	—	Low or high	h_{min}	d_m	5

基本拉力強度
高強度、
開裂/未開裂混凝土

新/舊鑽頭

裂縫寬度和載荷迴圈

穩固性
降低安裝強度（扭矩/膨脹），減少與鋼筋的接觸

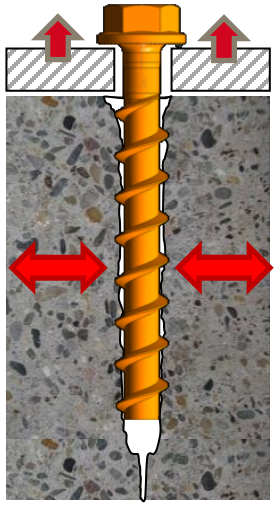
邊緣距離、間距

基本剪力

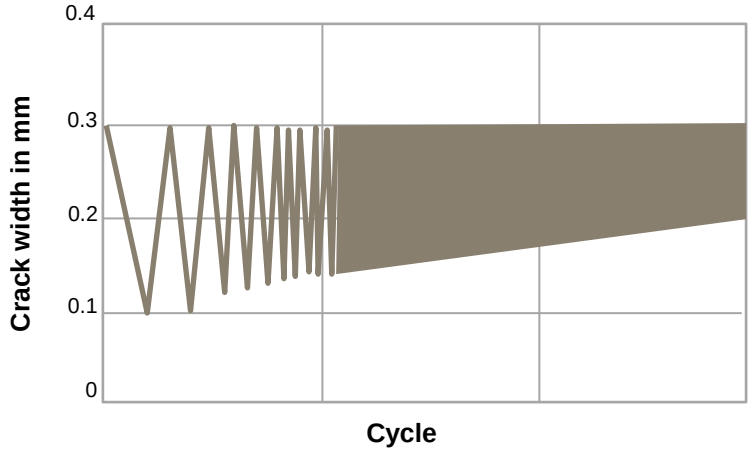
地震

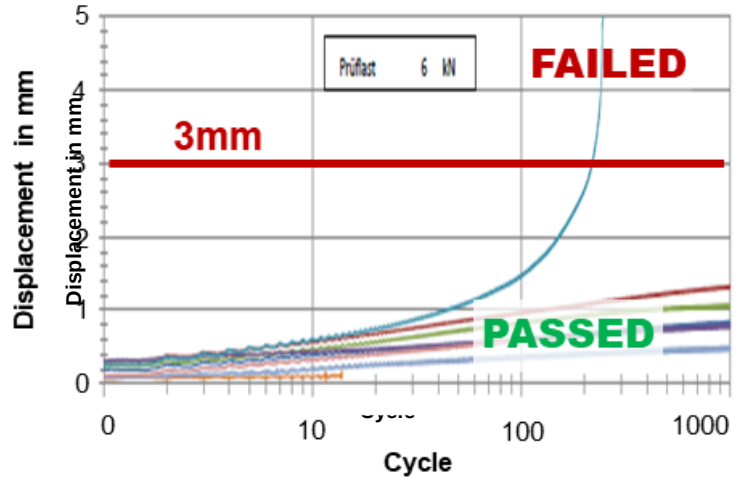
可靠性試驗:長期穩定移動裂縫試驗系列 9

N_{sust} = 0.3 x N_p of test series 3/4



Δw = 0,3 - 0,1 mm





測試9：裂縫移動功能

- 模擬長期受力的測試
- 錨栓承受持續荷載
- 裂縫開合，模擬建築物移動

裂縫循環期間

- 1000 次迴圈後位移小於 3mm，20 次迴圈後位移小於 2mm
- 如果 750-1000 次迴圈中位移的增加小於 500-750 次迴圈中位移的增加，則位移保持穩定

失效殘餘拉力荷載

- 分散COV < 20%
- 錨栓性能與測試系列 3 進行比較，以檢查穩固性
- 特性承載力應大於相應參考測試承載力的 80%，以獲得最佳設計性能。

ACI 355.2 地震測試協定

- 進行模擬地震拉力和地震剪力試驗。
- 成功完成測試後，錨栓可用於抗震設計類別 C、D、E 和 F。

Table 9.5.2—Required history of seismic tension load

Load level	N_{eq}	N_i	N_m
Number of cycles	10	30	100

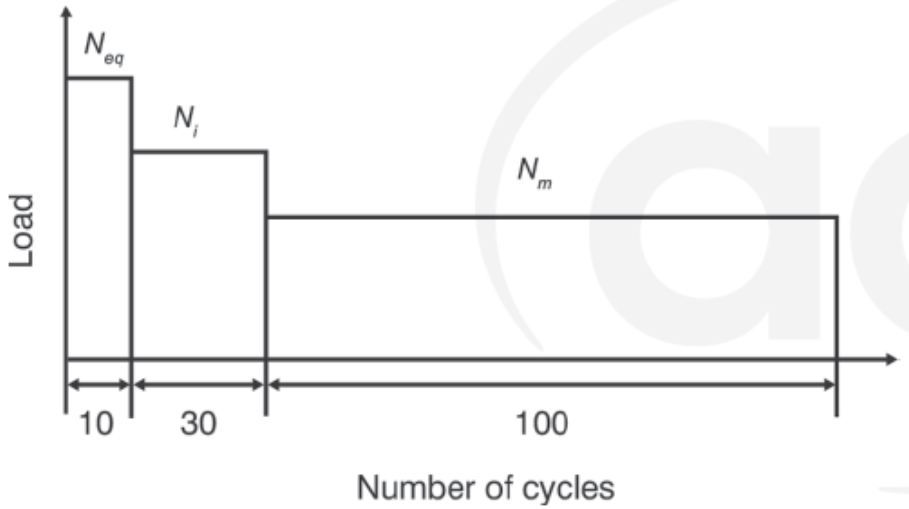


Fig. 9.5.2—Loading pattern for simulated seismic-tension test.

Table 9.6.2—Required history of seismic shear load

Load level	$\pm V_{eq}$	$\pm V_i$	$\pm V_m$
Number of cycles	10	30	100

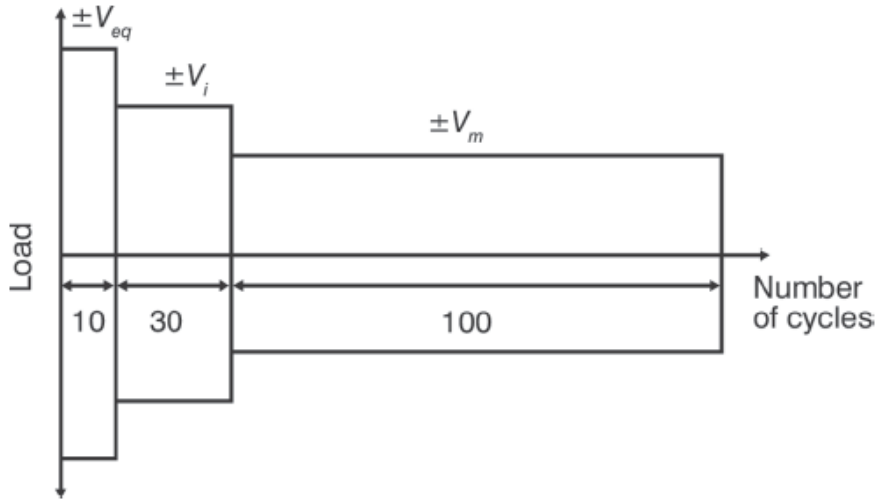


Fig. 9.6.2a—Loading pattern for simulated seismic-shear test.

