

NAR Labs

國家實驗研究院

2016 建築物耐震評估與補強技術講習會

耐震補強工程之植筋應用

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梁柱構件內



翼牆補強

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有地梁內

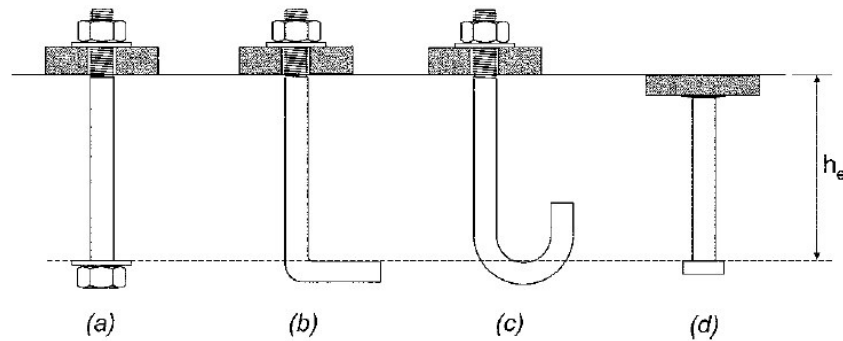


牆筋植入舊有梁
柱構件內



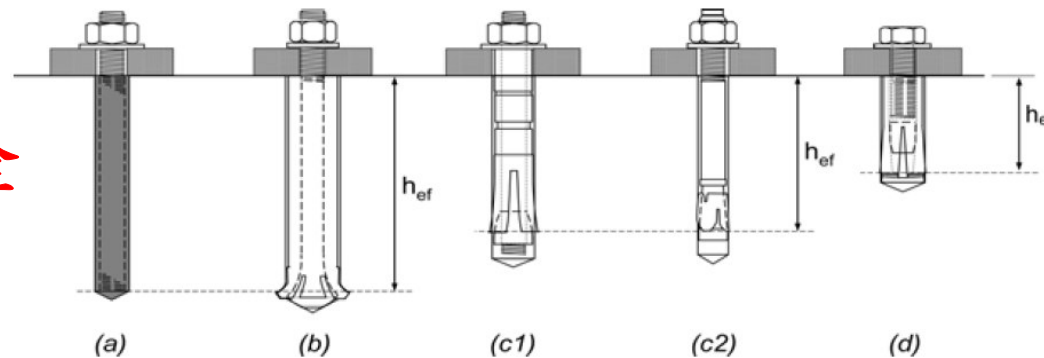
錨栓種類

預埋式錨栓



(a) 六角頭螺栓含墊片 (b)L-型錨栓 (c)J形錨栓 (d)焊接剪力釘

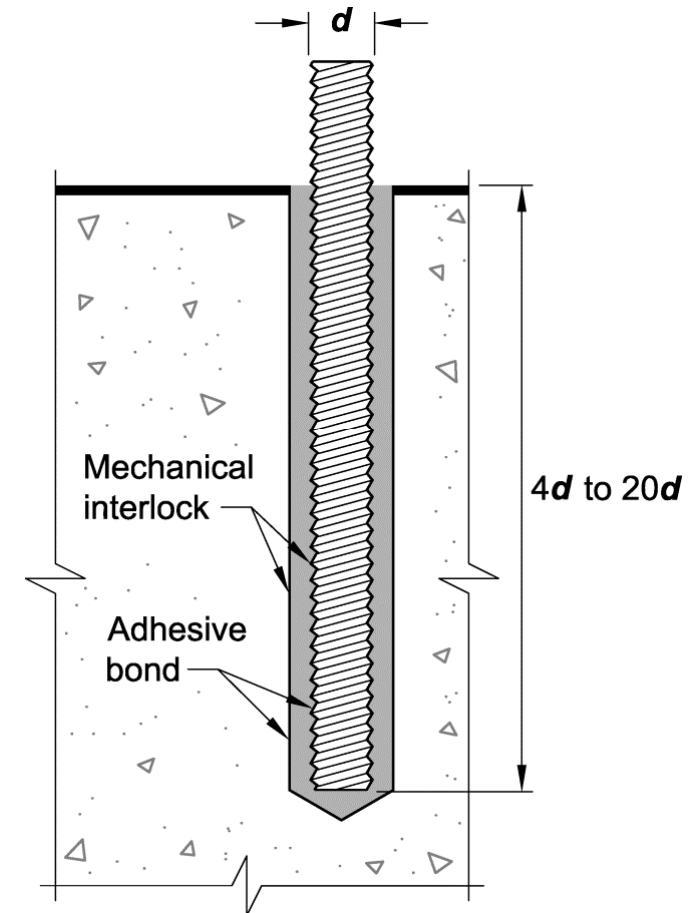
後置式錨栓



(a) 黏結式錨栓 (b)擴底式錨栓 (c1)扭力控制膨脹錨栓
(c2)Stud型 (d)位移控制型膨脹錨栓

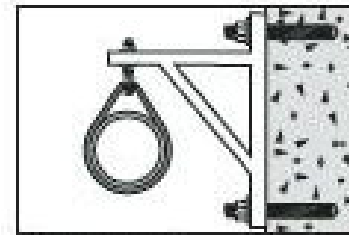
黏結式錨栓之原理

- 不同於利用摩擦力或支承作用力之後置式機械錨栓，化學錨栓主要係藉由黏著劑對混凝土以及錨栓兩者產生之黏著力，進而連結於混凝土或石材內。

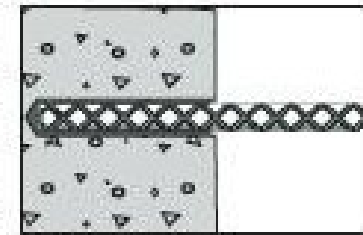


黏結式錨栓之優點

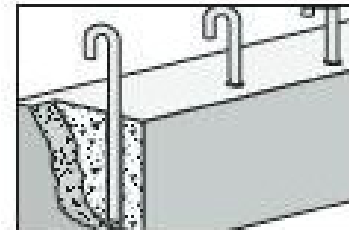
- 高性能
- 可輕易依據變更設計而調整位置
- 可使用多種錨栓因應不同方案
- 且安裝設備要求不繁複



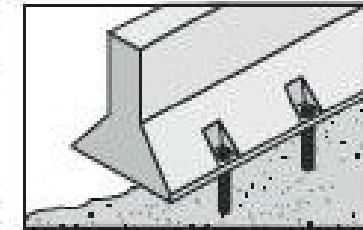
Pipe support



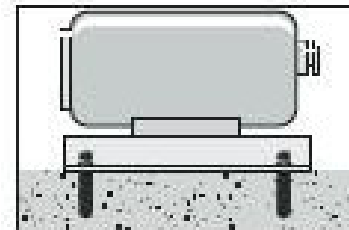
Reinforcing bars



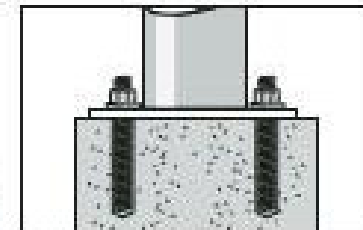
Hooked bars



Median barriers



Machine bases



Light poles

2006 美國 “Big Dig” 隧道意外

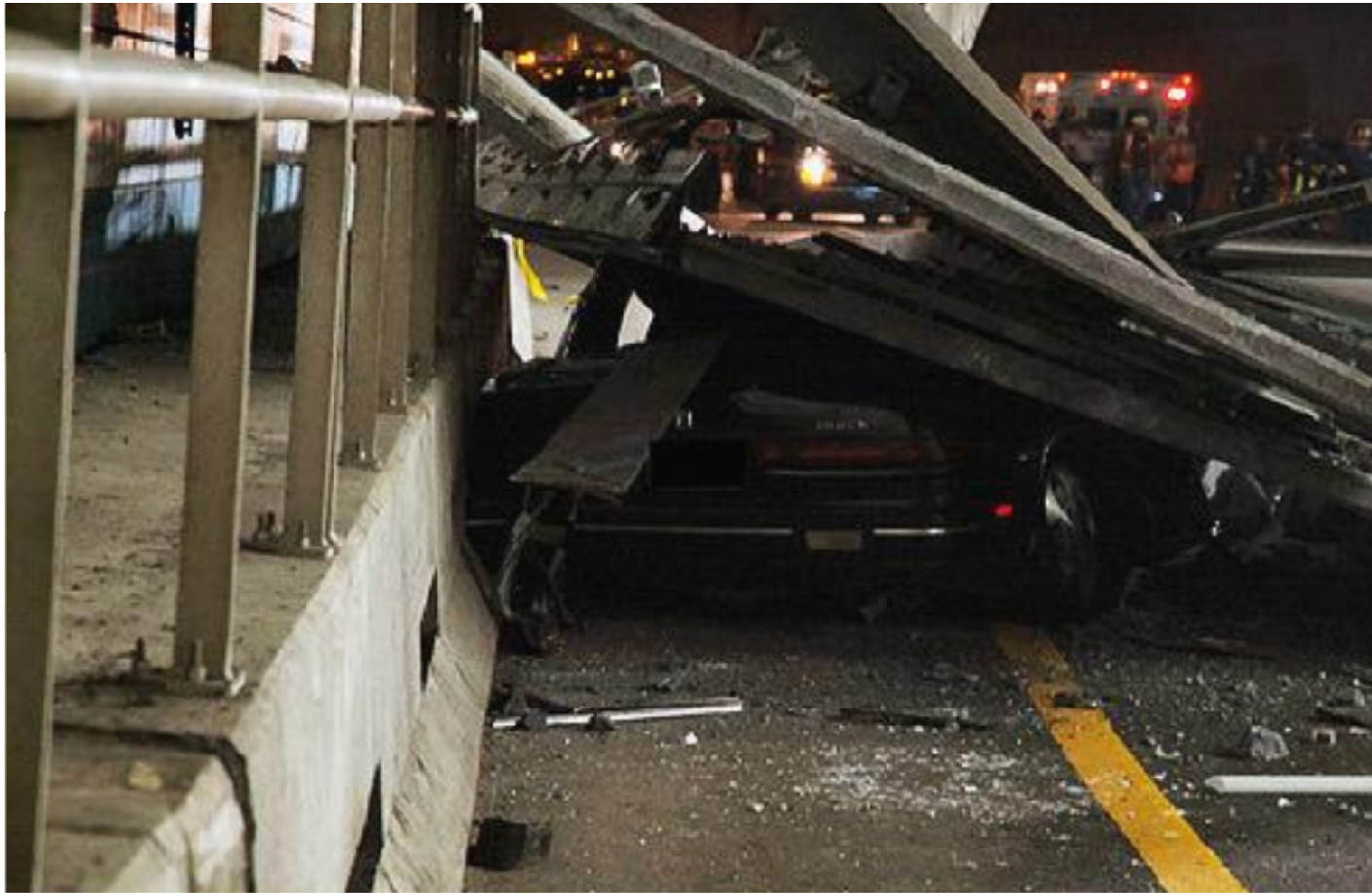




Figure 3. Plan view (top) and aerial view (bottom looking west) of the D Street portal

- 發生時間：2006年7月10日（日）11：01分
- 發生場所：波士頓90號州際公路連接隧道
- 發生狀況：隧道內混凝土天花頂板掉落
- 人員損傷狀況：死者1人、負傷者1人

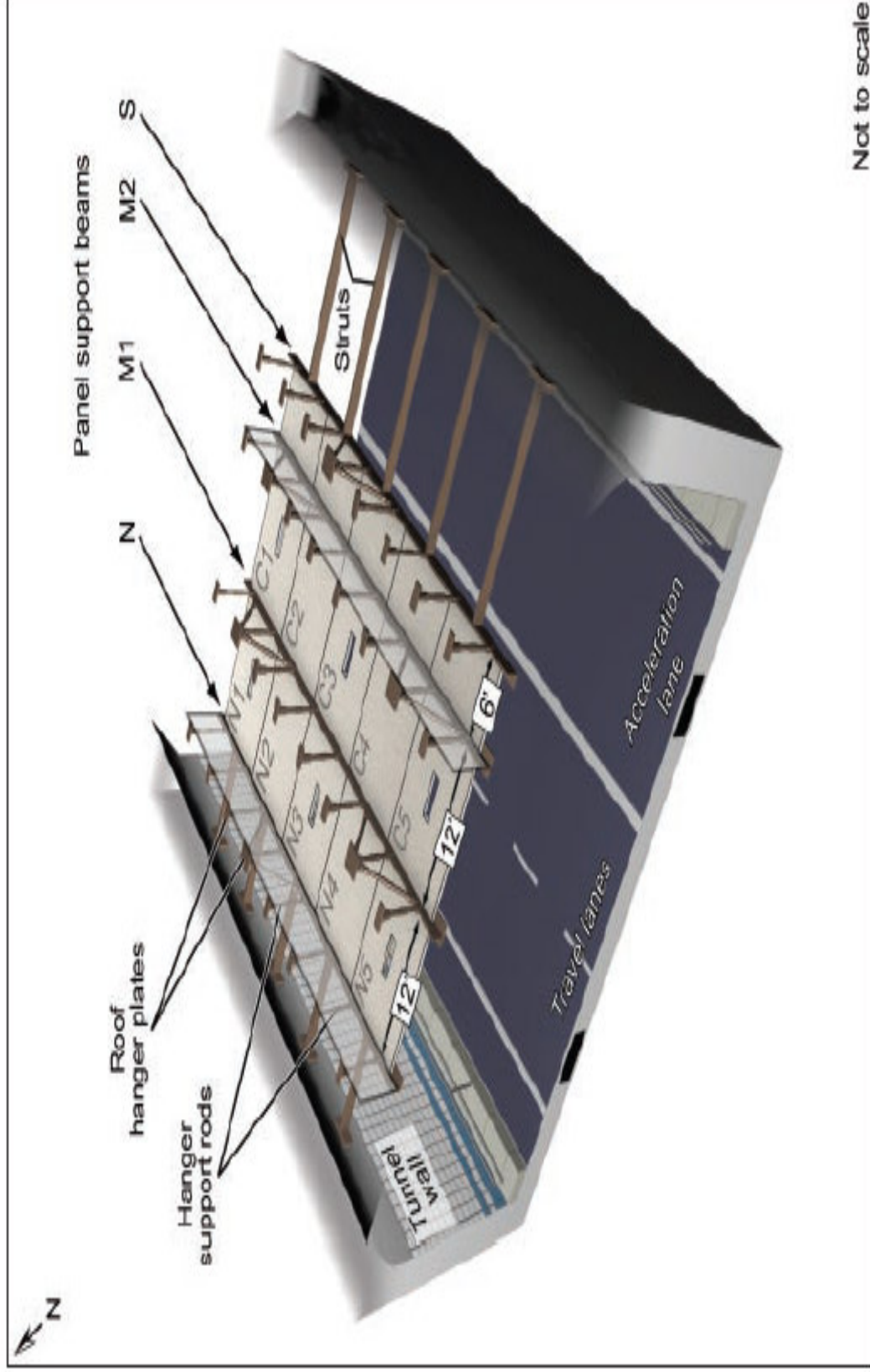


Figure 5. Overview of the support structure for the accident ceiling module. Panels and support beams show alphanumeric designations that were assigned during postaccident reconstruction.

