PIR OVERVIEW

PIR DESIGN BASIC

IMAGINE WE ARE CONSTRUCTING A NEW SLAB ON A EXISTING WALL STRUCTURE

Using Post-installed rebar…

According to catalogue: 10D? ✗

Treat it as Cast-in Rebar: ~40D? ✗

Too aggressive design

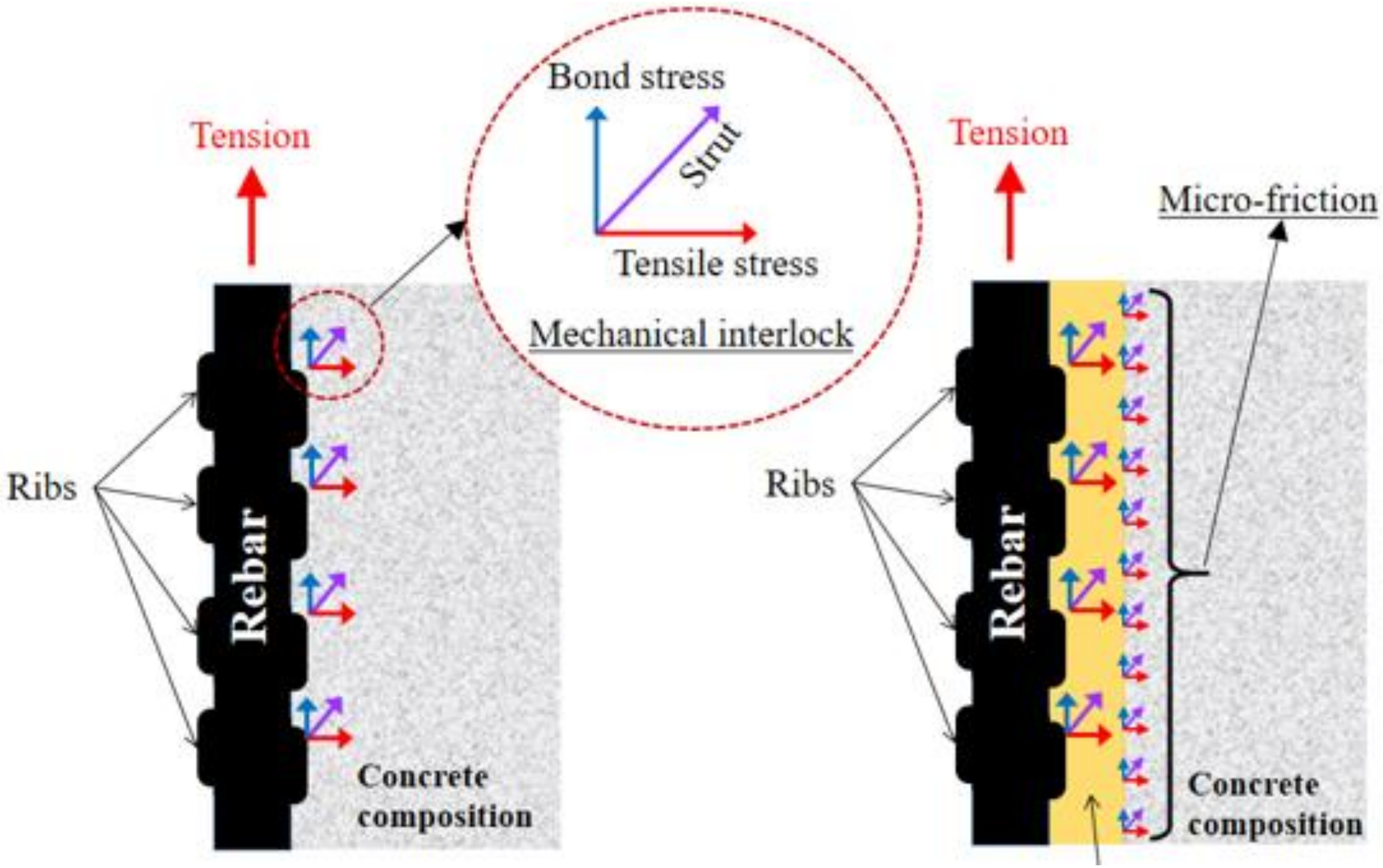
Must be safe but over-designed

Which of the depth should we choose?