化學錨栓需要額外的測試

- 與ACI 355.2測試機械錨固件的方法相同，化學錨固件也必須通過嚴格的ACI 355.4測試標準。

化學藥劑，如鋁箔包裝

扭矩控制的化學錨栓

螺桿

竹節鋼筋

內螺紋桿

Table 3.2—Test program for evaluating adhesive anchor systems for cracked and uncracked concrete

Test no.	Test reference	Purpose	Test parameters	Crack width Δ_w, in.	Assessment: α_{req}	Assessment: Load and displacement	f_c*	h_{ef}†	Minimum sample size n_{min}
			Reliability tests						
2a	7.5	Sensitivity to hole cleaning, dry substrate	Tension, confined, single anchor away from edges	—	10.4.6	10.4.2 10.4.4	low	max	Five§
2b	7.6	Sensitivity to hole cleaning, installation in water-saturated concrete	Tension, confined, single anchor away from edges	—	10.4.6	10.4.2 10.4.4	low	max	Five§
2c	7.7	Sensitivity to hole cleaning, installation in a water-filled hole‖	Tension, confined, single anchor away from edges	—	10.4.6	10.4.4 10.4.4	low	max	Five§
2d	7.8	Sensitivity to hole cleaning, installation in submerged concrete‖	Tension, confined, single anchor away from edges	—	10.4.6	10.4.4	low	max	Five#
2e	7.9	Sensitivity to mixing effort	Tension, confined, single anchor away from edges	—	10.4.6	10.4.2 10.4.4	low	max	Five**
2f††	7.10	Sensitivity to installation in water-saturated concrete	Tension, confined, single anchor away from edges	—	10.4.6	10.4.2 10.4.4	low	max	Five§
2g	7.11	Sensitivity to installation in a water-filled hole‖	Tension, confined, single anchor away from edges	—	10.4.6	10.4.2 10.4.4	low	max	Five§
2h	7.12	Sensitivity to installation in submerged concrete‖	Tension, confined, single anchor away from edges	—	10.4.6	10.4.2 10.4.4	low	max	Five#
6	7.16	Sensitivity to freezing/thawing conditions	Sustained tension, residual capacity, confined test	—	0.90	10.4.2 10.4.4 10.10	high	min‡‡	Five**
7	7.17	Sensitivity to sustained load	Sustained tension, residual capacity, confined test	—	0.90	10.4.2 10.4.4 10.11	low	min‡‡	Five**
8	7.18	Sensitivity to installation direction‖	Tension, confined, single anchor away from edges	—	0.90	10.4.2 10.4.4 10.12	low	max	Five**
9	7.19	Torque test§§	Application of torque, single anchor away from edges	—	—	10.8	high	min	Five#
12a	8.5	Tension at elevated temperatures	Tension, confined single anchor away from edges	—	—	10.4.2 10.4.4 10.13	low	min	Five**
12b	8.6	Tension at decreased installation temperature‖	Tension, confined single anchor away from edges	—	—	10.4.2 10.4.4 10.14	low	min	Five**
12c	8.7	Curing time at standard installation temperature	Tension, confined single anchor away from edges	—	—	10.4.2 10.4.4 10.15	low	min	Five**
13a	8.8	Resistance to alkalinity	Slice test	—	—	10.16	low	—	Ten**
13b	8.8	Resistance to sulfur‖	Slice test	—	—	10.16	low	—	Ten**
19	9.1	Round-robin tests for regional concrete variation	Tension, confined/unconfined, single anchor away from edges	—	—	10.4.1	low†††	$7d_a$	Five**
20	9.2	Minimum member thickness‖	Installation tests##	—	—	10.7	low	max	Ten#