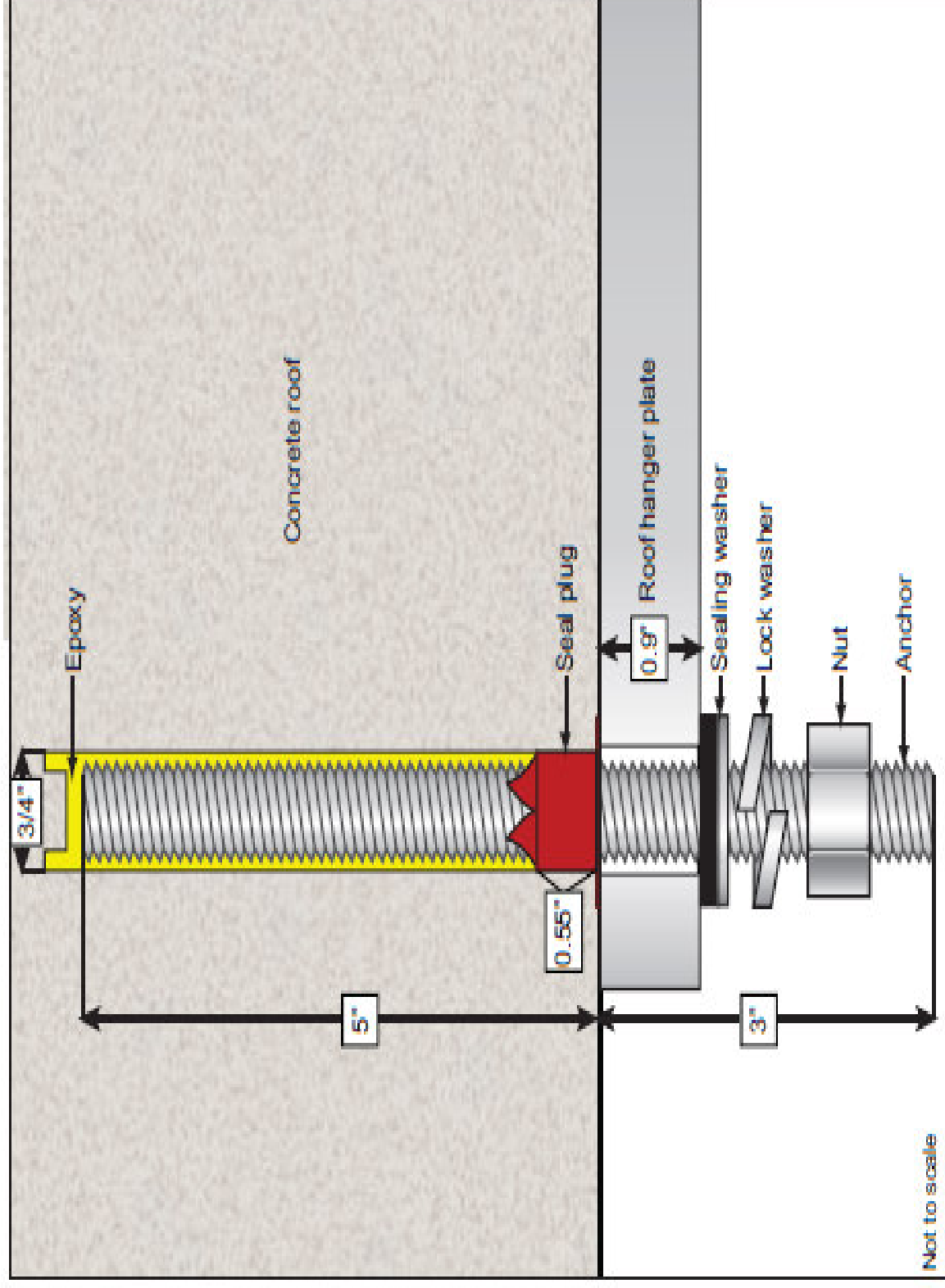


Figure 7. Typical adhesive anchor and roof hanger plate assembly.

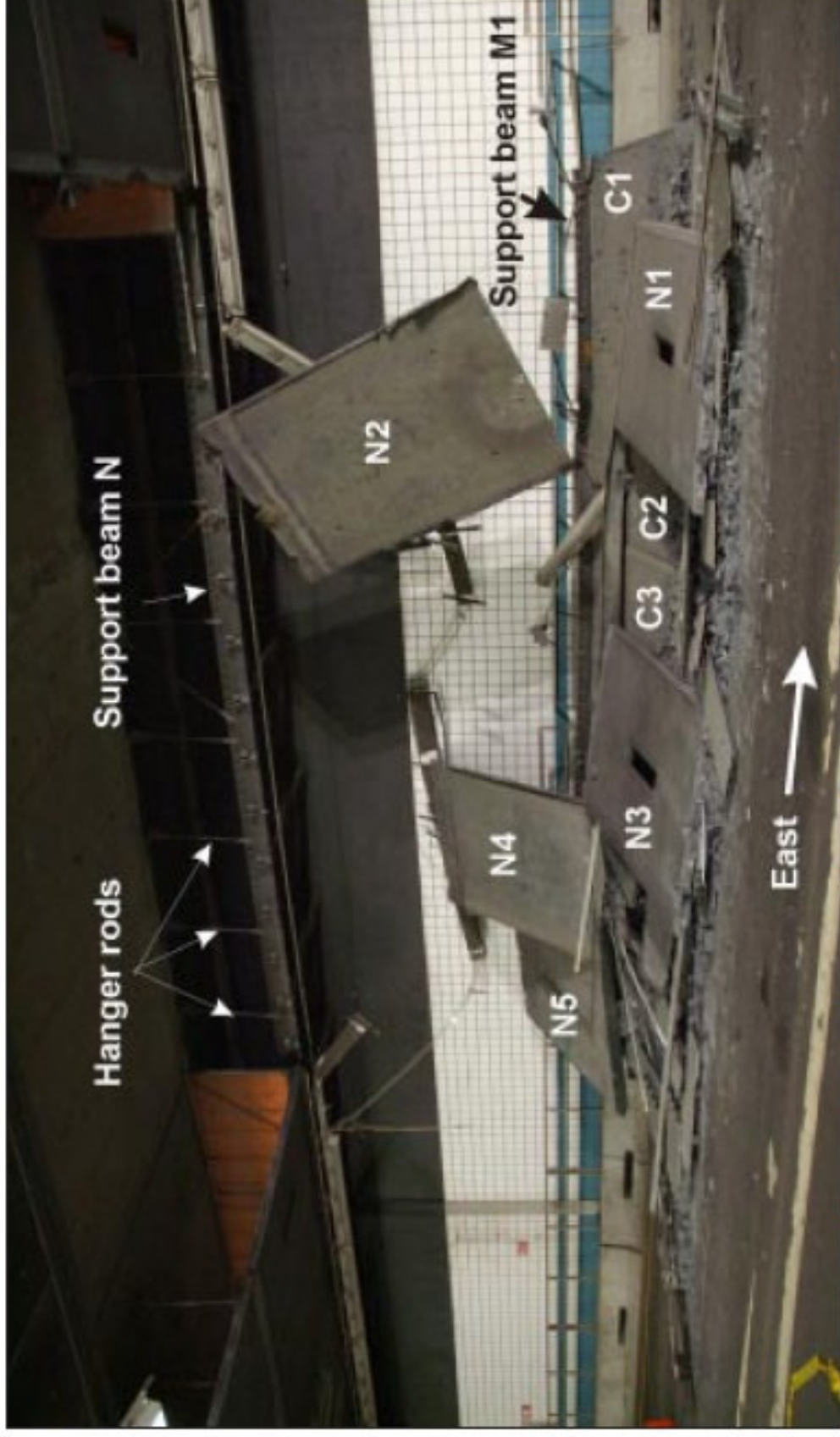


Figure 8. Looking north at the collapsed concrete panels before removal from the tunnel. Components shown as labeled for postaccident reconstruction. (Photograph courtesy Massachusetts State Police)





Big Dig 錨栓損壞案例

- 為回應NTSB之建議，ACI 318-11之附錄D要求使用這類化學錨栓應通過合格檢驗。此外，附錄D要求水平方向或斜上方向(倒吊面)之安裝方式，如用於支撐長期張力荷重者，應由通過認證程序之技術人員執行，如ACI-CRSI化學植筋與錨栓安裝技術員認證課程。

黏結式錨栓之強度設計

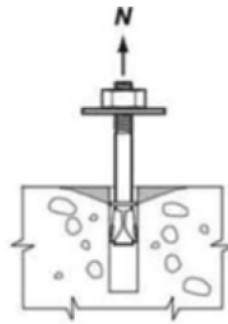
錨栓設計依據

- 完整
 - ACI 318-11 Appendix D Anchoring to Concrete
 - ACI 318-14 Chapter 17 Anchoring to Concrete
- 過渡
 - ACI 318-05 Appendix D Anchoring to Concrete
 - (現行混凝土設計規範 附篇D 錨栓應用混凝土結構)

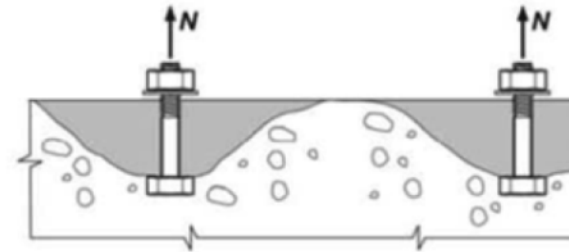
拉力破壞模式



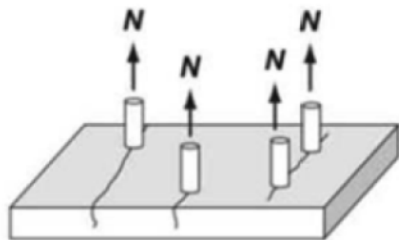
鋼材破壞



拔出



混凝土拉破



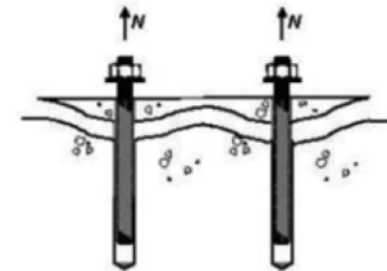
混凝土劈裂



脹破



Single

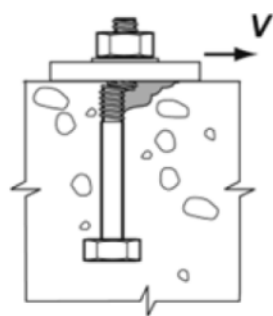


Group

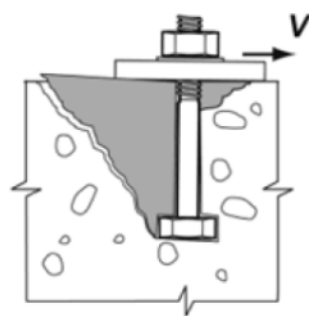
植筋膠黏著強度不足
(植筋特有之破壞模式)

拉力

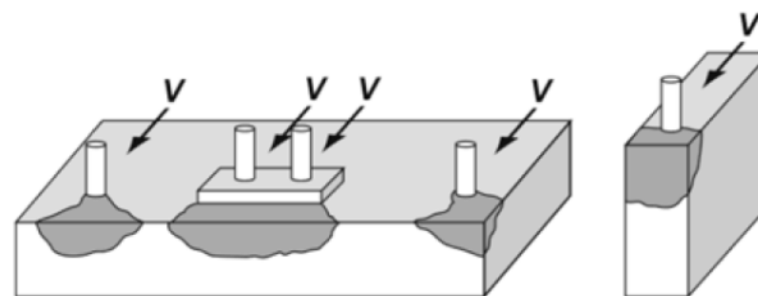
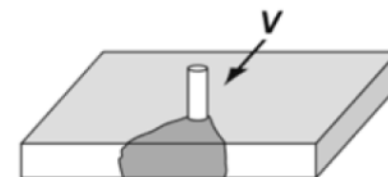
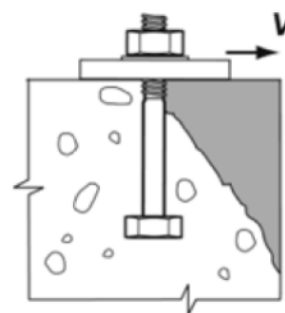
剪力破壞模式



錨栓鋼材剪斷



混凝土撬破



混凝土剪破

剪力

鋼材破壞



混凝土拉破

- 錨栓植入過淺，通常是導致此種破壞之原因



混凝土劈裂

- 易發生於錨栓位置過度靠近混凝土邊緣或另一錨栓時。除非另有特殊規定，化學錨栓之最小邊距需求應為 $6d_a$ （標稱直徑）以上



植筋膠黏著強度不足

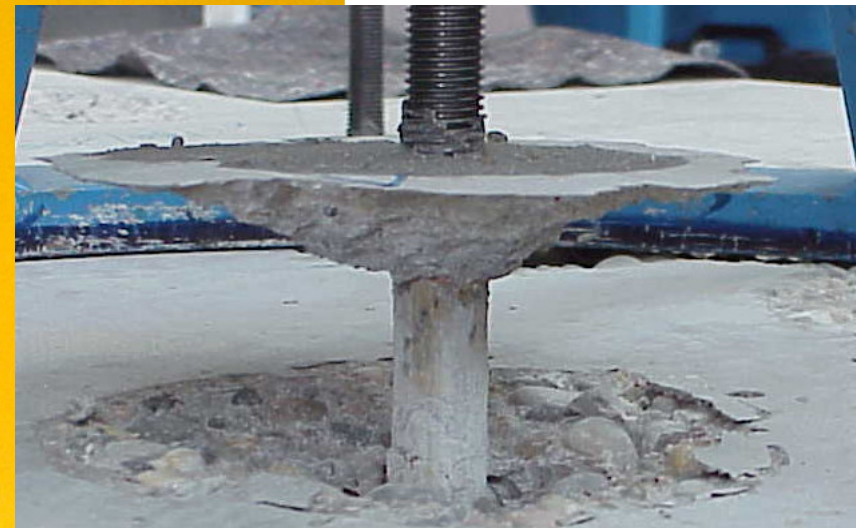
- 荷重超過黏著劑與混凝土，或與錨栓之結合強度



植筋膠黏著強度不足



photos courtesy of University of Stuttgart



化學錨栓之剪力破壞



混凝土剪裂破壞

- 在錨栓以及結構邊緣間之混凝土受剪裂而剝脫，此種破壞通常是因為錨栓前方混凝土太少所造成



錨栓之強度設計考量

ACI 318-14第17.3節

- 拉力
 - 錨栓鋼材拉力強度 N_{sa}
 - 混凝土拉破強 N_{cb}
 - 錨栓拔出強度 N_{pn} (預埋、後置膨脹、擴底錨栓)
 - 混凝土邊緣脹破強度 N_{sb} (擴頭撓栓)
 - 黏結式錨栓之握裹強度 N_b
- 剪力
 - 錨栓鋼材剪力強度 V_{sa}
 - 混凝土剪破強度 V_{cb}
 - 混凝土撓破強度 V_{cp}

植筋之拉力強度設計(1)