Case:
Wall-to-slab A&A works
Cast-in Rebar is not possible

The most optimal design is by calculation based on EC2 design code

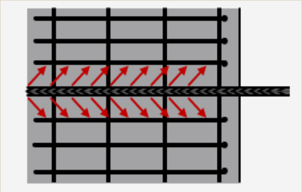
DIFFERENT LOAD-TRANSFER MECHANISM BETWEEN POST-INSTALLED AND CAST-IN REBARS



The interaction bar-mortar-concrete is strongly product dependent and therefore it requires an assessment procedure

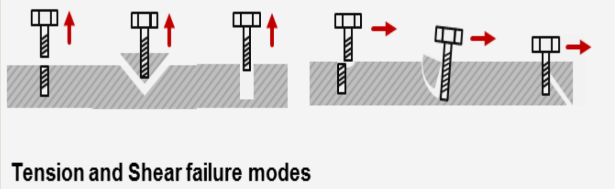
KEY FEATURES ON POST-INSTALLED REBAR DESIGN

Load Transfer

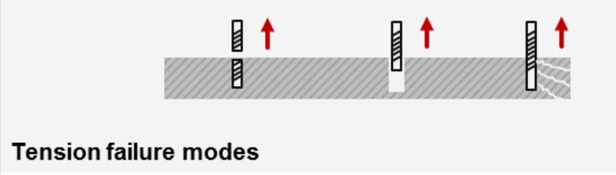


- ➢ Transfer to the existing reinforcement through concrete

Possible Failure Mode



- ➢ Steel, Pull out & Concrete breakout for both tension & shear



- ➢ Steel, Pull out & Splitting and only for tension

Bond Strength

Design bond strength in N/mm² for good bond conditions

All allowed drilling methods									
Rebar - size	Concrete class								
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
ϕ8 - ϕ32	1,6	2,0	2,3	2,7	3,0	3,4	3,7	4,0	4,3

- ➢ Bond strength is controlled by the concrete bond strength

POST-INSTALLED REBAR DESIGN – OVERVIEW

Design Codes

RC Codes – Technical Specifications – Other Building Codes

Design Check

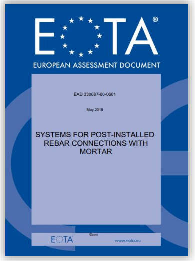
Ultimate Limit State (ULS)
Anchorage Length

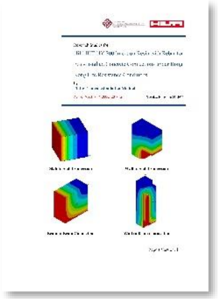
Fire Limit State (FLS)
Anchorage Length

Product Qualification

EAD

HK Fire Assessment





Governing Anchorage Length

POST-INSTALLED REBAR DESIGN – OVERVIEW

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1992-1-1

December 2004

ICS 91.010.30; 91.080.40

Incorporating corrigenda January 2008 and November 2010
Supersedes ENV 1992-1-1:1991, ENV 1992-1-3:1994, ENV 1992-1-4:1994, ENV 1992-1-5:1994, ENV 1992-1-6:1994, ENV 1992-3:1998

English version

Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

Eurocode 2: Calcul des structures en béton - Partie 1-1 : Règles générales et règles pour les bâtiments

Eurocode 2: Bemessung und konstruktion von Stahlbeton- und Spannbetontragwerken - Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau

This European Standard was approved by CEN on 16 April 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

cen

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 1992-1-1:2004: E

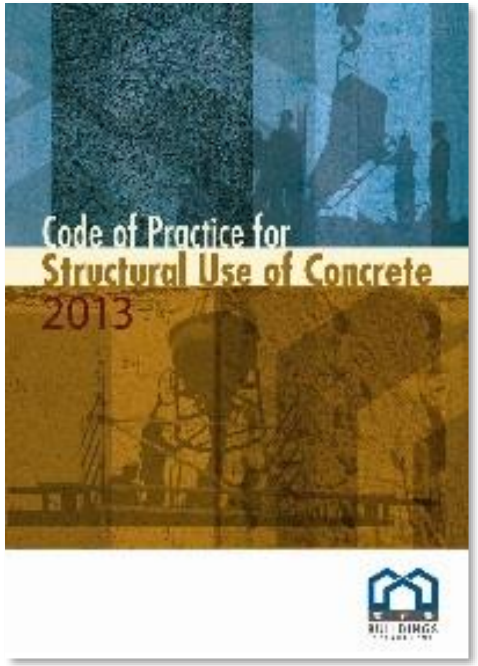
Eurocode 2

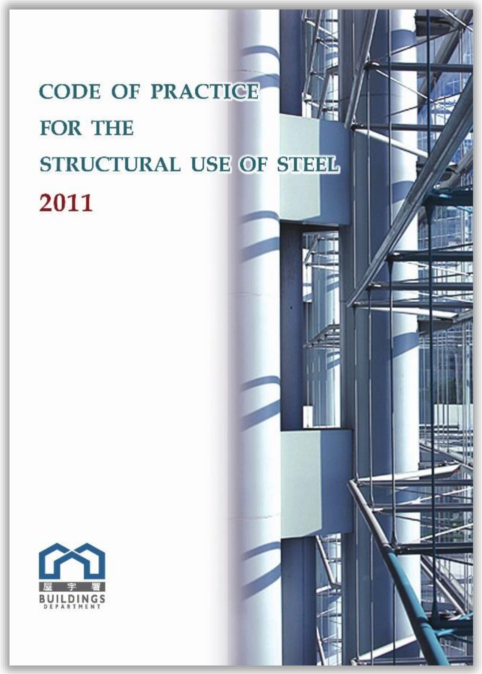
EOTA TR023 superseded by EAD 330087	Assessment of post-installed rebar connections	2006