穩固性/孔洞清理

潛變

安裝方向

溫度

耐用性

混凝土混合物

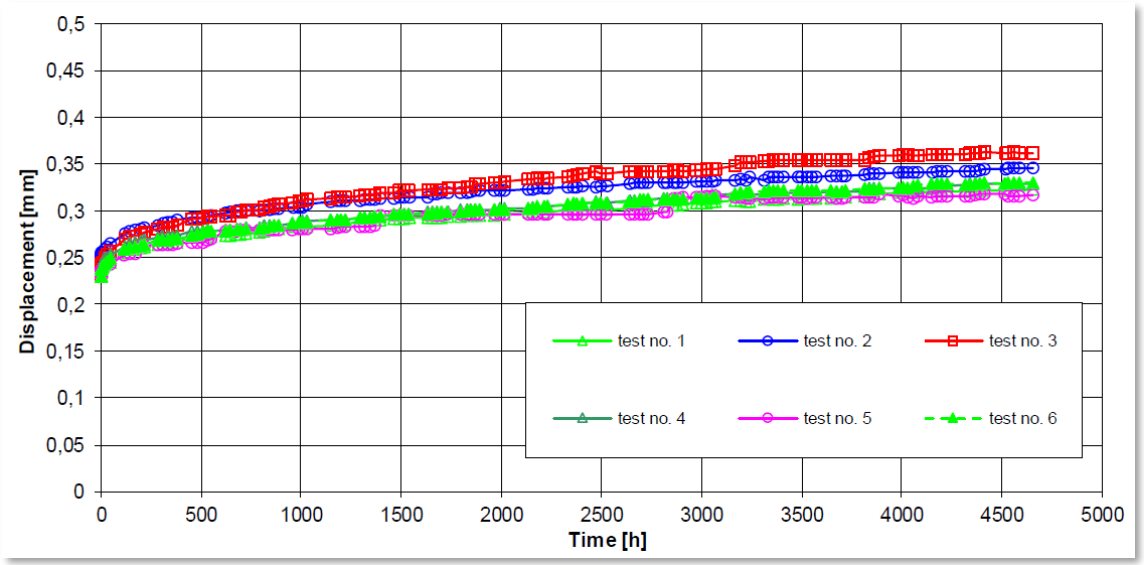
通過潛變測試檢查粘結緊固件的長期性能

化學錨栓 的長期測試

最重要的測試參數

- 施加的持續負載(粘結應力)
- 測試期間的溫度

測試結果和評估



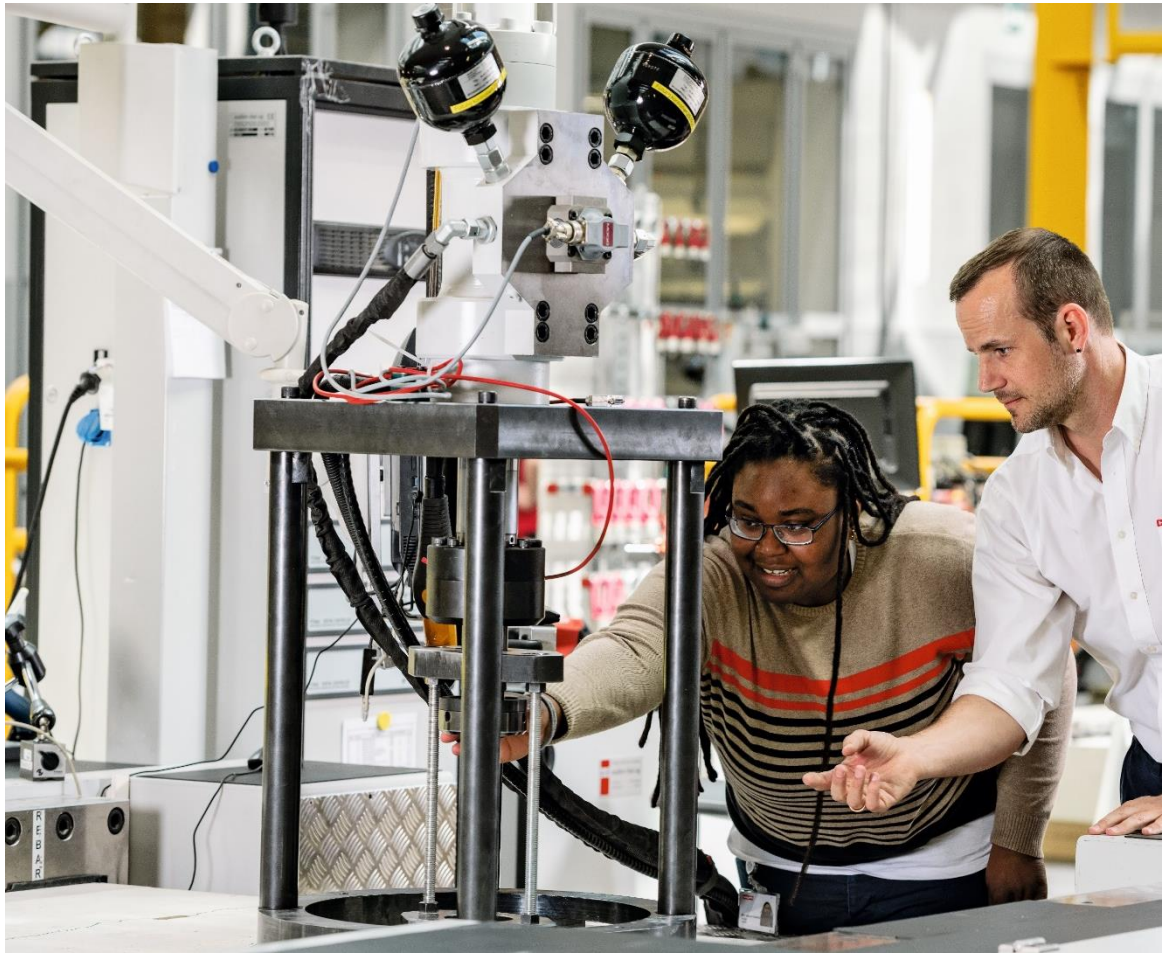
測試結果：
測試期間的位移至少為3
剩餘載荷能力

評估：
根據緊固件的使用壽命推斷位移量
將極限載荷和位移與參考短期試驗進行比較

對後置安裝的化學藥劑進行測試，以確定其能力是否等同於預埋鋼筋

隨著後置植筋連接在建築行業越來越普遍，AC308 中的一種測試方法—後置化學錨栓驗收標準--已被開發出來，用於確定後置植筋的承載能力是否等同於預埋鋼筋。

該測試方法可提供一份評估報告，使工程師能夠根據 ACI 318 第 25 章的發展長度和搭接規定設計後厚植筋，證明其符合現代建築規範。



關於後置鋼筋的追加測試 (AC 308)

- 不止於ACI 355.4的化學錨栓測試，還必須通過嚴密的AC 308測試體系.

化學藥劑,
e.g. 鋁箔包裝

竹節鋼筋

Table 3.8– Test program for evaluating deformed reinforcing bars for use in post-installed reinforcing bar connections

Testing				Bar size	Assessment			Bar embedment	Minimum sample size
Test no.	Test ref.	Purpose	Test parameters	US/M[§,‖]	α_{req}	Load & displ.	f_c *	ℓ_b	n_{min}
1d	9.6.3.1	Bond resistance[§§]	Tension, confined, single reinforcing bar[†]	$d_{b,max}$	–	10.25.2 10.25.3	high	$7d_b$	Five
1e[††]	9.6.3.1	Bond resistance[§§]	Tension, confined, single reinforcing bar[†]	#4/12		10.25.2 10.25.3	high	$7d_b$	Five
2	9.6.3.2	Bond/splitting behavior	Tension, confined, single bars in corner condition	#4/12		10.25.6	low	$35d_b$	Six[‡]
Installation procedure verification									
9	9.6.5.1	Installation at deep embedment	Bar installation in injected hole, horizontal	$d_{b,max}$	–	10.25.8	–	$60d_b$	Three
10	9.6.5.2	Injection verification	Injection in clear tube	$d_{b,max}$	–	10.25.8	–	$60d_b$	Three
Durability									
11a	9.6.6.1.1	Resistance to alkalinity[#]	Slice test	#4/12	–	10.25.10	low	-	Ten
11b	9.6.6.1.2	Resistance to sulfur[#]	Slice test	#4/12	–	10.25.10	low	-	Ten
12	9.6.7	Corrosion resistance	Current and potential test	#4/12	–	10.25.9	low	$2^3/_4$"	Three
Special conditions									
13	9.6.8	Seismic qualification for reinforcing bar connections[##]	Cyclic tension, confined, single reinforcing bar	$d_{b,max}$	–	10.25.11	low	$7d_b$	Five
14	9.6.8	Seismic qualification for reinforcing bar connections[§§]	Cyclic tension, confined, single reinforcing bar	$d_{b,max}$	–	10.25.11	high	$7d_b$	Five
15	9.6.9	Fire resistance##	Tension, confined, single reinforcing bar	#4/12	–	10.25.12	low	4-3/4" (120 mm)	Twenty

黏著強度/劈裂現象

安裝

地震力

耐火

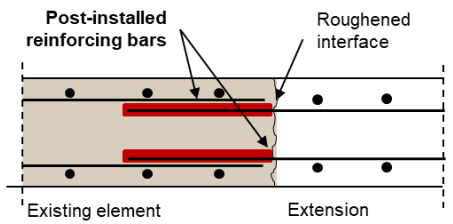
後置植筋連接根據 AC 308 進行地震荷載測試：推/拉測試

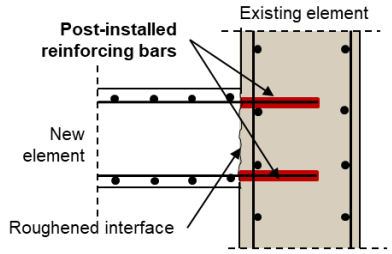
抗震鑑定：

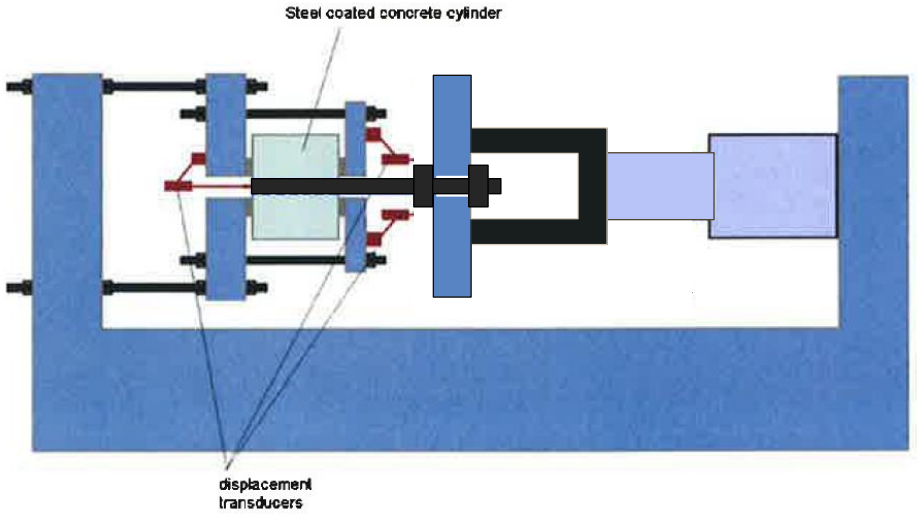
根據表 10.10，後置植筋在循環拉力和壓力作用下進行測試

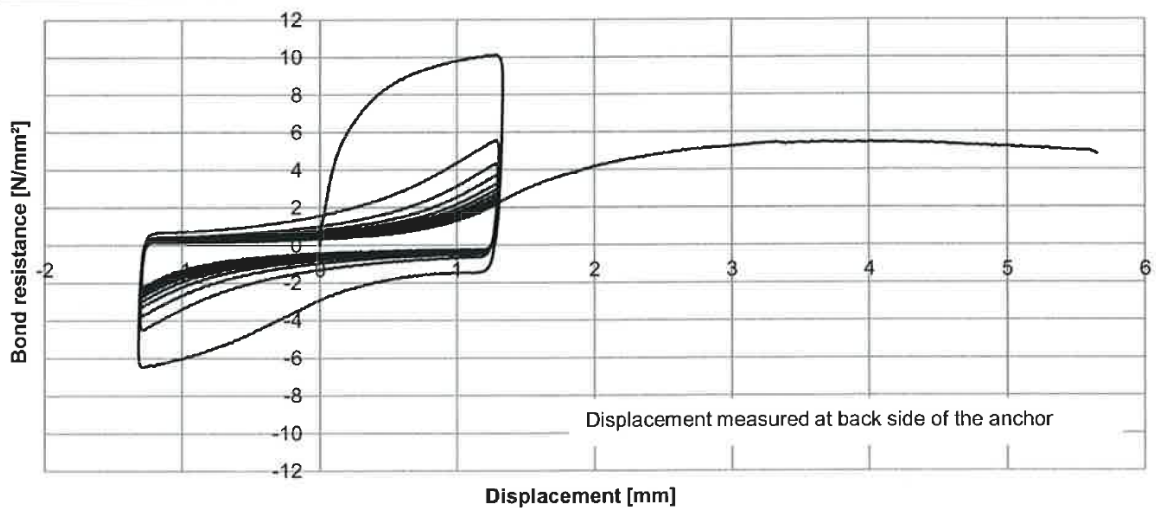
Table 10.10 – Requirements on bond stress for cyclic seismic test[1]