錨栓鋼材拉力強度 N_{sa}

$$N_{sa} = A_{se,N} f_{uta}$$

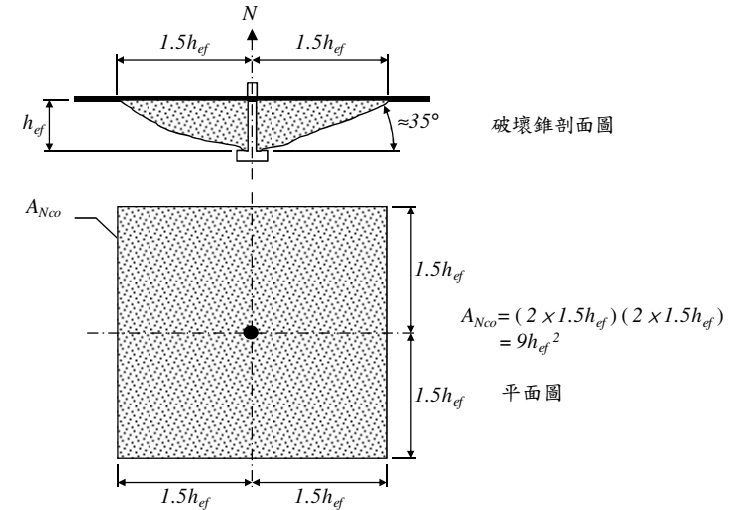
其中，

$A_{se,N}$ 為單根錨栓拉力之有效斷面積，
 f_{uta} 不可超過 $1.9f_{ya}$ 或 $8,750\text{kgf/cm}^2$ 。

植筋之拉力強度設計(2-1)

混凝土拉破強度 N_{cb}

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



A_{Nc} 為單根錨栓之混凝土破壞錐面積

A_{nco} 為邊距足夠時混凝土破壞錐面積

$\psi_{ed,N}$ 為邊距修正因數

$\psi_{c,N}$ 為未開裂混凝土修正因數

$\psi_{cp,N}$ 為配置輔助鋼筋之修正因數

N_b 為單根錨栓之基本混凝土拉破強度

植筋之拉力強度設計(2-2)

單根錨栓之基本混凝土拉破強度 N_b

$$N_b = k_c \sqrt{f'_c} h_{ef}^{1.5}$$

k_c 為基本混凝土拉力破裂之因數

預埋式錨栓為 10 kgf/cm^2

預埋式錨栓為 7.2 kgf/cm^2

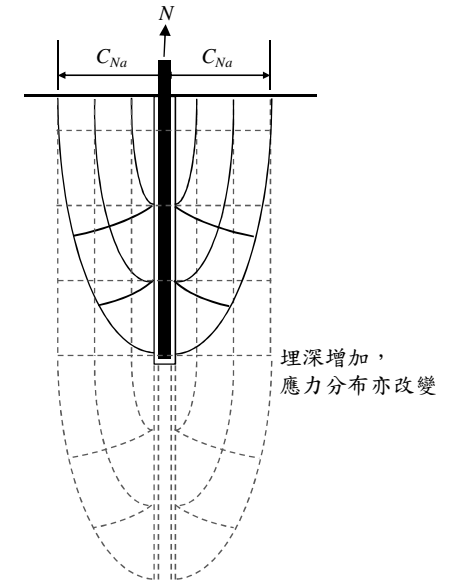
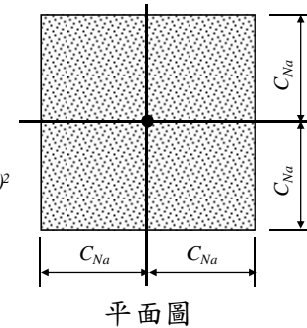
h_{ef} 為錨栓之埋置深度

植筋之握裹強度設計(3-1)

混凝土握裹強度 N_a

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

$$A_{Na0} = (2C_{Na})^2 = 4C_{Na}^2$$



A_{Na} 為單根錨栓之握裹破壞錐面積

A_{Na0} 為邊距足夠時之握裹破壞錐面積

$\psi_{ed,Na}$ 為邊距修正因數

$\psi_{cp,Na}$ 為配置輔助鋼筋之修正因數

N_{ba} 為單根錨栓之基本握裹強度

植筋之拉力強度設計(3-2)

單根錨栓之基本握裹強度 N_{ba}

$$N_{ba} = \lambda_a \tau_{cr} \pi d_a h_{ef}$$

λ_a 為輕質混凝土修正因數

τ_{cr} 為特徵握裹應力

h_{ef} 為錨栓之埋置深度

安裝和 使用環境	錨栓安裝時之 混凝土濕度	混凝土使用期間 最高溫度(°C)	τ_{cr} (kgf/cm ²)	τ_{cr} (kgf/cm ²)
室外	乾燥至完全飽和	80	14	45.5
室內	乾燥	37.7	21	70

植筋之需求埋置深度 h_{ef} 計算

- 校舍耐震補強工程圖說
 - 一 植入之鋼筋能承受不小於鋼筋規定降伏強度之拉力

以混凝土拉破強度計算埋置深度

$$\phi N_{cb} = A_s \times f_y \quad \longrightarrow \quad h_{ef} = 8.67\text{cm}$$

以錨栓握裹強度計算埋置深度

$$\phi N_a = A_s \times f_y \quad \longrightarrow \quad h_{ef} = 42.4\text{cm} \quad \text{需求深度過深}$$

特徵握裹應力之採用

- 依據ACI 318之說明，特徵握裹應力可使用ACI 355.4試驗方法進行評估之結果值。
- 參考ICC Evaluation Service(ICC-ES)之報告
 - 對建築產品、組件、方法和材料進行評估的非營利機構
 - 評估產品是否符合規範要求
- 採常用之HILTI RE500-SD植筋藥劑為參考
 - ICC-ES Report ESR-2322

常用鋼筋對應之需求埋置深度

- 採用 HILTI RE500-SD 植筋藥劑之 ICC-ES Report ERS-2322

設計條件		#3	#4
ACI 318-14	τ_{cr} (kgf/cm ²)	21	21
	SD 280 h_{ef} (cm)	42.0	57.2
	SD 420 h_{ef} (cm)	63.0	85.9
ICC-ES Report ESR-2322	τ_{cr} (kgf/cm ²)	76.6	75.3
	SD 280 h_{ef} (cm)	11.6	16.0
	SD 420 h_{ef} (cm)	17.3	24.0

低強度鋼筋混凝土植筋

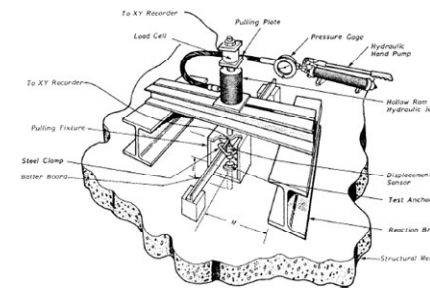
- ACI 318規範與ICC-ES Report ERS-2322均適用在混凝土強度 175 kgf/cm^2 以上
- 對於低強度混凝土植筋需修正植筋深度

$$h_{ef} = h_{ef,175} \times \sqrt{\frac{175}{f'_c}}$$

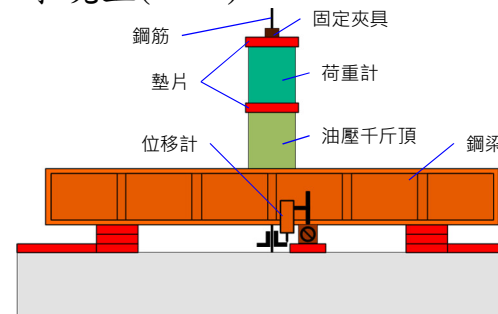
低強度鋼筋混凝土植筋拉拔試驗

- 李曉盈(2013)
- 共計87支#3、#4植筋
- SD 420鋼筋
- 植筋藥劑為HILTI RE500-SD
- 依廠商提供之安裝說明植筋
- 試驗裝置參考ASTM E488

ASTM E488

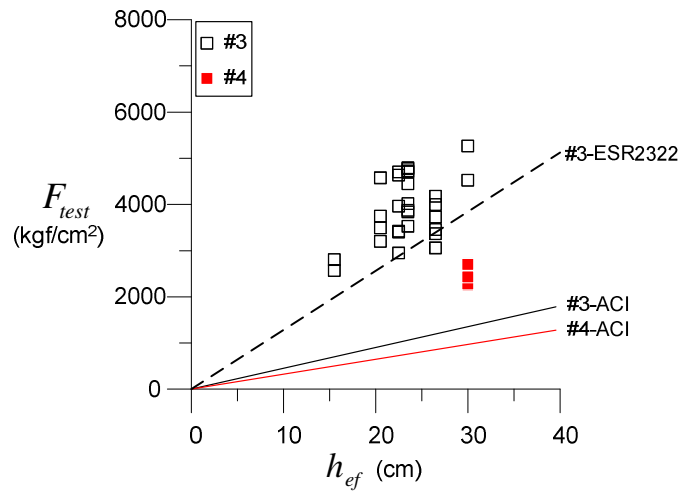


李曉盈(2013)

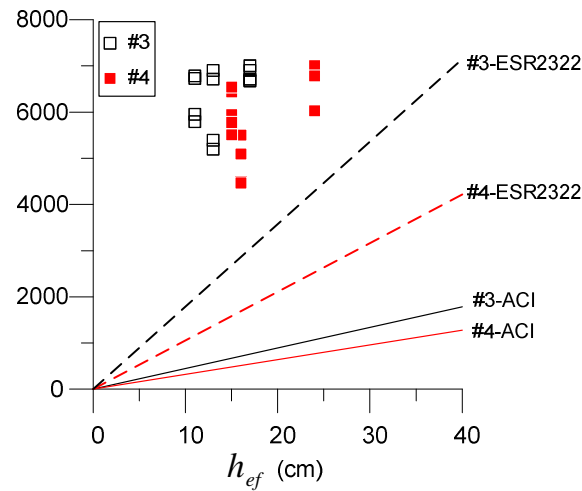


	50 kgf/cm^2		100 kgf/cm^2		150 kgf/cm^2	
SD420鋼筋	#3	#4	#3	#4	#3	#4
深度-數量 (cm)-(支)	15.5-2	30-6	11-4	15-5	9.5-2	13-4
	20.5-4		13-4	16-4	11-2	20-6
	22.5-6		17-6	24-5	14-9	
	23.5-10					
	26.5-6					
	30-2					

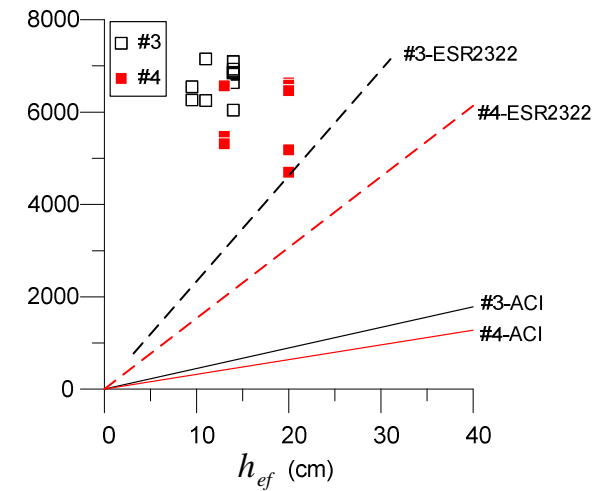
植筋拉拔試驗結果比較



(a) $f'_c = 50 \text{ kgf/cm}^2$



(b) $f'_c = 100 \text{ kgf/cm}^2$



(c) $f'_c = 150 \text{ kgf/cm}^2$

- $50(\text{kgf/cm}^2)$ 之混凝土不建議使用#4鋼筋植筋
- 100 及 $150(\text{kgf/cm}^2)$ 之混凝土採用建議之植筋深度表，經低強度修正後仍屬保守

植筋施工步驟

植筋施工之步驟(1/2)

- 施工應嚴格遵守**原廠安裝指示書(Manufacturer's Printed Installation Instructions, MPII)**所規定之步驟
 - **植筋之施工**：需要由合格之專業技術人員施做。
 - **鑽孔位置**：須按照設計圖指定之位置施做。
 - **避免鑽到原有鋼筋**：植筋鑽孔前應使用鋼筋探測器或可行之方法確認原結構之鋼筋位置，並繪製預定鑽孔位置於原混凝土表面，經由與工程司會勘核可後方可施工。
 - **鑽孔深度**：依照設計圖指定之深度施做，由於各廠牌間植筋藥劑成分不同且既有結構物之混凝土強度亦有差異，承包商施工前應會同監造單位須進行施工前拉拔試驗，並提出書面文件及試驗相片以供確認。

植筋施工之步驟(2/2)

- 鑽孔過程若遇鋼筋，不可破壞或鑽斷，若在未達設計孔深就遇到鋼筋，則此鑽孔應予以廢棄，另行鑽孔，**廢孔應以無收縮水泥砂漿填實**。
- 鑽孔完畢後應徹底以**高壓空氣及毛刷**清除孔內灰屑，清除過程中應注意避免造成空氣汙染。
- 將植筋藥劑裝入原廠指定之注射器，以裝有混合器之注射頭深入孔底緩緩將植筋藥劑打入孔內，邊打邊退，直到至少六分滿為止，再將鋼筋慢慢旋入孔內至底部，且可目視藥劑外溢，不可將鋼筋直接插入，以避免鋼筋與孔壁間殘留空隙。
- 植筋施作後之**硬化過程中**，應避免碰觸且**不得矯正鋼筋**，待硬化完成後，始可進行負載或後續之施工。
- 施工完成後，須會同監造單位進行**現場拉拔試驗**，並提送完整紀錄備核。

原廠安裝指示書

NARLabs

(Manufacturer's Printed Installation Instructions, MPII)

製造商必須為其製造販售之每一個化學錨栓系統提供安裝說明，此說明書一般稱之為MPII。安裝前，安裝技術員應詳閱並理解說明書內容。



原廠安裝指示書

NARLabs

(Manufacturer's Printed Installation Instructions, MPII)

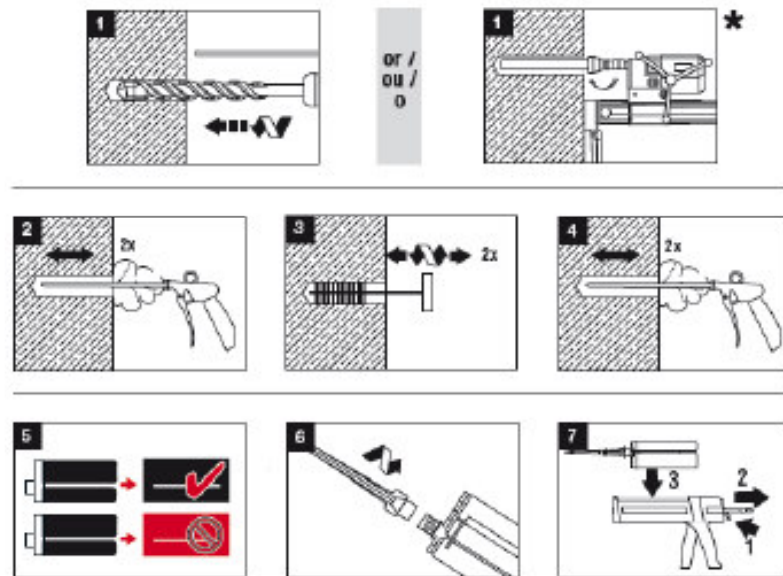
MPII至少包含以下項目：

- 鑽孔
- 清潔孔洞灰塵、鑽屑、泥漿，及碎片
- 準備安裝設備
- 以黏著劑灌注孔洞
- 安裝錨栓
- 黏著劑之膠結時間
- 黏著劑固化
- 錨栓尺寸
- 黏著劑之處理及儲存

原廠安裝指示書

NAR Labs

(Manufacturer's Printed Installation Instructions, MPII)



Simpson Strong-Tie® Anchoring and Fastening Systems for Concrete and Masonry

Adhesive Anchoring Installation Instructions

NOTE: Always check expiration date on product label. Do not use expired product.