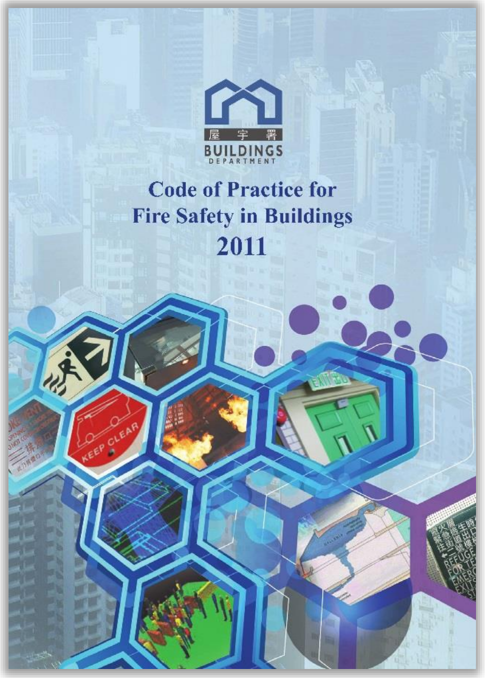
EAD 330087

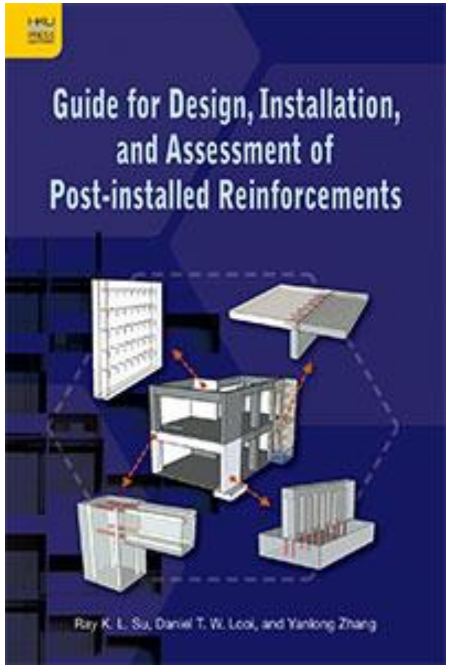
- According to the approval, the post-installed rebar connect with HY200 / RE500, it has **similar performance** as cast-in rebar.

POST-INSTALLED REBAR DESIGN – OVERVIEW









POST-INSTALLED REBAR DESIGN – EXAMPLE

Information required

1) Design stress (from structural analysis) and/or required embedment;

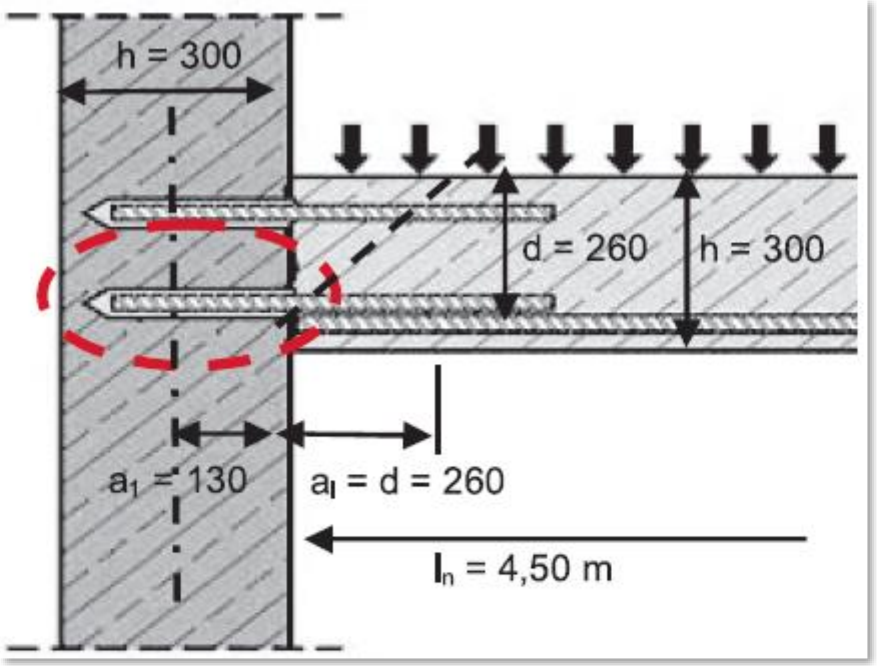
   σ_{sd}= 178 N/mm^2

2) Bar size and spacing = T12-200

3) Concrete Grade = C20/25

<u>Design Input</u>

Design force in bar	F_E	20.1 kN	EC2 9.2.1.4(2)
Required reinforcement	$A_{s,rqd}$	231 mm²/m	
Provided reinforcement	Ø = 12 mm, s = 200 mm → $A_{s,prov}$	565 mm²/m	
Stress in bars	$\sigma_{sd} = F_E/A_{s,prov}$	178 N/mm²	
Adhesive used	Hilti HIT-RE 500 V3		



Loading:
Shear: 90kN (downward)

POST-INSTALLED REBAR DESIGN – EXAMPLE

STEP 1: Basic Anchorage Length

$$l_{b,rqd} = \frac{\phi}{4} \times \frac{\sigma_{sd}}{f_{bd}}$$

Where;

$\emptyset = 12mm, \sigma_{sd} = 178N/mm^2$

Bond condition	Good → η_1	1.00	(input)
Bond strength	$f_{bd,pi}$	2.30 N/mm^2	ETA 16/0142
Basic anchorage length	$l_{b,rqd} = (\emptyset/4)\cdot(\sigma_{sd}/f_{bd,pi})$	232 mm	

8.4.3 Basic anchorage length

(1)P The basic anchorage length, l_b, is the straight length required for anchoring the force $A_s.f_{yd}$ in a bar assuming constant bond stress equal to f_{bd}; in setting the basic anchorage length, the type of the steel and the bond properties of the bars shall be taken into consideration.