Cycle no. n	$\overline{\tau}_{u,n}$			
	2500 psi		8000 psi	
	(psi)	(MPa)	(psi)	(MPa)
1	1670	10.5	2680	18.5
2	960	6.0	1350	9.3
5	540	3.4	800	5.5
10	360	2.3	540	3.7
residual ult.	680	4.3	1090	7.5









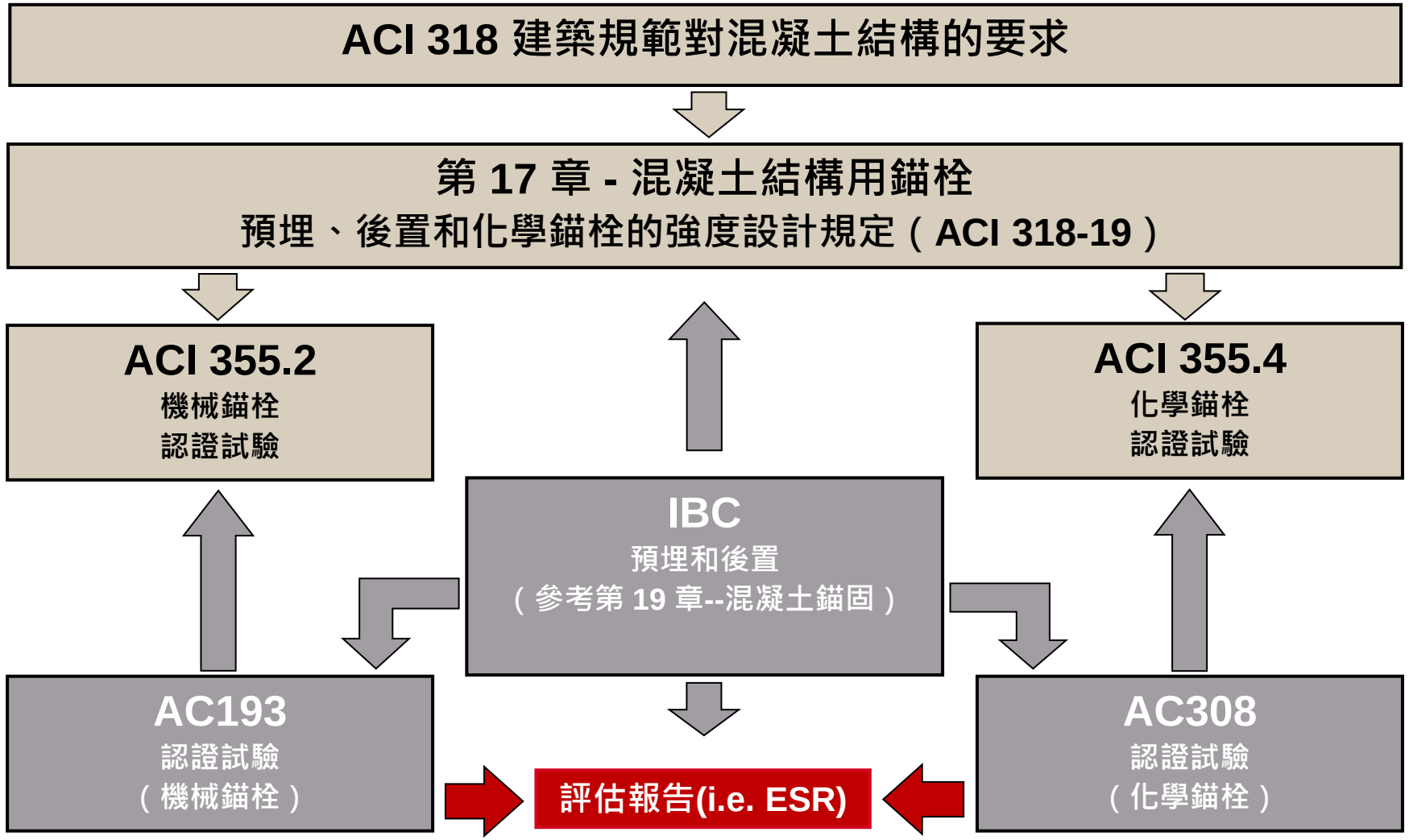
對喜利得 HIT-RE 500 V3 進行 ACI 355.4 測試

- 完成 ACI 355.4 測試程式需要哪些條件？
  - 喜利得 HIT-RE 500 V3
    - 喜利得 SafeSet™ 配中空鑽頭
    - 英制和公制元件
    - 螺桿、鋼筋、HIS-N 內螺紋桿
    - 電錘鑽孔、鑽石洗孔和打毛過的鑽石洗孔
  - **進行了多少次測試？**

- **> 4,900 次外部測試！**
- **出於品質控管目的，內部測試了 > 3,000 包藥劑！**
- **潛變測試、高低溫測試**
- **地震測試**
  - **拉力和剪力**
  - **錨固和鋼筋應用**

第三方認證評估報告流程

- ACI 不提供評估報告來證明已進行 ACI 355 測試
- 第三方評估服務如 ICC 評估服務 (ICC-ES) 和 IAPMO UES經認可提供評估報告，證明符合 ACI 318 和 IBC 標準
- 驗收標準參照 ACI 355 測試標準
- 公佈的評估報告顯示符合相關規範



第三方評估報告剖析

- **A** CSI 部門編號
- **B** 報告持有人
- **C** 評估主題
- **1.0** 評估範圍
- **2.0** 使用
- **3.0** 描述
- **4.0** 設計與安裝
- **5.0** 使用條件
- **6.0** 提交的證據
- **7.0** 鑒定
- **I** 安裝參數
- **II** 設計參數表
- **III** 計算範例
- **IV** 安裝說明（**MPII**）
- **V** 補充數據和認證

ICC EVALUATION SERVICE

ICC-ES Evaluation Report
ESR-3814

Reissued January 2023
Revised March 2023
This report is subject to renewal January 2025.

www.icc-es.org | (800) 423-6587 | (562) 699-0543 *A Subsidiary of the International Code Council®*

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.

EVALUATION SUBJECT:

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

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2021, 2018, 2015, and 2012 *International Building Code®* (IBC)
- 2021, 2018, 2015, and 2012 *International Residential Code®* (IRC)

For evaluation for compliance with the *National Building Code of Canada®* (NBCC), see listing report ELC-3814.

For evaluation for compliance with codes adopted by Los Angeles Department of Building and Safety (LADBS), see ESR-3814 LABC and LARC Supplement.

Property evaluated:

Structural

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 and lightweight concrete having a specified compressive strength, f'_c, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

The anchor system complies with anchors as described in

3.0 DESCRIPTION

3.1 General:

The Hilti HIT-RE 500 V3 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are comprised of the following components:

- Hilti HIT-RE 500 V3 adhesive packaged in foil packs
- Adhesive mixing and dispensing equipment
- Equipment for hole cleaning and adhesive injection

The Hilti HIT-RE 500 V3 Adhesive Anchoring System may be used with continuously threaded rod, Hilti HIS-(R)N internally threaded inserts or deformed steel reinforcing bars as depicted in Figure 4. The Hilti HIT-RE 500 V3 Post-Installed Reinforcing Bar System may only be used with deformed steel reinforcing bars as depicted in Figures 2 and 3. The primary components of the Hilti Adhesive Anchoring and Post-Installed Reinforcing Bar Systems, including the Hilti HIT-RE 500 V3 Adhesive, HIT-RE-M static mixing nozzle and steel anchoring elements, are shown in Figure 7 of this report.

The manufacturer's printed Installation instructions (MPII), as included with each adhesive unit package, are consolidated as Figure 8A and 8B.