WARNING: When drilling and cleaning hole, use eye protection. When installing adhesive, use eye and skin protection.

1. HOLE PREPARATION: Horizontal, Vertical and Overhead Applications

- Drill**—Drill hole to specified diameter and depth.
- Blow**—Remove dust from hole with oil-free compressed air for a minimum of 4 seconds. Compressed air nozzle must reach the bottom of the hole.
- Brush**—Clean with a nylon brush for a minimum of 4 cycles. Brush should provide resistance to insertion. If no resistance is felt, the brush is worn and must be replaced.
- Blow**—Remove dust from hole with oil-free compressed air for a minimum of 4 seconds. Compressed air nozzle must reach the bottom of the hole.

Refer to page 77 or visit www.strongtie.com for proper brush part number.

2. CARTRIDGE PREPARATION:

- Check**—Check expiration date on product label. Do not use expired product. Product is visible until end of printed expiration month.
- Open**—Open cartridge per package instructions.
- Attach**—Attach Simpson Strong-Tie® mixing nozzle. Do not use other nozzles.
- Insert**—Insert cartridge into dispensing tool.
- Dispense**—Dispense adhesive to the side until properly mixed (uniform color).

Refer to www.strongtie.com for proper mixing nozzle and dispensing tool part number.

3. FILLING THE HOLE: Vertical Anchorage

Prepare the hole per instructions "Hole Preparation" on product label.

Dry and Damp Holes:

- Fill**—Fill hole 1/2-3/4 full, starting from bottom of hole to prevent air pockets. Withdraw nozzle as hole fills up.
- Insert**—Insert clean, oil-free anchor, turning slowly until the anchor contacts the bottom of the hole.
- Do not disturb**—Do not disturb anchor until fully cured. (See cure schedule for specific adhesive.)

Water-Filled Holes:

- Fill**—Fill hole completely full, starting from bottom of hole to prevent water pockets. Withdraw nozzle as hole fills up.
- Insert**—Insert clean, oil-free anchor, turning slowly until the anchor contacts the bottom of the hole.
- Do not disturb**—Do not disturb anchor until fully cured. (See cure schedule.)

Note: Nozzle extensions may be needed for deep holes.

4. THE HOLE: Horizontal and Overhead Anchorage

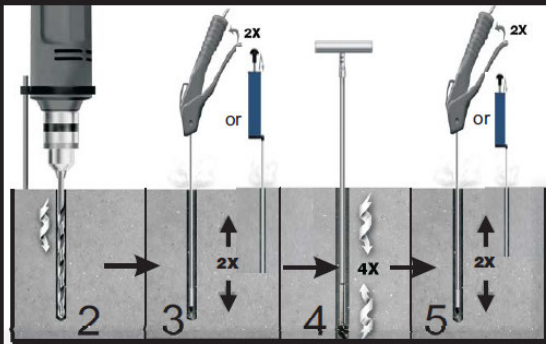
Prepare the hole per instructions "Hole Preparation" on product label.

- Install**—Install Simpson Strong-Tie® ARC adhesive retaining cap. Refer to page 74 or visit www.strongtie.com for proper ARC size.
- Fill**—Fill hole 1/2-3/4 full, starting from bottom of hole to prevent air pockets. Withdraw nozzle as hole fills up.
- Insert**—Insert clean, oil-free anchor, turning slowly until the anchor contacts the bottom of the hole.
- Do not disturb**—Do not disturb anchor until fully cured (see cure schedule).

Note: Nozzle extensions may be needed for deep holes.

Composite Representation of Manufacturer's Printed Installation Instructions (MPII) "For Fictitious Product Only".

(Note: **Not** to be used for Actual Product Installations)



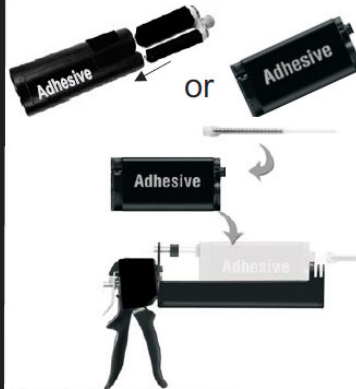
Drilling and Hole Cleaning

1. Remove water and loose debris from the concrete surface adjacent to the borehole.
2. Drill hole with a hammer-drill in rotation-hammer mode using the appropriate diameter carbide bit to the embedment depth required for the specified anchor. Observe all dimensional requirements of Table 5 of this instruction. For holes drilled with other drill types contact the manufacturer.
 - a. For 3/8" nominal rod (#3 deformed bar) use a bit equal to the nominal rod/deformed bar diameter plus 1/16".
 - b. For 1/2", 5/8", 3/4", 7/8", and 1", nominal rod (#4, #5, #6, #7, and #8, deformed bar) use a bit equal to the nominal rod/deformed bar diameter plus 1/8".

Caution: Wear suitable eye and skin protection.

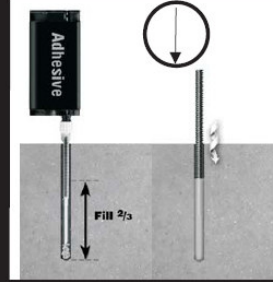
Avoid inhalation of dust during drilling and/or debris removal.

3. Starting from the bottom or back of the hole, blow out the hole with oil-free compressed air (using a compressed air nozzle or a hand pump) inserting and retracting the air wand of proper length (for deep holes use extension) a minimum of 2 times (2x) or until air runs clear.
4. Determine the proper brush diameter and length (for deep holes use extension) to be used (refer to Table 1). Clean the hole with a brush of proper length by inserting and removing the brush from top to bottom of the borehole a minimum of 4 times (4x) using a plunging and rotational motion.
Caution: Do not use worn brushes.
5. Blow out the hole again by inserting and retracting the proper air wand a minimum of 2 times (2x) or until air runs clear.



Cartridge Use and Preparation

1. Check expiration date on the adhesive cartridge or foil pack. Do not use expired adhesive. Review the Material Safety Data Sheet (MSDS) before use. Cartridge temperature at installation must be in the range of 40°F and 100°F at time of injection. The permitted range of concrete temperatures, adhesive gel (working) time, and full cure time are given in the Table 2.
2. Open the cartridge/foil pack and attach the proper mixing nozzle to the cartridge. Do not modify the mixer in any way and make sure the mixing elements are contained inside the nozzle. Make sure that the nozzle is long enough to reach the bottom of the hole. Use proper tube extension and piston to reach bottom of the hole if needed.
3. Insert the assembled cartridge and nozzle into the correct dispensing tool and correct alignment parallel with drive pistons.



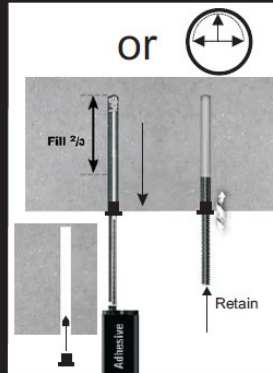
Adhesive Vertical Down Hole Installation

1. Fill the cleaned hole approximately 2/3 full of adhesive starting from the bottom of the anchor hole. Slowly withdraw the mixing nozzle as the hole fills to avoid creating air pockets (voids).
2. The anchor rod should be free of dirt, grease, oil, or other contaminants. Mark the anchor rod with the required embedment depth. Insert the anchor rod into the adhesive with a slight rotational motion to ensure positive distribution of adhesive until the desired embedment depth is reached. Observe gel time. Refer to Table 2.
3. Be sure that the anchor is fully seated at the bottom of the hole and that the gap between the anchor rod and the hole wall is fully filled with adhesive up to the concrete surface. If excess adhesive appears on the concrete surface it has to be carefully removed before hardening. Under filled hole installations and minor adjustments after anchor rod insertion are beyond the scope of this MPII.
4. The anchor shall not be moved or disturbed after final placement and during cure.



Adhesive Horizontal and Overhead Installation (Using Piston Plugs)

1. For horizontal and overhead installations, piston plugs that attach to the mixing nozzle or extension tubing must be used (refer to Table 3).
2. Insert the piston plug to the back of the drilled hole and fill the cleaned hole approximately 2/3 full of adhesive starting from the bottom of the anchor hole. Slowly withdraw the mixing nozzle as the hole fills to avoid creating air pockets (voids). During installation the piston plug will naturally be pushed from the drilled hole by the adhesive pressure.
3. The anchor rod should be free of dirt, grease, oil, or other contaminants. Mark the anchor rod with the required embedment depth. Insert the anchor rod into the adhesive with a slight rotational motion to ensure positive distribution of adhesive until the desired embedment depth is reached. Observe gel time. Refer to Table 2.
4. Be sure that the anchor is fully seated at the bottom of the hole and that the gap between the anchor rod and the hole wall is fully filled with adhesive. Under filled hole installations and minor adjustments after anchor rod insertion are beyond the scope of this MPII. For overhead installations, the anchor rod must be secured from moving/withdrawing during the cure time (e.g. wedges or other restraint methods).



Adhesive Horizontal and Overhead Installation (Using Retaining Caps)

1. For horizontal and overhead installations, retaining caps must be used. Insert the appropriate retaining cap into the drill hole (refer to Table 4).
2. Perform the installation through the retaining cap. Fill the cleaned hole approximately 2/3 full of adhesive starting from the bottom of the anchor hole. Slowly withdraw the mixing nozzle as the hole fills to avoid creating air pockets (voids).
3. The anchor rod should be free of dirt, grease, oil, or other contaminants. Mark the anchor rod with the required embedment depth. Insert the anchor rod into the adhesive with a slight rotational motion to ensure positive distribution of adhesive until the desired embedment depth is reached. Observe gel time. Refer to Table 2.
4. Be sure that the anchor is fully seated at the bottom of the hole and that the gap between the anchor rod and the hole wall is fully filled with adhesive. Under filled hole installations and minor adjustments after rod insertion are beyond the scope of this MPII. For overhead installations, the anchor rod must be secured from moving/withdrawing during the cure time (e.g. wedges or other restraint methods).

Curing and Final Installation

1. Allow the adhesive anchor to fully cure before applying any load (see Table 2). Do not disturb, torque, or load the anchor until it is fully cured.
2. After the specified cure time has elapsed, the anchor may be loaded and/or torque applied using a calibrated torque wrench up to the maximum permissible torque (see Table 5).

Allow curing time...



Table 1 - Brush sizes

Threaded rod size, inches	Deformed bar size	Recommended brush size
3/8	(#3)	use brush XYZ1 (minimum brush diameter = 0.475")
1/2	(#4)	use brush XYZ2 (minimum brush diameter = 0.675")
5/8	(#5)	use brush XYZ3 (minimum brush diameter = 0.825")
3/4	(#6)	use brush XYZ4 (minimum brush diameter = 0.920")
7/8	(#7)	use brush XYZ5 (minimum brush diameter = 1.045")
1	(#8)	use brush XYZ6 (minimum brush diameter = 1.425")

Table 2 - Gel and full curing times

Temperature of base material	Gel (working) time	Full curing time
40°F 4°C	180 minutes	48 hours
55°F 13°C	90 minutes	24 hours
70°F 21°C	30 minutes	12 hours
85°F 29°C	20 minutes	6 hours
100°F 38°C	15 minutes	4 hours

Table 3 - Piston plug sizes for horizontal and overhead installations

Threaded rod size, inches	Deformed bar size	Hole size, inches	Recommended Piston Plug
3/8	(#3)	7/16	Use 7/16 in. plug PLG1
1/2	(#4)	5/8	Use 5/8 in. plug PLG2
5/8	(#5)	3/4	Use 3/4 in. plug PLG3
3/4	(#6)	7/8	Use 7/8 in. plug PLG4
7/8	(#7)	1	Use 1 in. plug PLG5
1	(#8)	1-1/8	Use 1-1/8 in. plug PLG6

Table 4 - Retaining cap for horizontal and overhead installations

Threaded rod size, inches	Deformed bar size	Hole size, inches	Recommended Retaining Cap
3/8	(#3)	7/16	use retaining cap ABC1
1/2	(#4)	5/8	use retaining cap ABC2
5/8	(#5)	3/4	use retaining cap ABC3
3/4	(#6)	7/8	use retaining cap ABC4
7/8	(#7)	1	use retaining cap ABC5
1	(#8)	1-1/8	use retaining cap ABC6

Table 5 - Setting Parameters

Anchor size	3/8" (#3)	1/2" (#4)	5/8" (#5)	3/4" (#6)	7/8" (#7)	1" (#8)
T _{max} = Maximum torque (ft-lbs) for A193 B7 carbon steel rod or F593 ss rod	16	33	60	105	125	165
T _{max} = Maximum torque (ft-lbs) for A36/A307 carbon steel rod only	10	25	50	90		
h _{ed, min} = Minimum embedment depth (inches)	2-1/2	2-3/4	3	3-1/4	3-1/2	4
h _{et, max} = Maximum embedment depth (inches)	5	6	7	9	10	12
s _{min} = Minimum spacing (inches)	2	2-1/2	3	3-1/2	4-1/2	5
c _{min} = Minimum edge distance (inches)	2	2-1/2	3	3-1/2	4-1/2	5
h _{min} = Minimum member thickness (inches)	Embedment Depth + 1		Embedment Depth + 2 times Anchor Diameter size			