(2) For bent bars the anchorage length is measured along the centre-line.

(3) The basic anchorage length required for the anchorage of a bar of diameter ϕ is:

$$l_b = (\phi / 4) (\sigma_{sd} / f_{bd}) \quad (8.3)$$

Where σ_{sd} is the design stress in the bar

Values for f_{bd} are given in 8.4.2.

EC2: EN 1992-1-1:2004

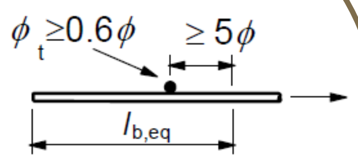
Table 5: Design values of the bond resistance f_{bd} in N/mm^2
Hammer drilling, Compressed air drilling
according to EN 1992-1-1 for good bond conditions
(for all other bond conditions multiply the values by 0.7)

Rebar-Ø	Concrete class								
d_s	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
8 to 32 mm	1,6	2,0	2,3	2,7	3,0	3,4	3,7	4,0	4,3

ETA-12/0083

FACTORS TO CONSIDER FOR MIN. ANCHORAGE LENGTH

Influence factor on the shape of bar



$\alpha_1 = 1$

Influence factor on the transverse pressure

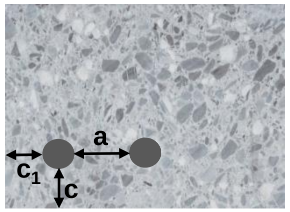
is for the effect of the pressure transverse to the plane of splitting along the design anchorage length

$l_{b,rqd} = (\phi / 4)\,(\sigma_{sd} / f_{bd})$

$$l_{bd} = \alpha_1\, \alpha_2\, \alpha_3\, \alpha_4\, \alpha_5\, l_{b,rqd} \geq l_{0,min}$$

$l_{0,min} = \max(0.3 l_{brqd}; 10\phi; 100mm)$

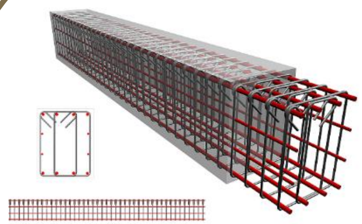
In most of the cases the minimum anchorage length must be amplified by a factor of 1.5 when the diamond core drilling is used.



$c_d = \min(a/2, c_1, c)$

$0.7 \leq \alpha_2 \leq 1$

Influence factor on Concrete Cover



$\alpha_3 = 1$

Influence factor on the confinement by Welded transverse reinforcement

Influence factor on the confinement by transverse reinforcement

POST-INSTALLED REBAR DESIGN – EXAMPLE

STEP 2: Design Anchorage Length

Where; $\alpha_1 = \alpha_3 = \alpha_4 = \alpha_5 = 1$

$$c_d = min\ (a/2, c1, c)$$
$$= min\ (94, c1, c)$$
$$= 94$$

Influence cover/spacing $\alpha_2 = \{0.7 \leq 1\text{-}0.15[(c_d\text{-}Ø)/Ø] \leq 1.0\} = 0.700$

Influence of transv. reinf. $\alpha_3 = \{0.7 \leq 1\text{-}K(\sum A_{st}\text{-}\sum A_{st.min})/(Ø^2\pi/4) \leq 1.0\}$