3.2 Materials:

3.2.1 Hilti HIT-RE 500 V3 Adhesive: Hilti HIT-RE 500 V3 Adhesive is an injectable, two-component epoxy adhesive. The two components are separated by means of a dual-cylinder foil pack attached to a manifold. The two components combine and react when dispensed through a static mixing nozzle attached to the manifold. Hilti HIT-RE 500 V3 is available in 11.1-ounce (330 ml), 16.9-ounce (500 ml), and 47.3-ounce (1400 ml) foil packs. The manifold attached to each foil pack is stamped with the adhesive expiration date. The shelf life, as indicated by the expiration date, applies to an unopened foil pack stored in a dry, dark environment and in accordance with Figure 8A.

3.2.2 Hole Cleaning Equipment:

3.2.2.1 Standard Equipment: Standard hole cleaning

2.0 USES

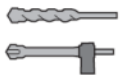
The Hilti HIT-RE 500 V3 Adhesive Anchoring System and Post-Installed Reinforcing Bar System are used to resist static, wind and earthquake (Seismic Design Categories A through F) tension and shear loads in cracked and uncracked normal-weight and lightweight concrete having a specified compressive strength,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

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Post-installed Adhesive Anchors in Concrete (AC308), dated June 2019 (Editorially revised March 2018), which incorporates requirements in ACI 355.4-11, including but not limited to tests under freeze/thaw conditions (Table 3.2, test series 6), and Table 3.8 for evaluating post-installed reinforcing bars.

Metric Threaded Rod

Bond Strength



Carbide Bit or Hilti Hollow Carbide Bit

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	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	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	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	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	$\phi_{d,dry}$, $\phi_{d,ws}$	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65

HILTI HIT-RE 500 V3 FOIL PACK AND MIXING NOZZLE

HILTI DISPENSER

議程

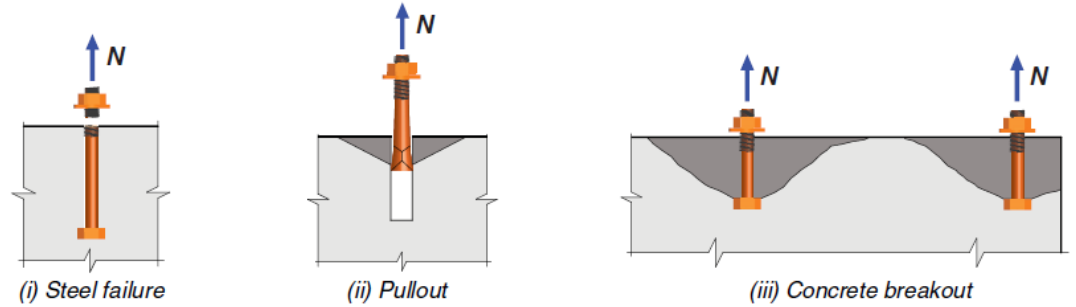
- 介紹
- 最關鍵的影響?
- **產品認證**
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

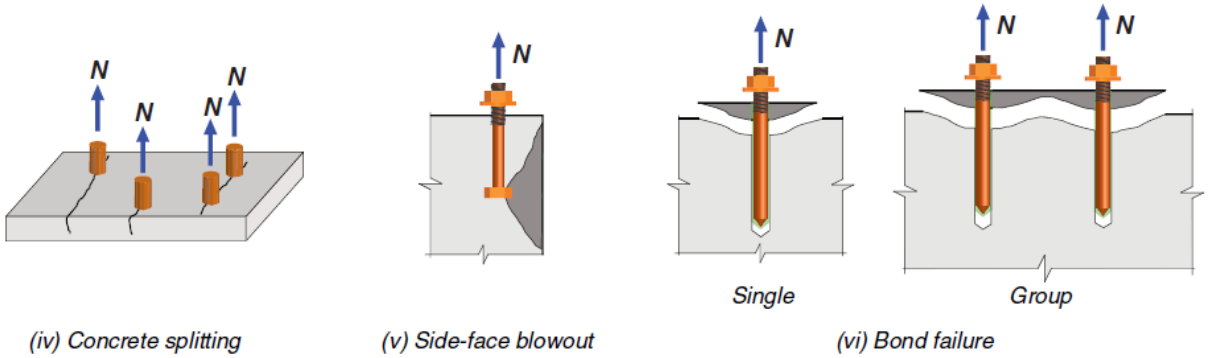
ACI 318-19
第 17 章 - 混凝土錨固

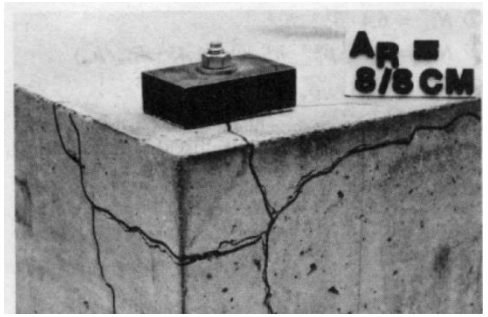
- ACI 318-19 第 17 章提供了混凝土澆注和後置機械錨栓和化學黏結錨栓系統的設計計算。
- 設計公式與混凝土測試中的特定破壞模式相關聯。

拉伸強度

Steel strength in tension (17.6.1)[2]	$\phi N_{sa} \geq N_{ua}$
Concrete breakout strength in tension[3] (17.6.2)	$\phi N_{cb} \geq N_{ua}$
Pullout strength in tension (17.6.3)	$\phi N_{pn} \geq N_{ua}$
Concrete side-face blowout strength in tension (17.6.4)	$\phi N_{sb} \geq N_{ua}$
Bond strength of adhesive anchor in tension (17.6.5)	$\phi N_a \geq N_{ua}$







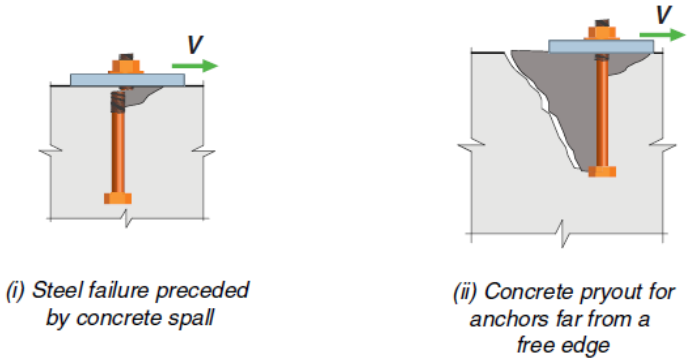
ACI 318-19
第 17 章 - 混凝土錨固

- ACI 318-19 第 17 章提供了混凝土澆注和後置機械錨栓和化學黏結錨栓系統的設計計算。設計公式與混凝土測試中的特定破壞模式相關聯。
- **拉伸強度**

Steel strength in tension (17.6.1)[2]	$\phi N_{sa} \geq N_{ua}$
Concrete breakout strength in tension[3] (17.6.2)	$\phi N_{cb} \geq N_{ua}$
Pullout strength in tension (17.6.3)	$\phi N_{pn} \geq N_{ua}$
Concrete side-face blowout strength in tension (17.6.4)	$\phi N_{sb} \geq N_{ua}$
Bond strength of adhesive anchor in tension (17.6.5)	$\phi N_a \geq N_{ua}$

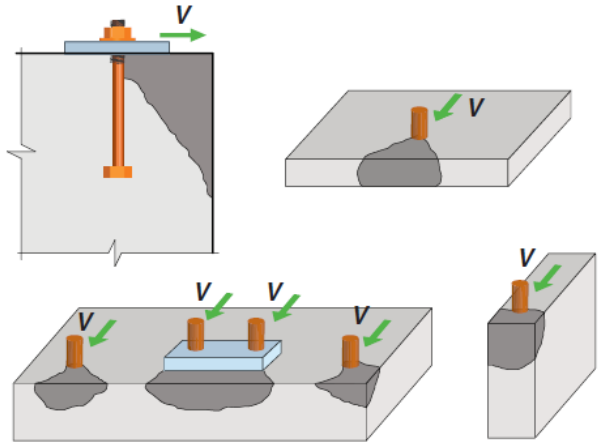
剪切強度

Steel strength in shear (17.7.1)	$\phi V_{sa} \geq V_{ua}$
Concrete breakout strength in shear[3] (17.7.2)	$\phi V_{cb} \geq V_{ua}$
Concrete pryout strength in shear (17.7.3)	$\phi V_{cp} \geq V_{ua}$