安全防護

- 依勞安規定通常包括：安全帽、安全眼鏡、防塵口罩、耳塞及手套等



鑽孔

MPII中有關鑽孔前之準備，俾利錨栓成功安裝。

- 選擇鑽孔機種類
- 鑽頭種類和尺寸
- 鑽掘一個適當深度
- 方向正確
- 清潔的孔洞



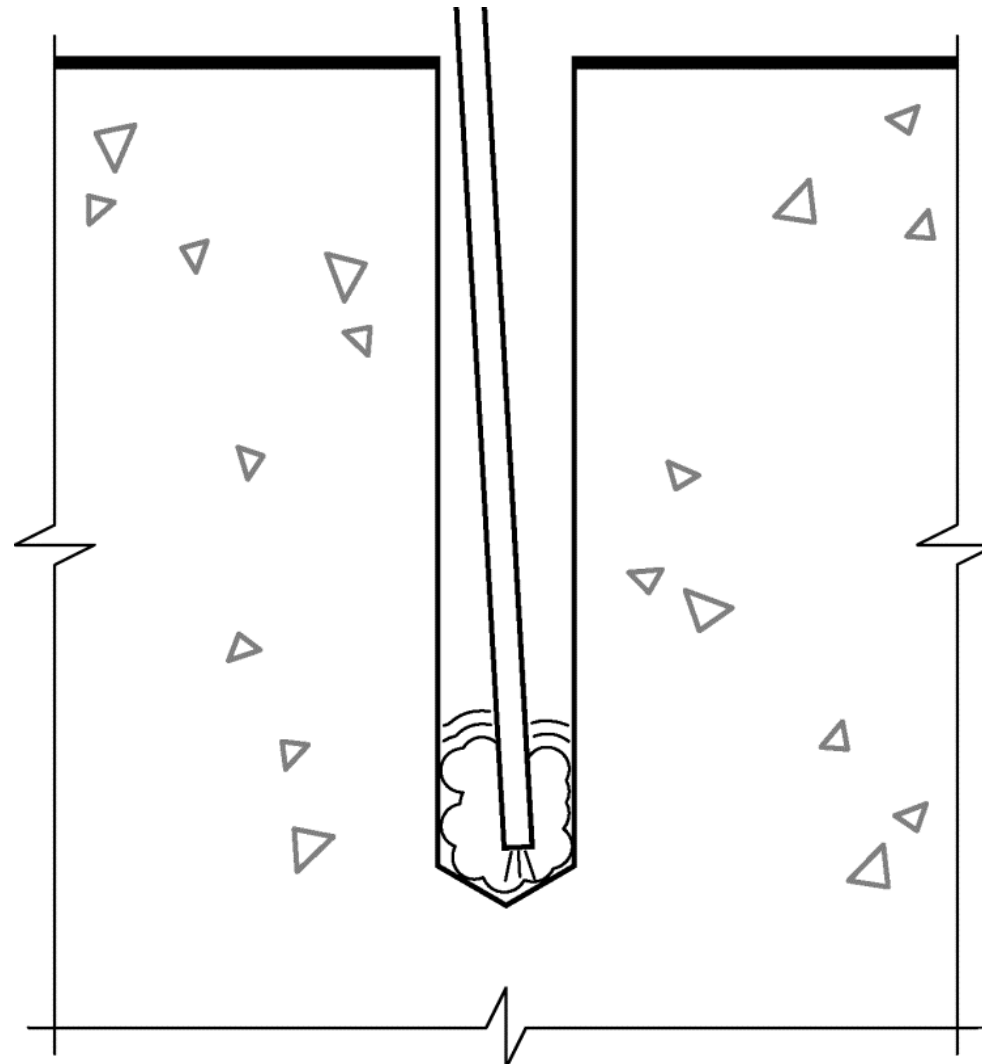
清孔-選擇適當清潔刷具

製造商之MPII

- 指定清潔刷種類(鋼質或尼龍纖維材質)
- 根據使用之鑽頭尺寸選擇適當清潔刷具
- 刷具尺寸應略大於鑽頭直徑，以確保能確實接觸孔壁。



清孔-空氣吹淨孔洞



清孔-用毛刷黏出鑽屑



清孔真的很重要！



清孔的重要性



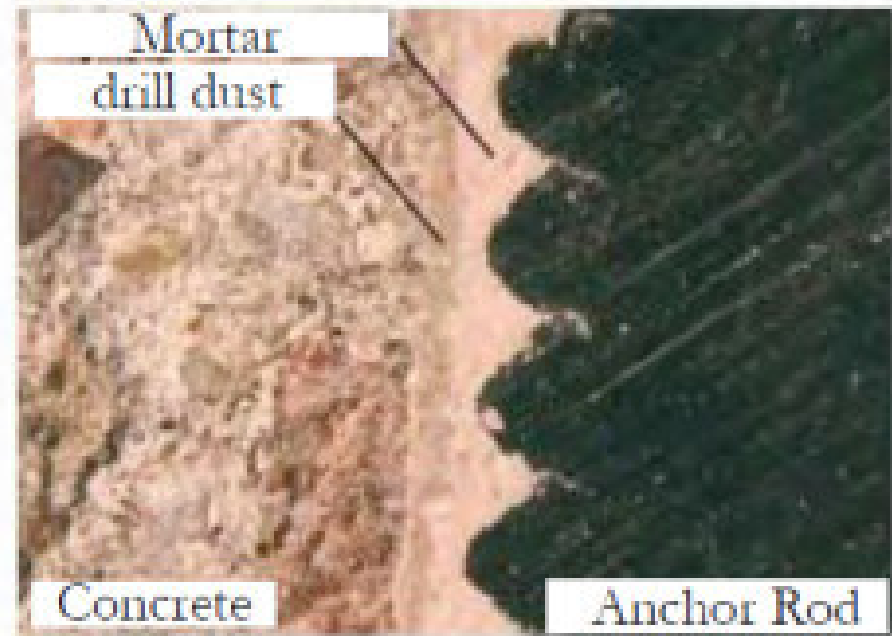
清孔的重要性



清孔的重要性-未確實清潔

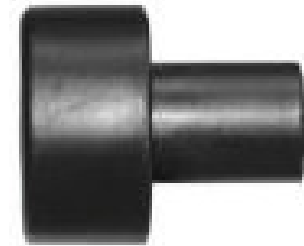


清孔的重要性-未確實清潔



特別指示

依據產品種類不同，或許必須使用**活塞或固定蓋**來輔助安裝作業。在**水平及倒吊面**作業中，此等裝置係用來將黏著劑留置於鑽孔中。固定蓋可使錨栓置中，活塞或固定蓋尺寸應依據安裝之錨栓尺寸決定。



卡匣系統



Cartridge



Dispenser



Static mixing nozzle

藥劑包式系統



藥劑包



包裝標籤

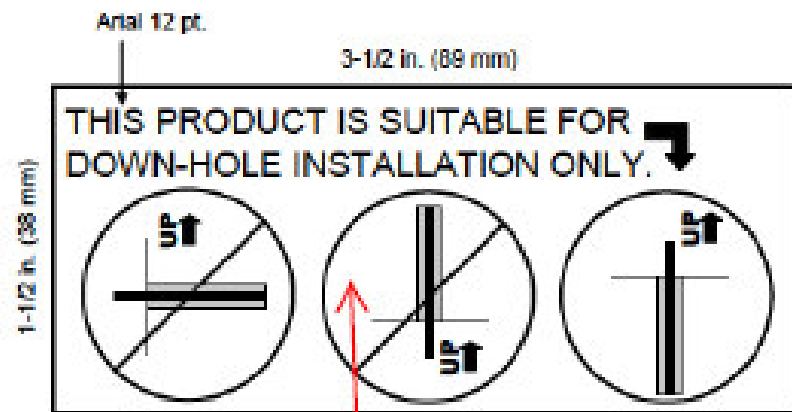


Fig. 2.7 Example of labeling required for adhesive anchor systems that are not tested for installation orientation sensitivity. Source: ACI 308.4.

Package Labeling

The information on the cartridges or capsules of adhesive includes pictorial selections of information from the MPEI and MSDS. ACI 308.4 requires the following minimum package labeling for adhesive components:

- Manufacturer's name and address;
- Lot number;
- Packing date and shelf life or product expiration date;
- MPEI and application information; and
- Sensitivity to installation orientation.

Figure 2.7 is an example of a label for sensitivity to installation orientation. The label shown indicates that the product is not to be used for horizontal or overhead installations. Therefore, this product should only be used for vertical down installations.