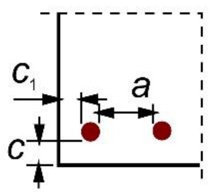
Influence of transv. pressure $\alpha_5 = \{0.7 \leq 1\text{-}0.04p \leq 1.0\}$

$$l_{b,d} = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,rqd} = 162.4 \text{ mm}$$

Table 8.3: Values of α_1, α_2, α_3 and α_4 coefficients

Influencing factor	Type of anchorage	Reinforcement bar: In tension	Reinforcement bar: In compression
Shape of bars	Straight	$\alpha_1 = 1,0$	$\alpha_1 = 1,0$
	Other than straight (see Figure 8.1 (b), (c) and (d))	$\alpha_1 = 0,7$ if $c_d > 3\phi$ otherwise $\alpha_1 = 1,0$ (see Figure 8.4 for values of	
Concrete cover	Straight	$\alpha_2 = 1 - 0,15\ (c_d - \phi)/\phi$ $\geq 0,7$ $\leq 1,0$	
	Other than straight (see Figure 8.1 (b), (c) and (d))	$\alpha_2 = 1 - 0,15\ (c_d - 3\phi)/\phi$ $\geq 0,7$ $\leq 1,0$ (see Figure 8.4 for values of	
Confinement by transverse reinforcement not welded to main reinforcement	All types	$\alpha_3 = 1 - K\lambda$ $\geq 0,7$ $\leq 1,0$	$\alpha_3 = 1,0$
Confinement by welded transverse reinforcement*	All types, position and size as specified in Figure 8.1 (e)	$\alpha_4 = 0,7$	$\alpha_4 = 0,7$
Confinement by transverse pressure	All types	$\alpha_5 = 1 - 0,04p$ $\geq 0,7$ $\leq 1,0$	-

design anchorage length



a) Straight bars
$c_d = \min(a/2, c_1, c)$

EC2: EN 1992-1-1:2004

POST-INSTALLED REBAR DESIGN – EXAMPLE

STEP 3: Check Minimum Requirement

$$l_{b,d} \geq l_{b,min} = max\ \{0.3 l_{b,rqd}, 10\phi, 100\}$$

$$l_{b,min} = max\ \{69.3, 120, 100\} = 120\text{mm}$$

$l_{b,d}$ *controls*

$$l_{b,d} = max(\alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,req}; l_{b,min}) = 162 \text{ mm}$$

$l_{b,rqd}$ is taken from Expression (8.3)

$l_{b,min}$ is the minimum anchorage length if no other limitation is applied:

- for anchorages in tension: $l_{b,min} \geq max\{0{,}3 l_{b,rqd}; 10\varphi; 100 \text{ mm}\}$ (8.6)
- for anchorages in compression: $l_{b,min} \geq max\{0{,}6 l_{b,rqd}; 10\varphi; 100 \text{ mm}\}$ (8.7)