(i) Steel failure preceded by concrete spall

(ii) Concrete pryout for anchors far from a free edge



(iii) Concrete breakout

議程

- 介紹
- 最關鍵的影響?
- 產品認證
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

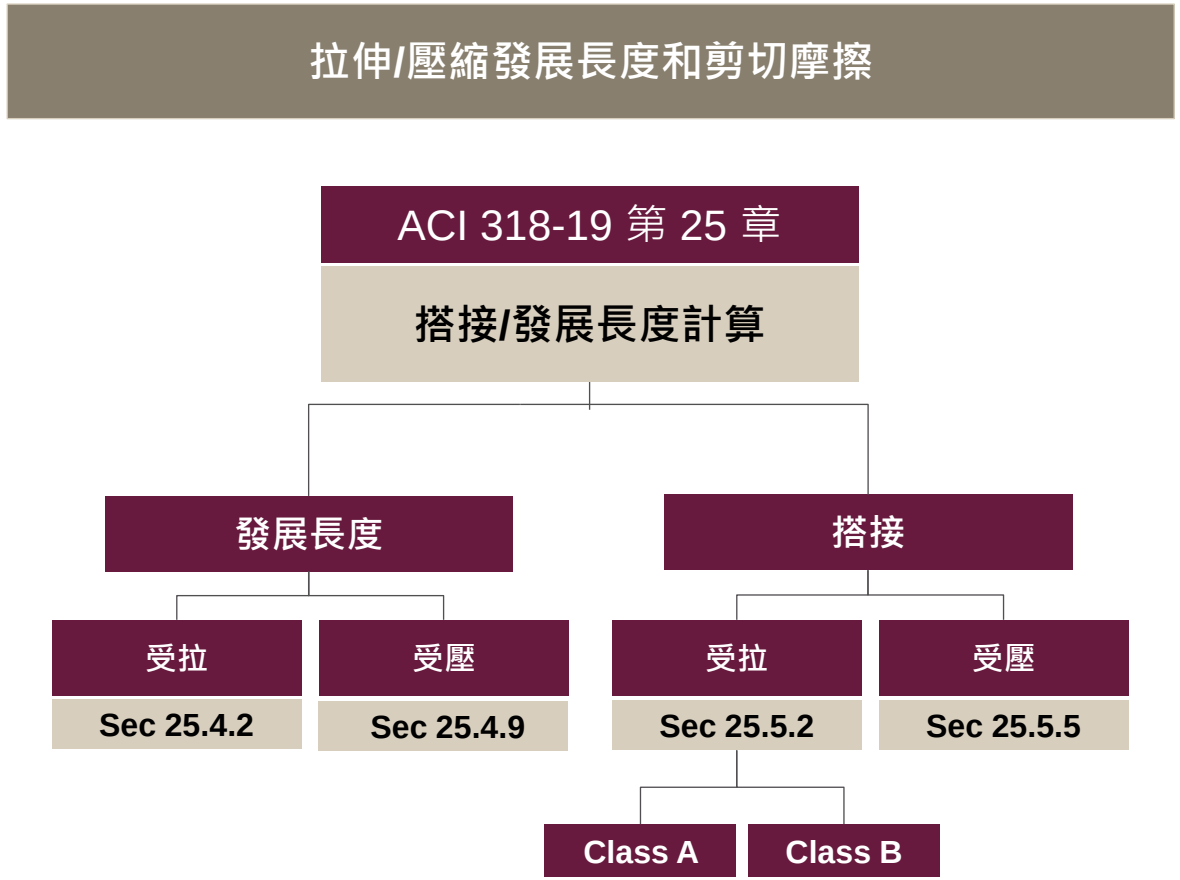
您目前混凝土與混凝土連接的設計方法是什麼？

ACI 318 第 25 章定義了設計後置鋼筋的發展長度和搭接規定。

但是，發展長度和搭接規定有最低埋入深度的要求，可能不適合您的應用。

25.4.2 *Development of deformed bars and deformed wires in tension*

25.4.2.1 Development length ℓ_d for deformed bars and deformed wires in tension shall be the greater of (a) and (b):
(a) Length calculated in accordance with 25.4.2.3 or 25.4.2.4 using the applicable modification factors of 25.4.2.5
(b) 12 in.



您通常如何設計混凝土與混凝土連接的鋼筋？

膠體經過測試來支持發展長度及搭接的計算

拉力發展長度：

ACI 318-19第25.4.2.4節

$$\ell_d = \left(\frac{3}{40} \frac{f_y}{\lambda \sqrt{f_c'}} \frac{\Psi_t \Psi_e \Psi_s \Psi_g}{\left(\frac{c_b + K_{tr}}{d_b} \right)} \right) d_b$$

根據ACI 318-19第25.4.2.4節，約束條件 $(c_b + K_{tr})/ d_b$ 不應大於 2.5，並且根據ACI 318-19第25.4.2.1節， l_d 的設計值不應**小於12英寸**

受壓發展長度:

ACI 318-19, 25.4.9.1

$$l_{dc} = MAX\left\{ \left(\frac{f_y \psi_r}{50\lambda\sqrt{f'_c}} \right) d_b \, ; \left(0.0003 f_y \psi_r \, d_b \right) ; \, 8 \, in. \right\}$$

認證過的後植鋼筋膠體系統
等同於預埋鋼筋

TABLE 32—DEVELOPMENT LENGTH FOR EU METRIC REINFORCING BARS IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT OR HILTI HOLLOW CARBIDE BIT OR CORE DRILLED WITH A DIAMOND CORE BIT OR A DIAMOND CORE BIT AND ROUGHENED WITH A HILTI ROUGHENING TOOL[1,2,5,6]

DESIGN INFORMATION	Symbol	Criteria Section of Reference Standard	Units	Bar Size					
				10	12	16	20	25	32
Nominal reinforcing bar diameter	d_b	BS4449: 2005	mm	10	12	16	20	25	32
			(in.)	(0.394)	(0.472)	(0.630)	(0.787)	(0.984)	(1.260)
Nominal bar area	A_b	BS 4449: 2005	mm^2	78.5	113.1	201.1	314.2	490.9	804.2
			(in^2)	(0.12)	(0.18)	(0.31)	(0.49)	(0.76)	(1.25)
Development length for f_y = 72.5 ksi and f'_c = 2,500 psi (normal weight concrete)[3,4]	l_d	ACI 318-19 25.4.2.4[7] ACI 318-14 25.4.2.3 ACI 318-11 12.2.3	mm	348	417	556	871	1087	1392
			(in.)	(13.7)	(16.4)	(21.9)	(34.3)	(42.8)	(54.8)
Development length for f_y = 72.5 ksi and f'_c = 4,000 psi (normal weight concrete)[3,4]	l_d	ACI 318-19 25.4.2.4[7] ACI 318-14 25.4.2.3 ACI 318-11 12.2.3	mm	305	330	439	688	859	1100
			(in.)	(12.0)	(13.0)	(17.3)	(27.1)	(33.8)	(43.3)