固定蓋

- 固定蓋可以幫助在水平或向上植筋時將植筋膠擋在固定蓋內



活塞

- 利用活塞幫助均勻從最深處填充向上植筋孔

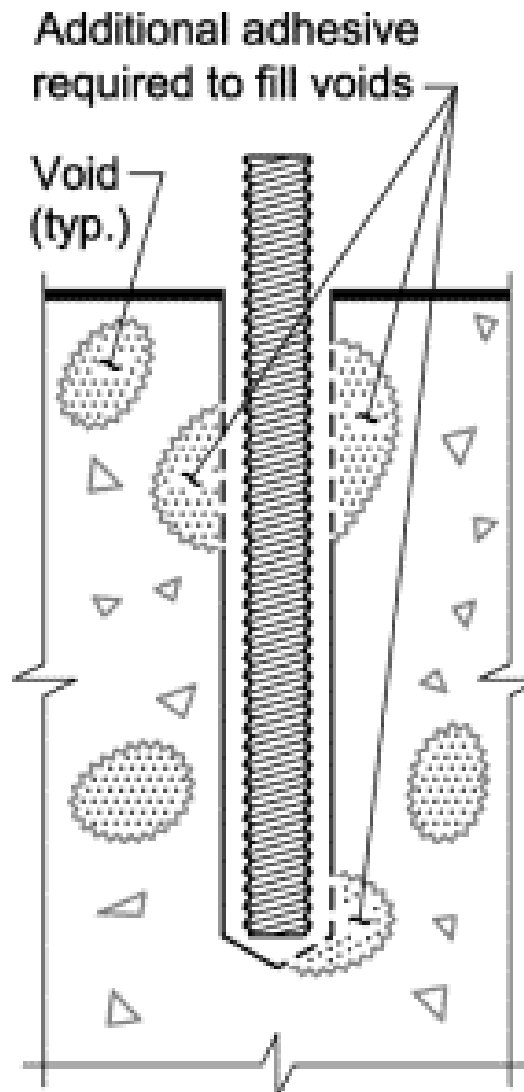


灌注前檢查

- 以正式灌注前先擠出一些植筋膠，以目視檢查，看是否有混合均勻

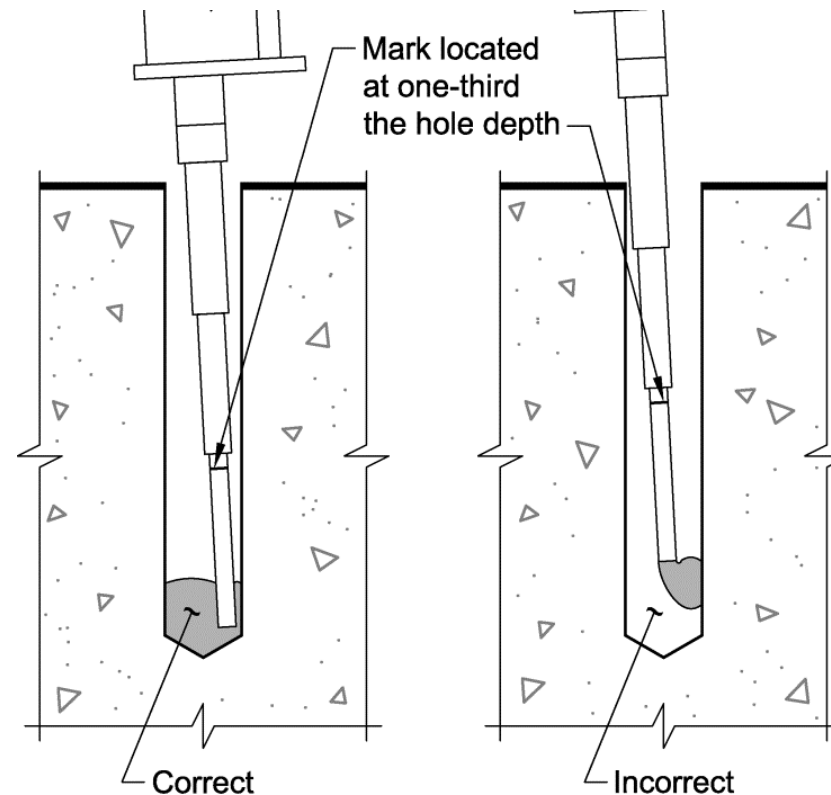


安裝之問題



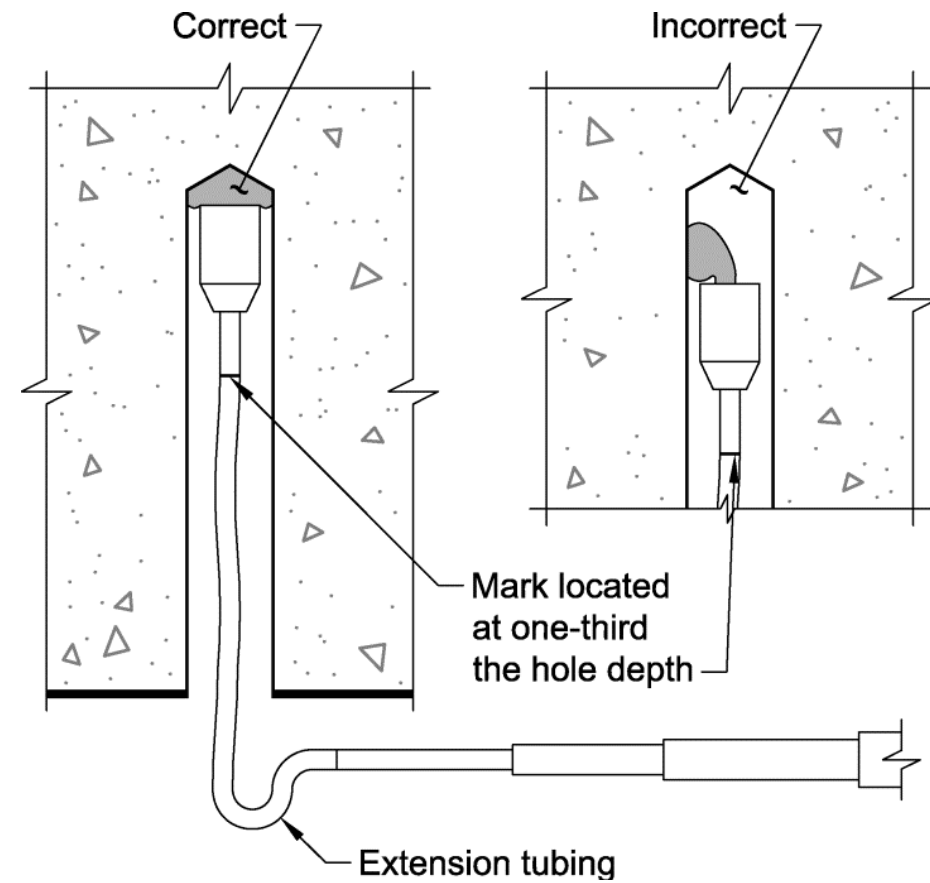
灌注植筋膠

- 垂直向下：
要從孔之最深處，平順的擠出並移動管嘴



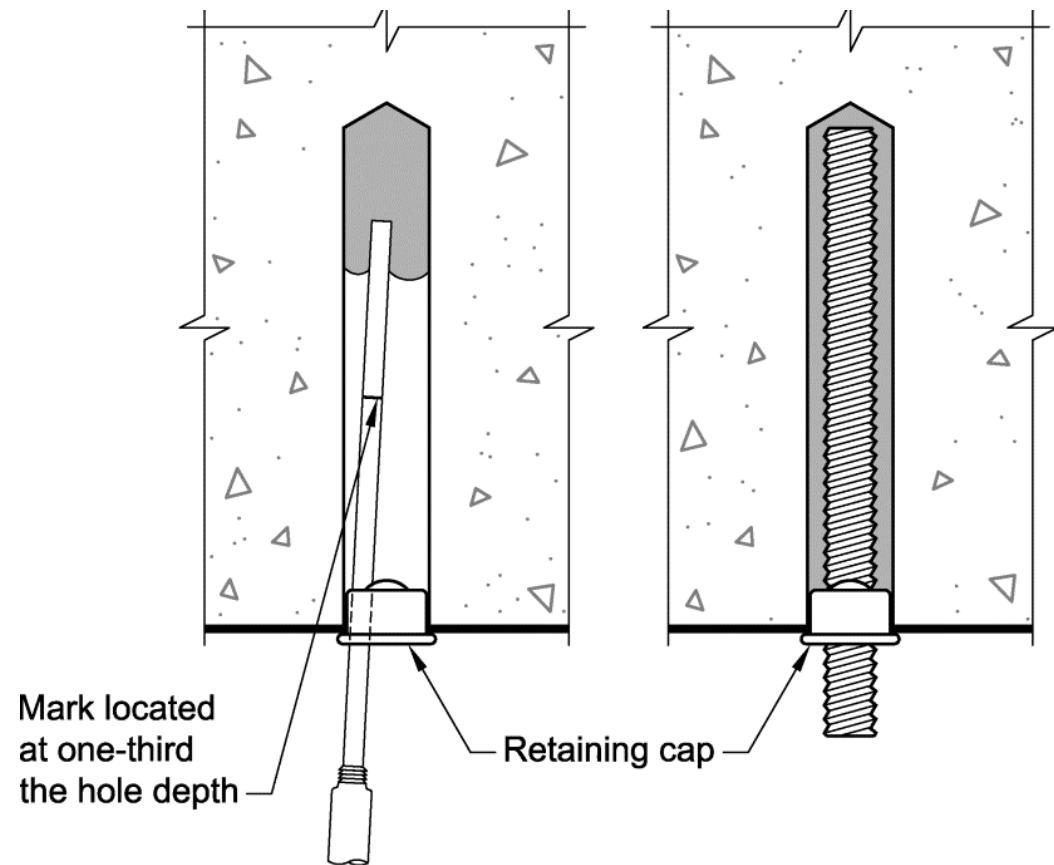
灌注植筋膠

- 水平或向上 - 活塞式：

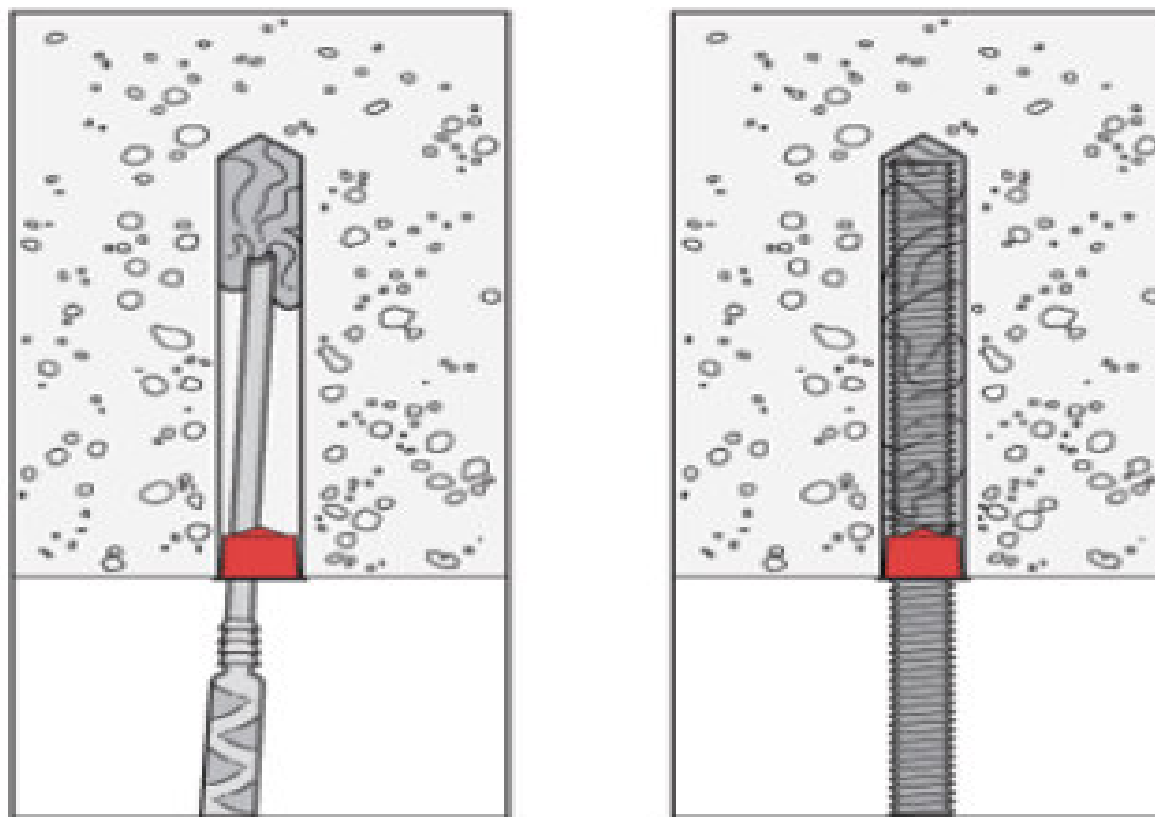


灌注植筋膠

- 向上 – 固定蓋：



向上植筋 - 固定蓋



The "X" cut in the cap allows the mixing nozzle and insert to pass through, while containing the adhesive in the hole.