EC2: EN 1992-1-1:2004

ULS Anchorage Length = 162 mm

Larger than 10D

FAILURE MODE AND LOAD TRANSFER IN CAST-IN AND POST-INSTALLED REBAR

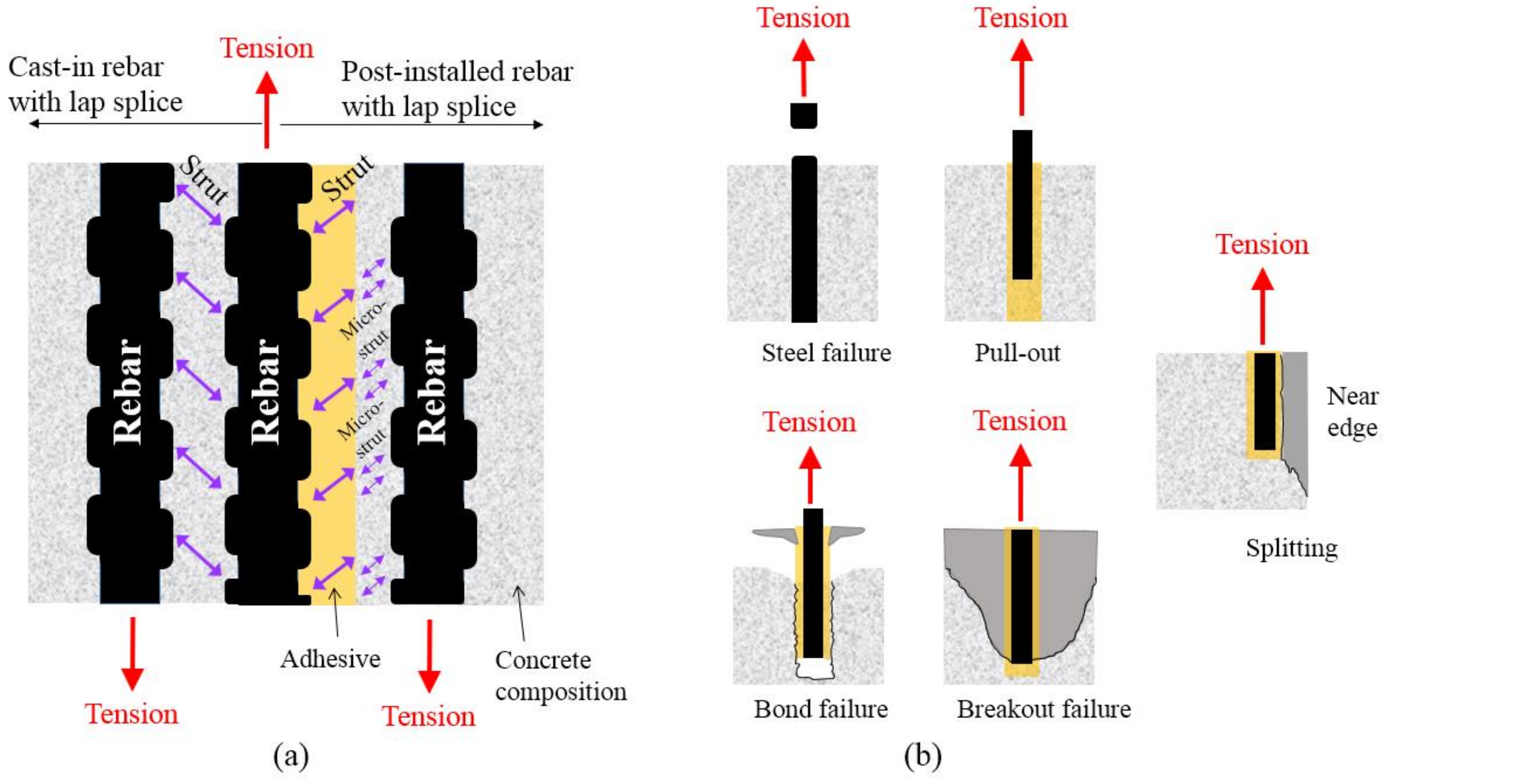


Fig. 1.3 Load transfers mechanism (a) lap splices in cast-in and post-installed reinforcement (b) without lap splices, anchor-dominated failure modes