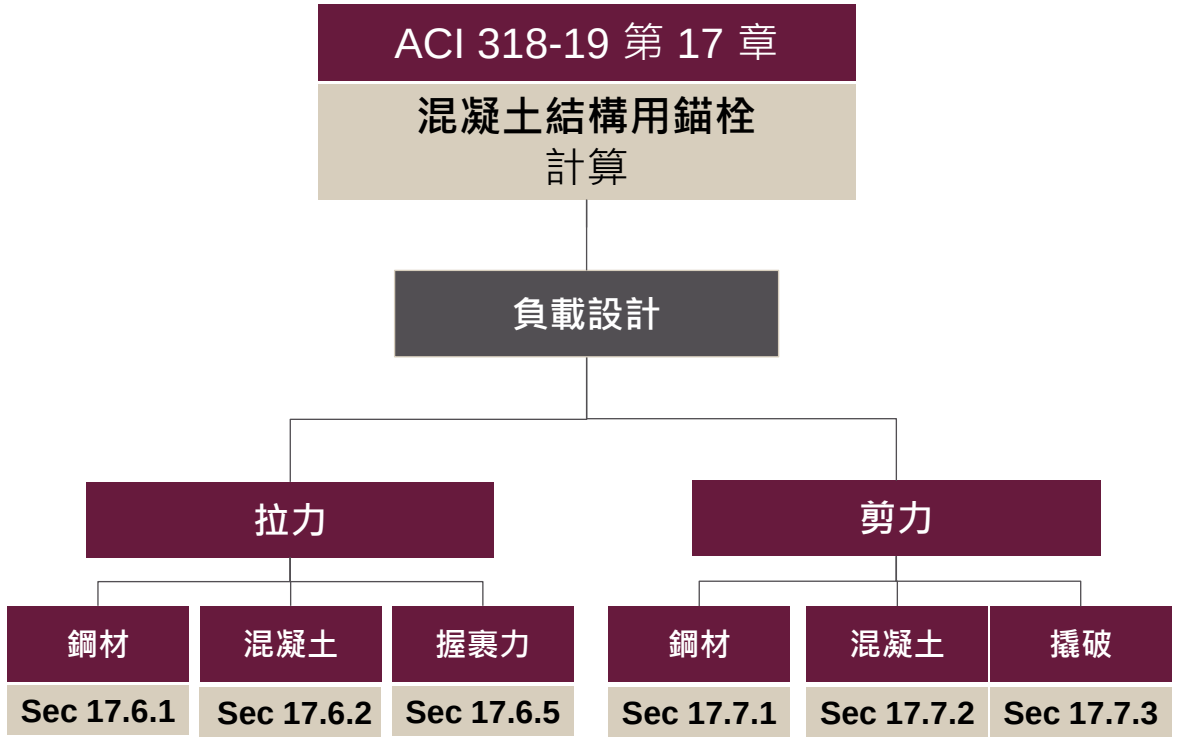
For **SI**: 1 inch ≡ 25.4 mm, 1 lbf = 4.448 N, 1 psi = 0.006897 MPa.
For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf, 1 MPa = 145.0 psi

[1]Development lengths valid for static, wind, and earthquake loads (SDC A and B).
[2]Development lengths in SDC C through F must comply with ACI 318 (-19 or -14) Chapter 18 or ACI 318-11 Chapter 21 and section 4.2.4 of this report.
[3] For all-lightweight concrete, increase development length by 33% unless the provisions of ACI 318-19 25.4.2.5 or ACI 318-14 25.4.2.4 are met to permit λ > 0.75. For sand-lightweight concrete, increase development length by 18% unless the provisions of ACI 318-19 25.4.2.5 or ACI 318-14 25.4.2.4 are met to permit λ > 0.85
[4] $\left(\frac{c_b+K_{tr}}{d_b}\right)$ = 2.5, ψ_t=1.0, ψ_e=1.0, ψ_s=0.8 for d_b < 20 mm,1.0 for d_b ≥ 20 mm
[5]Calculations may be performed for other steel grades per ACI 318 (-19 or -14) Chapter 25 or ACI 318-11 Chapter 12.
[6]Minimum development length shall not be less than 12 in (305 mm) per ACI 318 (-19 or -14) Section 25.4.2.1.
[7] l_d must be increased by 9.5% to account for ψ_g in ACI 318-19 25.4.2.4. ψ_g has been interpolated from Table 25.4.2.5 of ACI 318-19 for f_y = 72.5 ksi.

符合建築設計法規，並參照混凝土結構用錨栓設計規範

AC308表3.2概述了評估化學藥劑系統（產品+錨固件+安裝參數）是否符合ACI 318混凝土結構用錨栓規定的測試計畫。

測試計畫中可使用鋼筋作為錨固件。符合測試計畫的化學藥劑系統（產品 +錨固件+ 安裝參數）將會有一份公開的評估報告（ICC-ESR 或 IAPMO-ER），證明其符合規範的錨栓設計規定（如 ACI 318-19 第 17 章）。

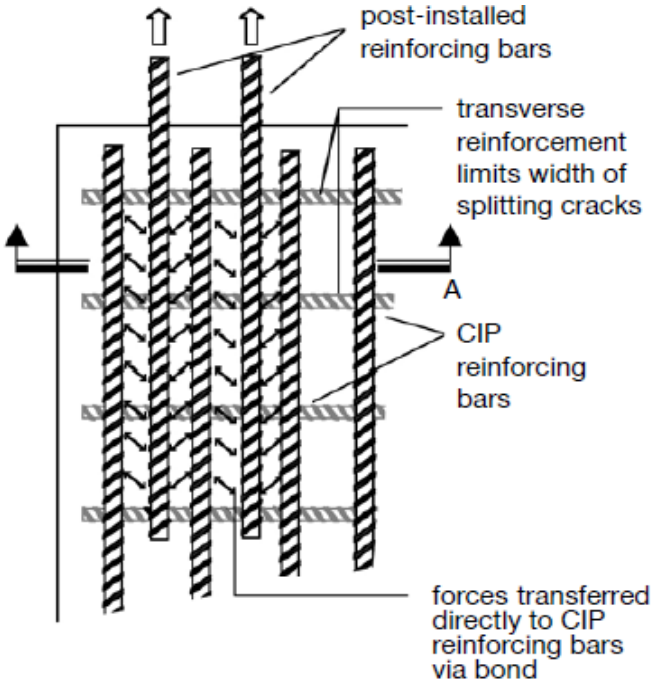


根據ACI 318第17章的規定，後置鋼筋可以設計為錨固件

混凝土對混凝土連接的設計

ACI 318-19 **25章**

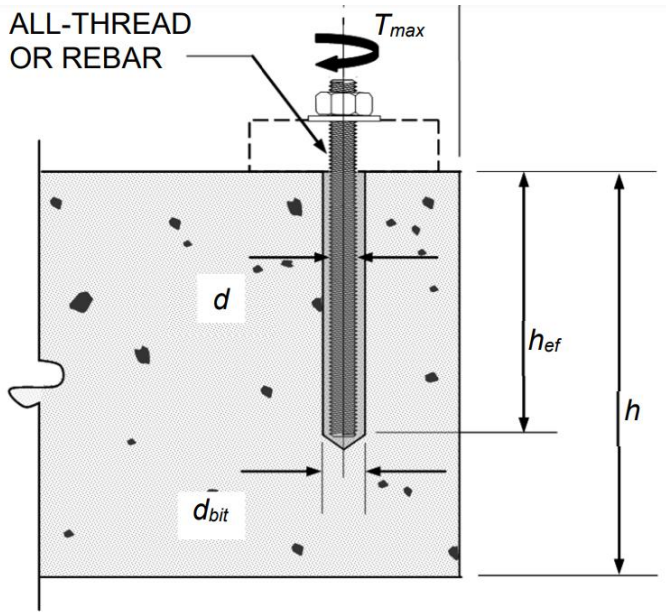
搭接 / 發展長度 計算



或者

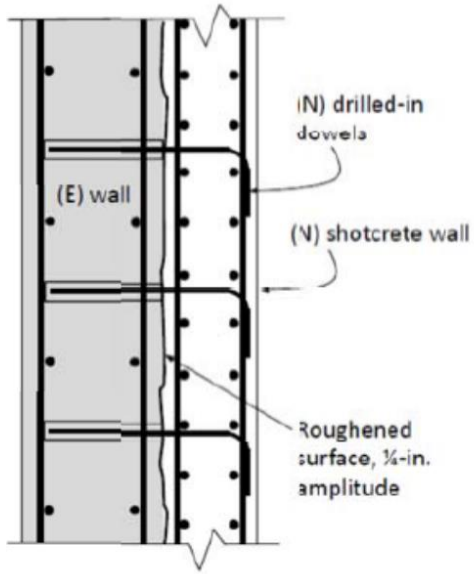
ACI 318-19 **17章**

錨栓條文 計算



ACI 318-19 **22章**

剪切界面 計算



為了滿足作業現場條件，後置植筋可以使用各種方法進行設計

拉力計算			剪力計算
發展/ 搭接長度		錨栓設計	介面剪力計算
ACI 318-19 第25章		ACI 318-19 第17章	ACI 318-19 第22章
發展	搭接	錨栓設計破壞模式	發展
在混凝土中發展鋼筋強度所需的長度	將應力從一鋼筋完全傳遞到另一鋼筋所需的長度	可以使用各種破壞模式來計算將荷載傳遞到混凝土所需的鋼筋	橫跨剪切平面的鋼筋將表面連在一起，允許通過摩擦進行剪切傳遞 假設鋼筋的降伏可以按第25章計算