向上植筋-固定蓋式



向上植筋-固定蓋式



向上植筋-固定蓋式



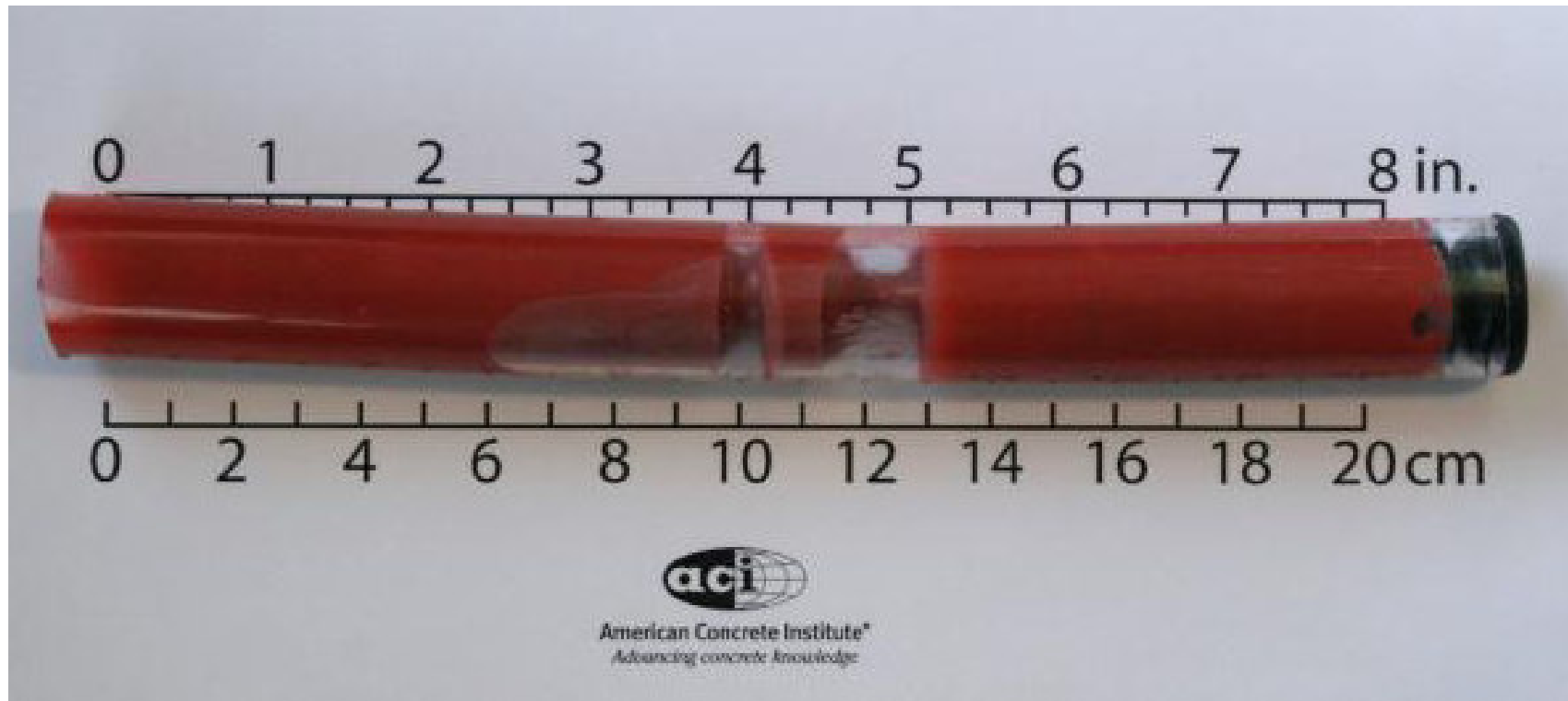
向上植筋-固定蓋式



向上植筋-固定蓋式

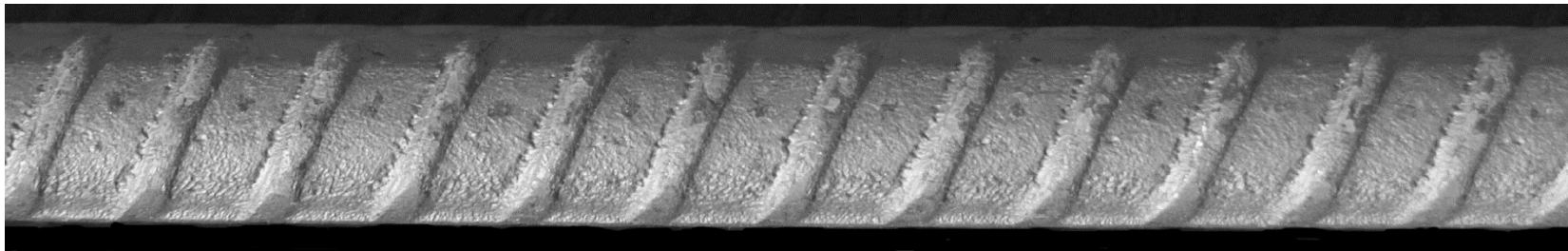


填充不良



竹節鋼筋

- 植入之鋼筋表面需保持清潔無油污

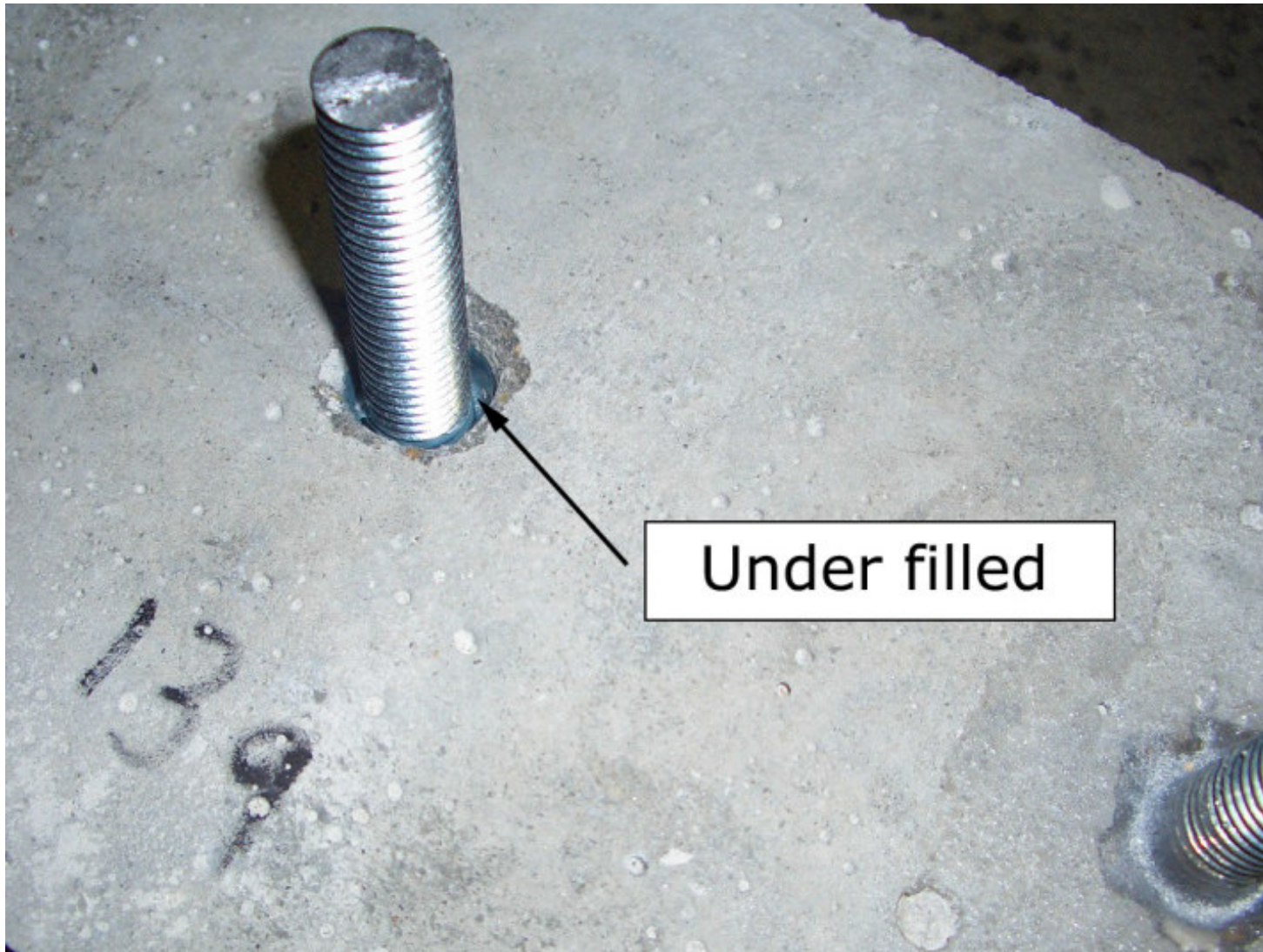


垂直度

- 容許垂直偏差
小於3度



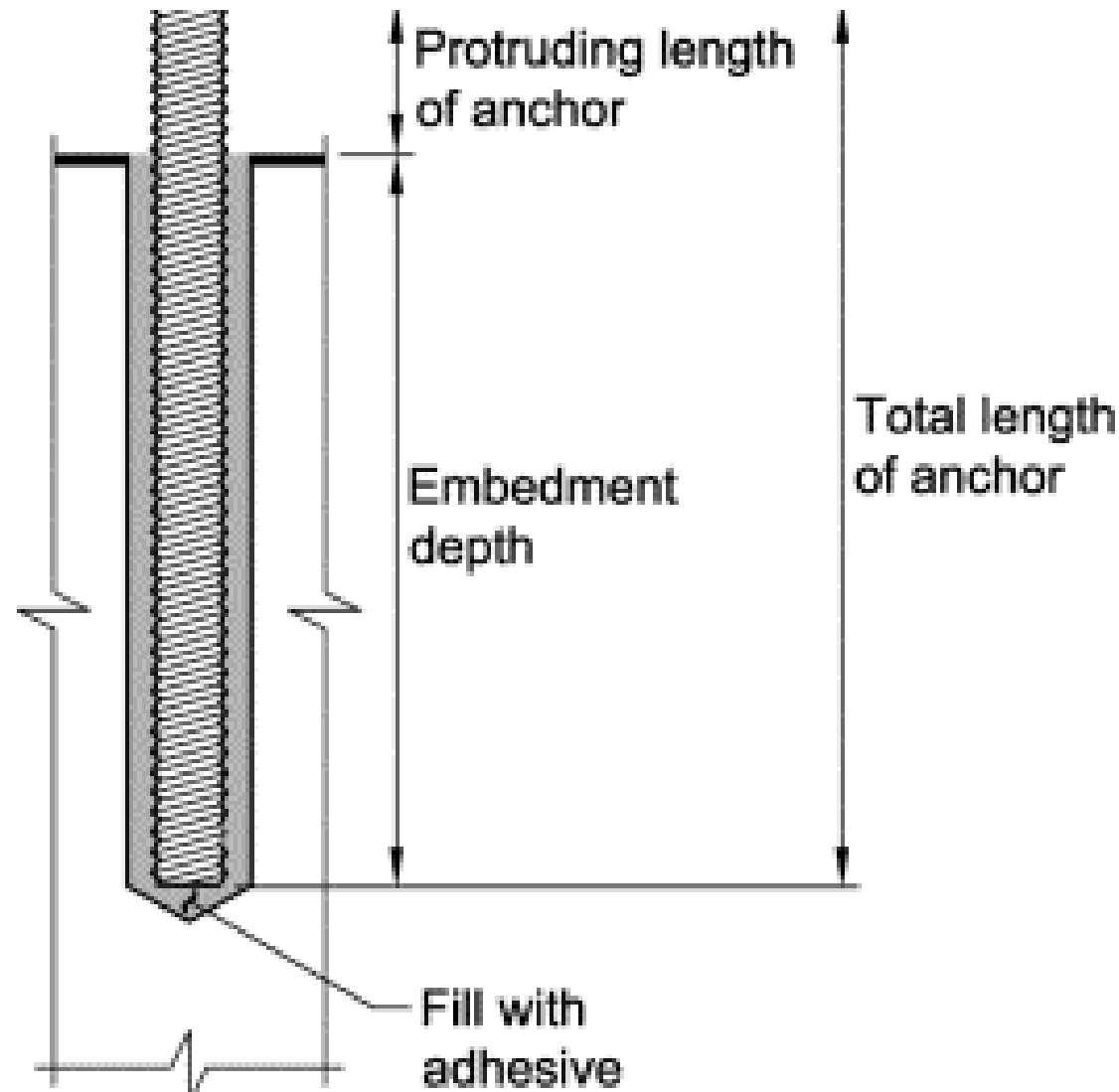
植入錨栓-填充不足



植入錨栓-填充過量



植入錨栓-檢查埋置深度



植入錨栓-安裝後不可再調整



植筋施工之品質管理

植筋施工之品質管理-拉拔試驗

- 由經監造單位認可之試驗單位，（目前通過TAF之試驗單位僅三家）
- 依據
 - ASTM E488 Standard Test Methods for Strength of Anchors in Concrete Elements
 - 中國國家標準CNS13975 A3370帷幕牆混凝土錨件強度試驗法
- 施工前拉拔試驗：
 - 測試拉力依設計之埋深以同尺寸鋼筋材料，以SD420鋼筋以1.25fy，SD280鋼筋以1.40fy為拉力在工地試作3支，並記錄孔深、使用藥劑廠牌、型號作為日後施作品管之依據。
- 施工後安裝品質試驗：
 - 測試拉力為1倍鋼筋降伏強度，每種尺寸100支抽驗1支。測試過程中若出現失敗樣本，則同一批樣本改作25%比例進行安全測試，若全部合格，則該批植筋視為合格，原有之失敗植筋由承包商無償補做；若25%之樣本中有任一支不合格，則該批植筋全部測試，若出現有任何不合格，植筋視同失效，後續依監造單位指示辦理補救措施。

試驗設備

- 油壓千斤頂、手動幫浦、校正報告、鋼筋夾片。
- 油壓千斤頂及手動幫浦須經國家標準局認證通過之檢驗單位校正，並檢附有效校正期限為一年內之校正報告

植筋拉拔測試報告

測試編號: TST11071102
本報告共 1 頁 第 1 頁
收件日期: 100/7/11
測試日期: 100/7/11
報告日期: 100/7/12

委託者: 桃園縣立東興國民中學
承攬商: 元隆營造股份有限公司
會驗者: 東建工程顧問有限公司-邱瑞倫 元隆營造-吳孟雄
工程名稱: 東興國中信義樓、八德樓耐震補強暨整建工程

監造單位: 東建工程顧問有限公司
施工單位: 元隆營造股份有限公司
施工位置: 信義樓-地下樓3、3樓4
試驗項目: 施工前植筋可行性試驗

試樣編號 (型號位置)	千斤頂油壓表讀值 kgf/cm ²	實測荷重 kgf	要求測試值 kgf	破壞形式	備註
#4-1	310	4743	4445	D	—
#4-2	310	4743	4445	D	—
#4-3	320	4908	4445	D	—
#3-1	180	2763	2485	D	—
#3-2	180	2763	2485	D	—
#3-3	190	2915	2485	D	—
以下空白					

備註: 1. 本試驗結果僅對樣品負責。
2. 千斤頂編號: 835, 壓力錶編號: WKA 3305。
3. 破壞形式: A. 植筋處拉出 B. 混凝土基座破壞 C. 樣品斷裂 D. 達鋼筋屈服
4. 本試驗室留存報告, 僅保存三年。
5. 本報告不得塗改、未得到本試驗室書面同意, 不得翻錄或複製。

報告簽署人: 

千斤頂荷重比對測試報告

測試編號: ST9072401
本報告共 2 頁 第 1 頁
收件日期: 99/7/24
測試日期: 99/7/24
報告日期: 99/7/24

委託者: 鄭兆鴻建築土木技師事務所
試驗名稱: 12T 千斤頂

比對日期: 民國99年7月24日
使用儀器: 100T 混凝土抗壓機
壓力錶編號: WKA 3305

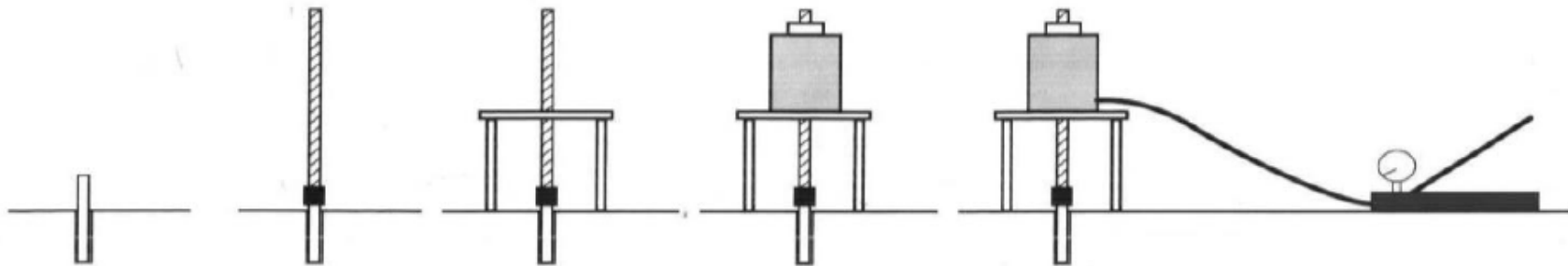
壓力錶指示值 (kg/cm ²)	比對實測荷重值 (kgf)	壓力錶指示值 (kg/cm ²)	比對實測荷重值 (kgf)	壓力錶指示值 (kg/cm ²)	比對實測荷重值 (kgf)
20	278	140	260	3982	
30	447	150	2302	270	4143
40	598	160	2455	280	4282
50	762	170	2605	290	4443
60	910	180	2763	300	4593
70	1062	190	2915	310	4743
80	1223	200	3055	320	4908
90	1367	210	3217	330	5052
100	1525	220	3370	340	5198
110	1683	230	3520	350	5357
120	1827	240	3672	360	5500
130	1990	250	3830	370	5660

備註: 1. 本試驗結果僅對樣品負責。
2. 本報告不得塗改、未得到本試驗室書面同意, 不得翻錄或複製。

報告簽署人: 

試驗步驟

- 確定試驗鋼筋周圍平面平坦且與植筋垂直(正交)，將腳座及夾具固定於受測樣本上，再套入千斤頂。測試時須裝置腳座以符合ASTM E488 Standard Test Methods for Strength of Anchors in Concrete Elements 或中國國家標準CNS13975 A3370帷幕牆混凝土錨件強度試驗法之裝置規定。
- 將手動幫浦油壓管接上千斤頂，並旋緊閥門。
- 確定油壓表歸零後由手動幫浦徐徐加壓，直到試驗拉力。
- 紀錄並拍照存證後打開閥門，解除拉力，試驗完成。



ASTM E488拉拔試驗-裝置

千斤頂 壓力計

支架



ASTM E488 拉拔試驗-流程



Hilti 之試驗裝置



施工抽查 - 植筋鑽孔深度



施工抽查 - 植筋位置與長度



施工抽查 - 施工後植筋拉拔

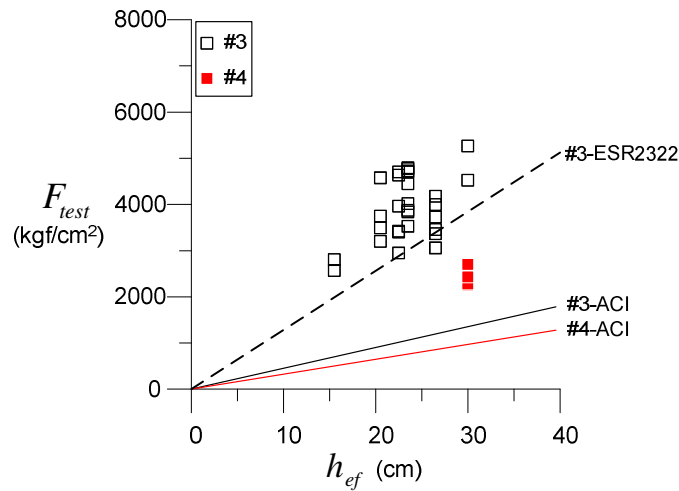


結論

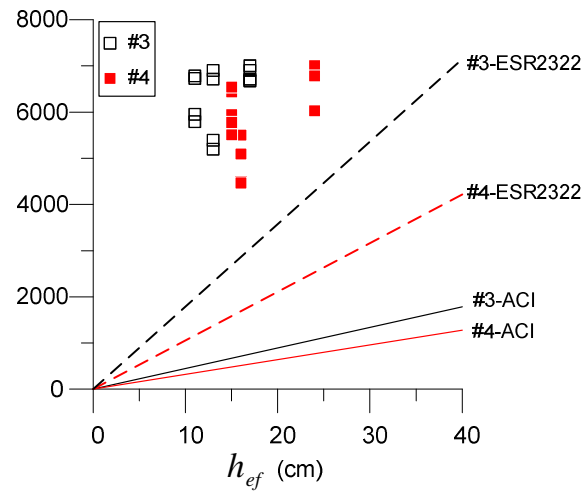
承包商常要求採用較短的錨錠深度施工

- 因為植筋深度除了依照植筋膠之黏著強度外，還考量了錨栓拉破、錨栓群強度折減、混凝土裂縫及其他安全係數，故通常試驗所得到的強度都會高出設計強度許多，但不宜因此採用較短的錨錠長度。

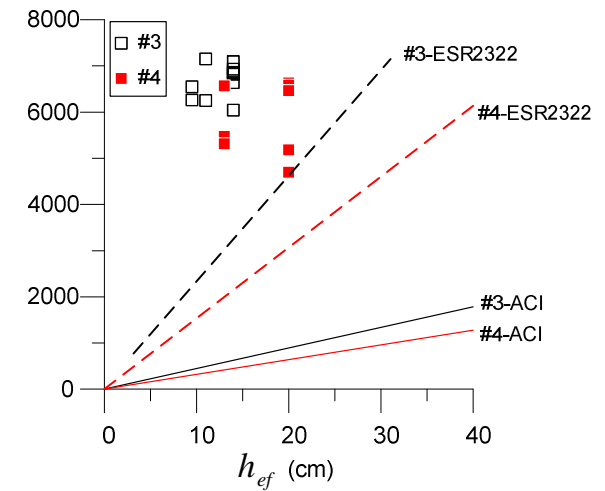
低強度混凝土之植筋



(a) $f'_c = 50 \text{ kgf/cm}^2$



(b) $f'_c = 100 \text{ kgf/cm}^2$

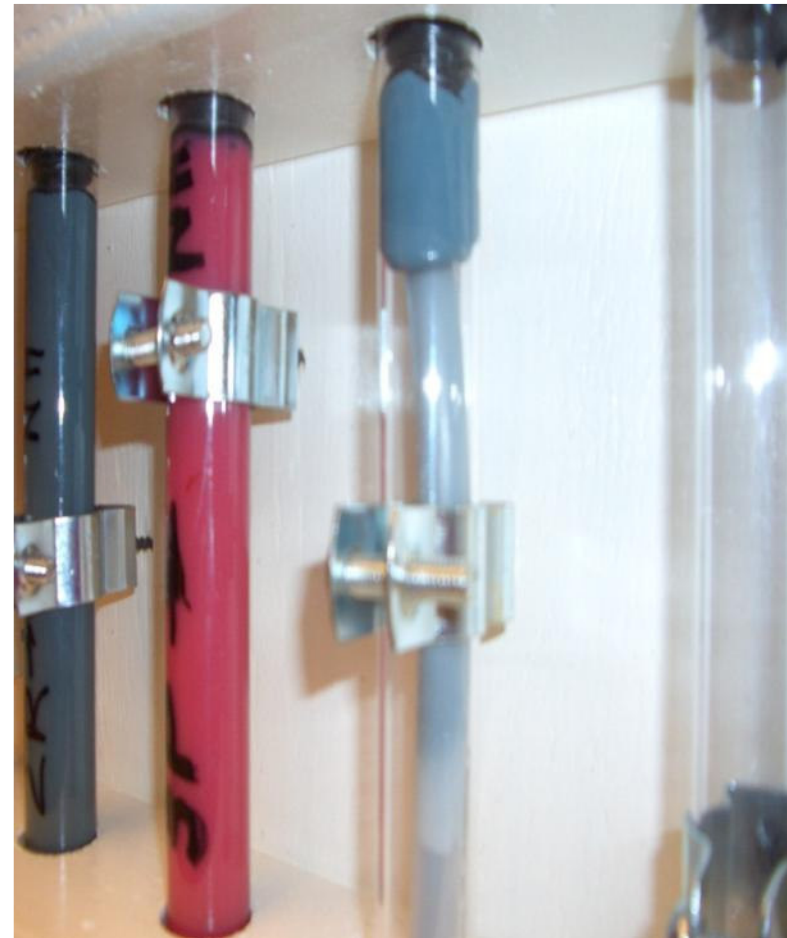


(c) $f'_c = 150 \text{ kgf/cm}^2$

- $50(\text{kgf/cm}^2)$ 之混凝土不建議使用#4鋼筋植筋
- 100 及 $150(\text{kgf/cm}^2)$ 之混凝土採用建議之植筋深度表，經低強度修正後仍屬保守