展望： 研究複雜的後置植筋設計的替代設計方法

拉力計算			剪力計算	
發展/ 搭接長度		錨栓設計	介面剪力計算	
ACI 318-19 第25章		ACI 318-19 第17章	ACI 318-19 第22章	Hilti 後置植筋方法
發展	搭接	錨栓設計破壞模式	剪切摩擦理論	替代設計方法
在混凝土中發展鋼筋強度所需的長度	將應力從一鋼筋完全傳遞到另一鋼筋所需的長度	可以使用各種破壞模式來計算將荷載傳遞到混凝土所需的鋼筋 可用於反向計算使鋼筋發展到降伏所需的長度	橫跨剪切平面的鋼筋將表面連在一起，允許通過摩擦進行剪切傳遞 假設鋼筋的降伏可以按第25章計算或第17章	橫跨剪力平面的鋼筋結合了摩擦和剪力榫作用機制的總和。 可減少埋入深度

研究的替代設計方法為後製植筋設計提供了靈活性。

ACI 318 第 22 章 - 剪切摩擦計算模型 - 剪力傳遞

ACI 318-19 **Chapter 22**

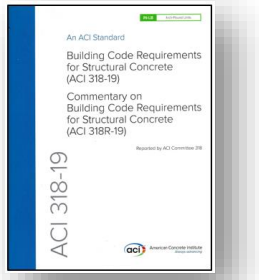
- 剪力摩擦 - 平面上的剪力傳遞假設鋼筋的面積 Avf 用於傳遞平面上的剪力
- 假設鋼筋在平面兩側降伏

$$\phi V_n = \phi\, \mu\, A_{vf}\, f_y \qquad \text{or} \qquad A_{vf} = \frac{V_u}{\phi\, \mu\, fy}$$

Table 22.9.4.2—Coefficients of friction

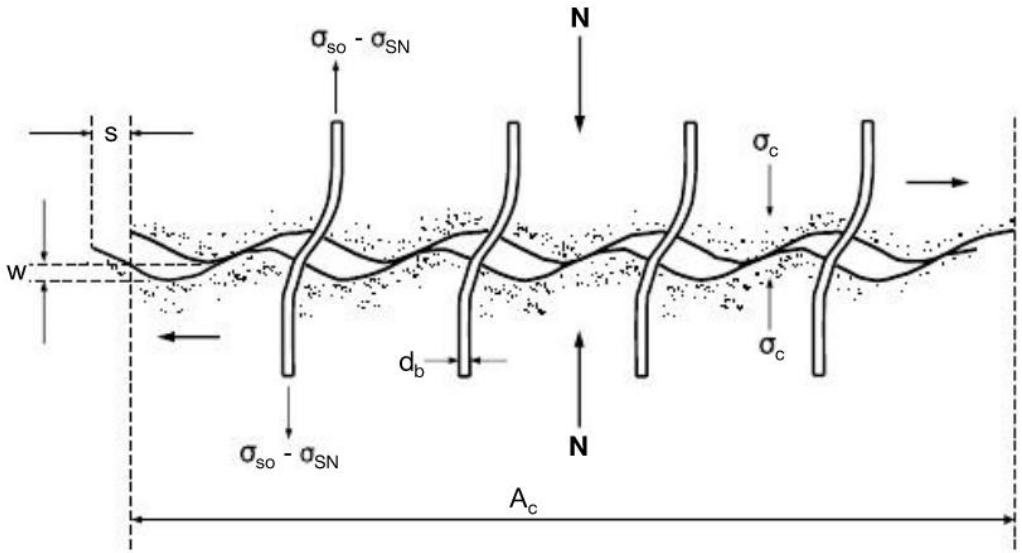
Contact surface condition	Coefficient of friction μ[1]	
Concrete placed monolithically	1.4λ	(a)
Concrete placed against hardened concrete that is clean, free of laitance, and intentionally roughened to a full amplitude of approximately 1/4 in.	1.0λ	(b)
Concrete placed against hardened concrete that is clean, free of laitance, and not intentionally roughened	0.6λ	(c)
Concrete placed against as-rolled structural steel that is clean, free of paint, and with shear transferred across the contact surface by headed studs or by welded deformed bars or wires.	0.7λ	(d)

[1]λ = 1.0 for normalweight concrete; λ = 0.75 for all lightweight concrete. Otherwise, λ is calculated based on volumetric proportions of lightweight and normalweight aggregate as given in 19.2.4, but shall not exceed 0.85.



Hilti Method (aka: Palieraki Method)

- 產生摩擦力的剪切面上的正向（夾緊）力與埋入量成正比
- 將基於介面條件的摩擦係數（不同於 ACI）乘以正向力，以確定跨平面的摩擦力



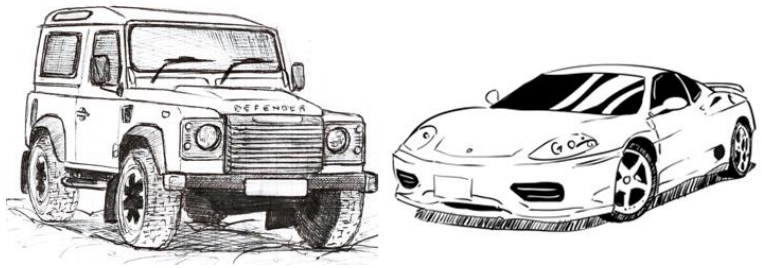
議程

- 介紹
- 最關鍵的影響?
- 產品認證
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

如何確保駕駛安全？

選擇適合的車

- 在什麼樣的道路上選擇什麼樣的汽車？



所有車輛必須經運輸部門認證！

訓練與駕駛執照

- 駕駛教練將教授**交通規則**
- 駕駛學員將學會**駕駛汽車和遵守規則**
- 考試合格後**頒發駕駛執照**

速度/合法性檢查

- 如果駕駛員車速過快，可能會被**罰款**
- 可能需要**額外培訓**
- 最糟糕的情況是，駕駛員可能會被**吊銷駕駛執照**

確保安全安裝品質的類似措施...

選擇緊固件

- 選擇緊固件時應考慮

施工現場的條件和

安裝人員的技能

- 安裝簡易性、安全性能 - 不盡相同。

安裝人員培訓和安裝人員認證

- 安裝人員和監造需要掌握正確工作的方法！
- 註：德國、美國或澳大利亞等國針對特定應用制定了安裝人員認證計畫

現場 "測試 "已安裝的緊固件

- 在沒有制定安裝者認證的情況下

議程

- 介紹
- 最關鍵的影響?
- 產品認證
- 後置錨栓 - 基於ACI 318 17章的設計
- 後置植筋 - 基於ACI 318 25章的設計
- 安裝品質
- 總結

總結

- 後置植筋應用於不同應用：混凝土與鋼的連接應按照 ACI 318-19 第 17 章進行設計；混凝土與混凝土的連接應遵循 ACI 318-19 第 25 章的規定，在長度範圍條件不允許設計發展長度的情況下，基於**另外研究的方法**可以被使用

- 產品應**根據 ACI 355 和相應的 ICC-ES 驗收標準**，在相應的施工現場條件（鑽孔和清潔方法、水等）下進行**靜態和地震荷載測試**。

- 測試結果由獨立機構進行評估，並匯總到 ICC-ES 或 IAPMO 等機構發佈的**評估報告**中。

- 如果採用了**正確的設計方法**，並根據 MPII（製造商產品安裝說明）使用了**符合應用要求的產品**，則連接是可靠的。

THANK YOU!