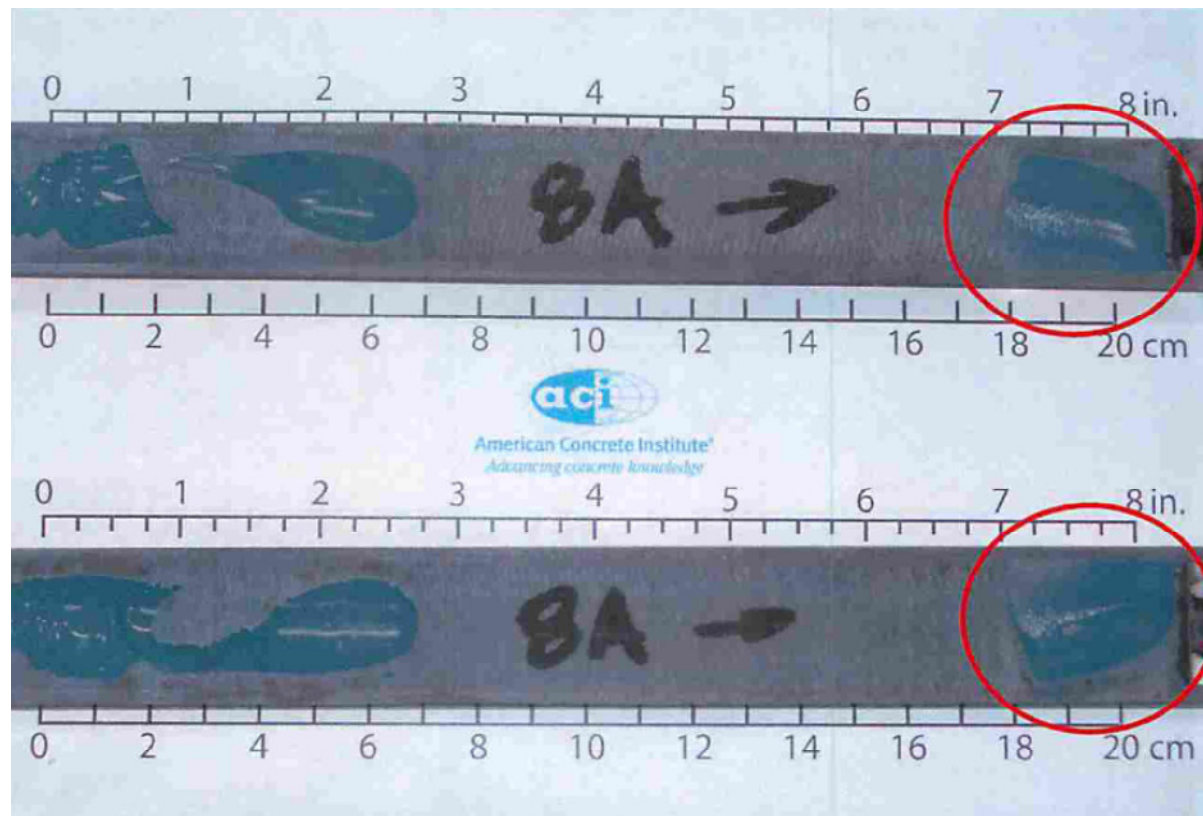
正確安裝之重要性

- 除非親眼看見這些測試結果，否則許多安裝技術員可能根本不知道其並未達成倒吊面、水平及垂直向下孔洞之填充工作。且黏著劑之抗流動性較高，需要專門程序，如緩慢從容之注射動作及專門設備，如活塞或固定蓋，方能妥善完成安裝。



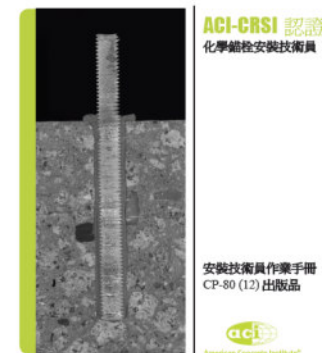
植筋膠未能充滿錨栓周圍

- 植筋若施作不良，除拉拔試驗外，幾乎不能由檢驗方式查出
- 植筋應由合格的專業技術人員施做，施做時**嚴格遵守原廠安裝指示書(MPII)**所規定之步驟。



合格植筋技術人員認證機制

- 目前國內並無相關之認證制度及認證機構。
- 目前台灣混凝土學會(TCI)參考美國ACI-CRSI植筋技術人員認證(Adhesive anchor installer certification)制度，建立國內的植筋技術人員的認證制度，以確保植筋工成之品質。



化學錨栓安裝技術員作業手冊

材料認證機制

- 目前國內並無植筋材料之國家標準，亦無認證制度，市場上之材料有進口材料也有國產材料，因缺乏標準，產品良莠不齊，監造單位通常只能以現場拉拔試驗做檢驗，但對於產品之耐久、耐候、可靠度則無管理的依據。應盡速建立植筋膠之認證標準及認證制度。



原廠安裝指示書

(Manufacturer's Printed Installation Instructions, MPII)

- 在國內銷售的各種植筋膠，並未嚴格要求安裝時要嚴格遵循原廠安裝指示書(MPII)規定之步驟，且進口廠牌並未提供**中文化之原廠安裝指示書(MPII)**。應請各**供應植筋膠之廠商應負起責任教育植筋專業技術人員**能確實遵循原廠安裝指示書(MPII)規定之步驟進行植筋施做。

簡報結束，敬請指教

影響黏結強度之因素

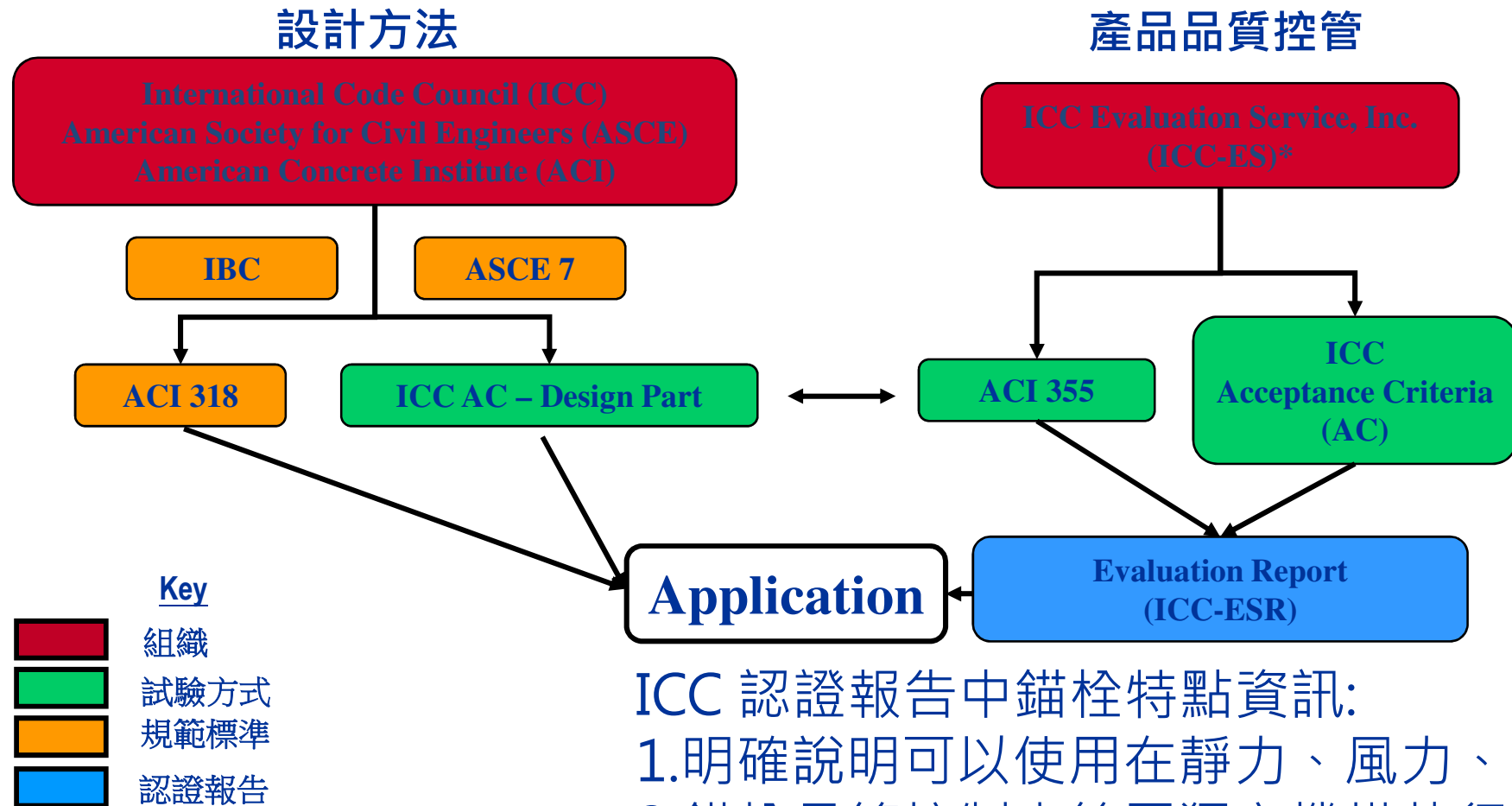
- 鑽孔方式；
- 孔洞清潔度；
- 混合程度；
- 於乾燥、潮濕、濕潤或浸水混凝土中安裝；
- 孔洞中是否有泥漿、冰或雪；
- 黏著劑條件/材齡；
- 孔洞直徑；
- 植入深度；
- 溫度；
- 固化程度；
- 固定錨栓方式。

關鍵因素

- 孔洞清潔度
- 溫度
- 常時荷載
- 孔洞潮溼
- 裂縫

1.2 品管建議規範

美國(ACI&ICC)- 錨栓(多為英制)設計與產品品質控制

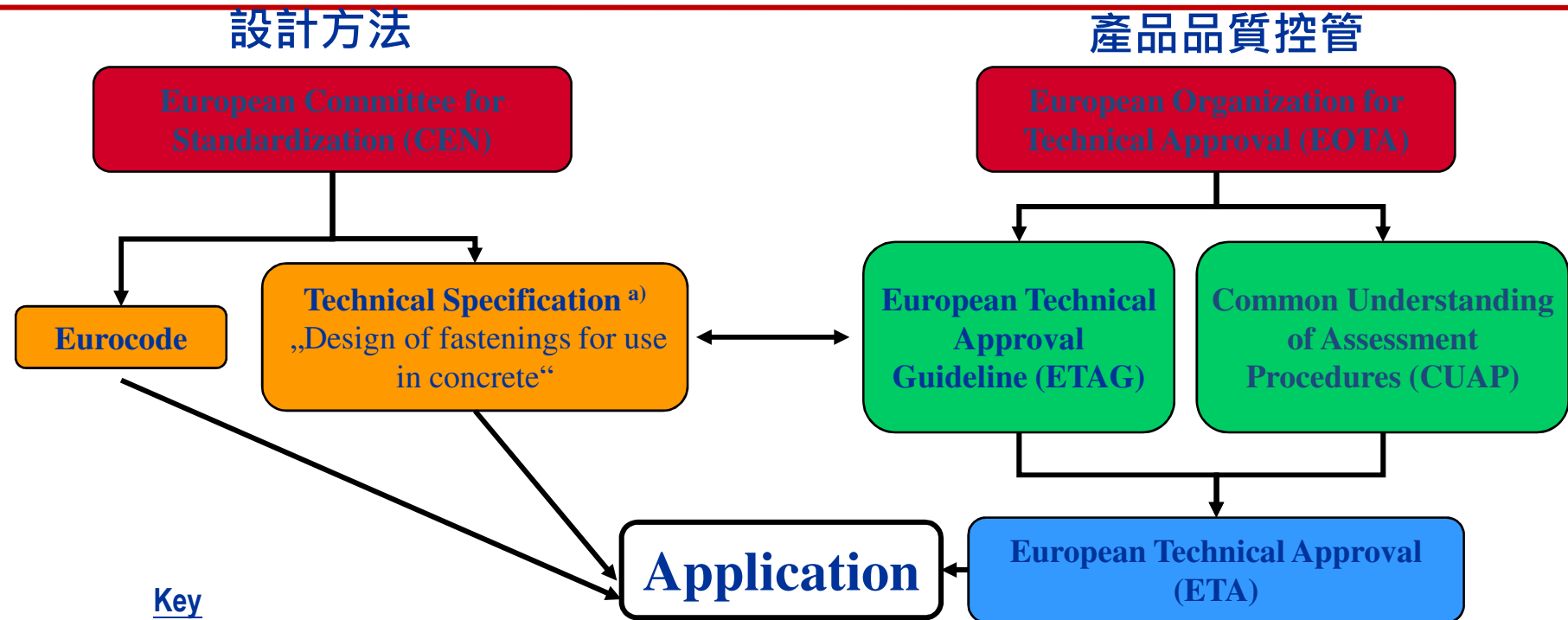


*) Main Evaluation body for anchors

ICC 認證報告中錨栓特點資訊:

- 1.明確說明可以使用在靜力、風力、地震
- 2.錨栓品管控制由第三獨立機構執行(如L)
- 3.錨栓可否用於開裂混凝土認證

歐洲(ETA)- 錨栓(公制)設計與產品品質控制

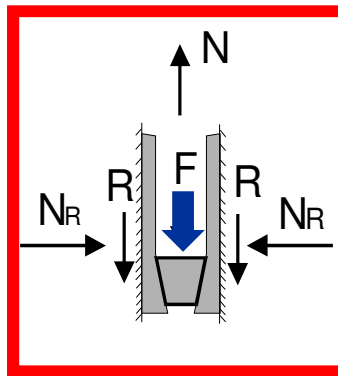


CEN/TS 1992-4

ETA 認證報告中錨栓特點資訊:

1. 正確安裝下錨栓可確保50年工作年限
2. 錨栓短期潛變值
3. 錨栓長期潛變值
4. 錨栓可否用於開裂混凝土認證

2.要了解 後置金屬錨栓的類型 由 固定形式 區分為 位移控制式與扭矩控制式的膨脹螺栓、切底式螺栓、化學錨栓(ACI 318-11年加入)

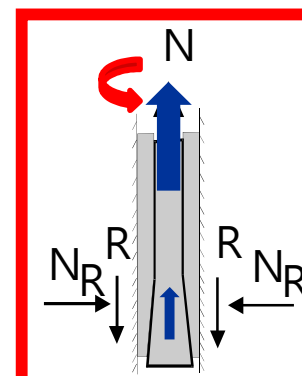


$$N_R > 5 N$$

膨脹式錨栓 Type 1 :
位移控制型;無後續膨脹性



膨脹錐向下擊入

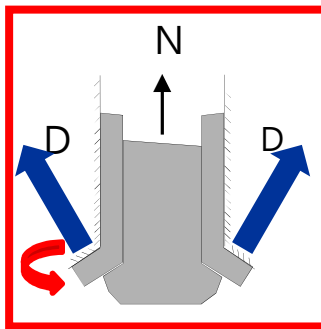


$$N_R > 5 N$$

膨脹式錨栓 Type 2
扭矩控制型;後續膨脹性



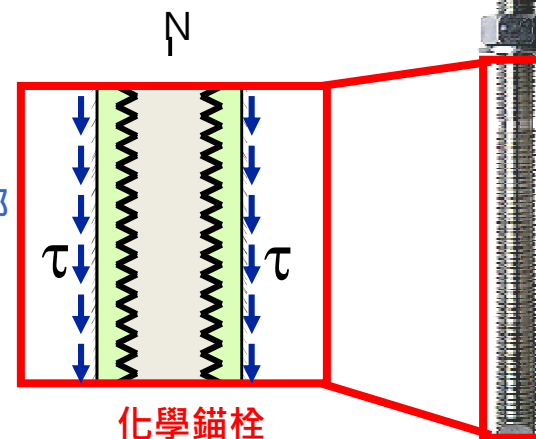
初始扭力帶動膨脹錐
後續外力帶動膨脹錐



切底 (削切)式錨栓



削切混凝土底部
使之形同預埋



化學錨栓

較大的鑽孔孔徑
螺桿與混凝土之間
充滿藥劑黏著握裹
外力由上傳遞至最底端

不同固定方式的後置金屬錨栓其力學行為與應力行為的區別