INSTALLATION PROCEDURE

TYPICAL WORKFLOW ON POST-INSTALLED REBAR (PIR) INSTALLATION

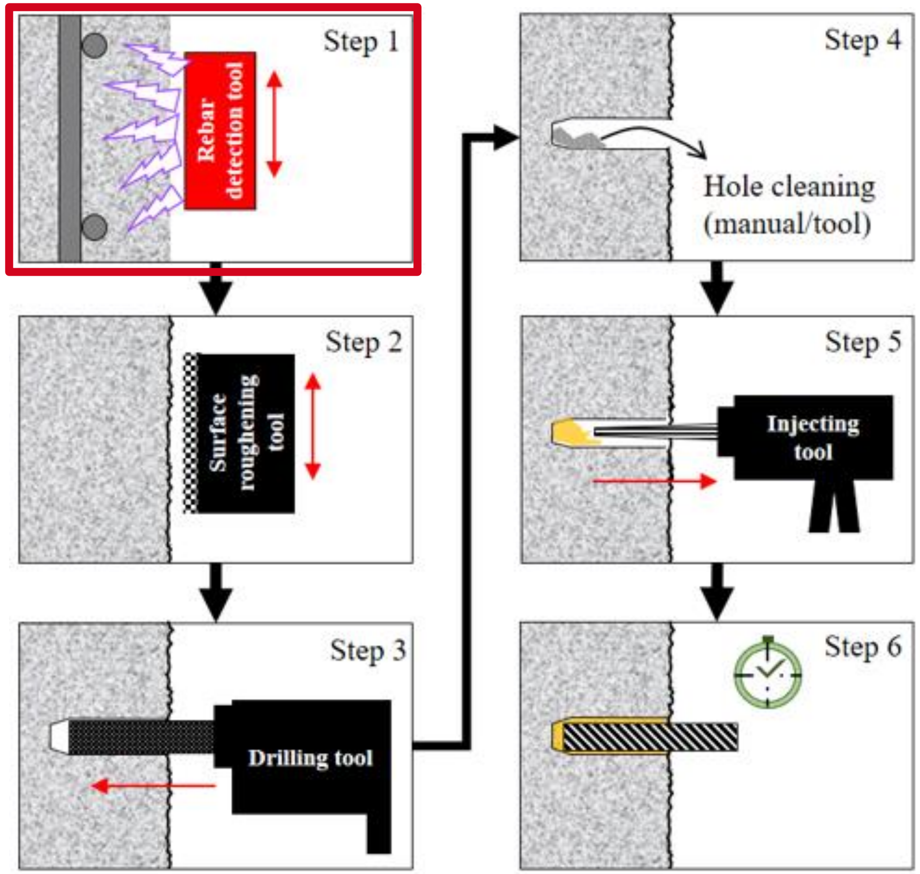
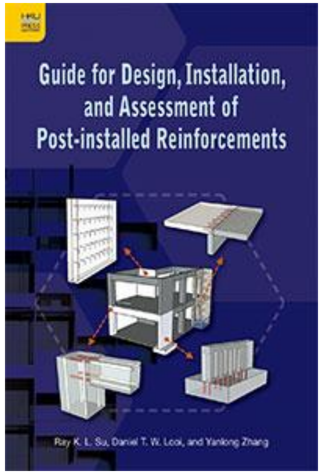


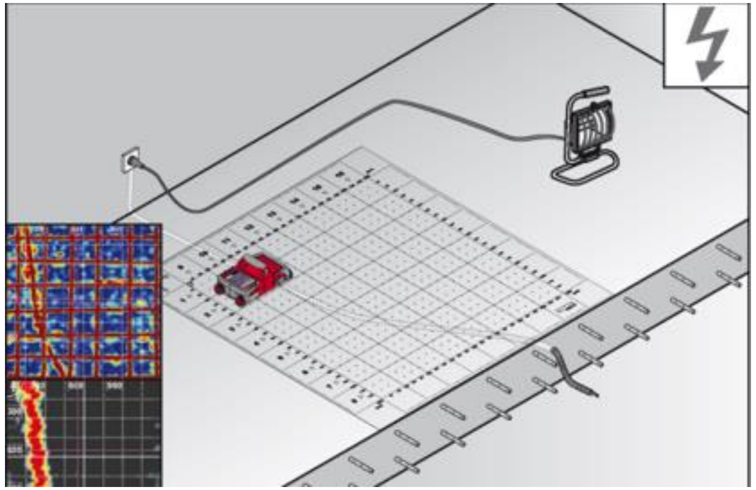
Fig. 3.1 Typical installation sequential procedure of post-installed rebar



CONSTRUCTION ELEMENTS THAT CAN BE FOUND IN EXISTING CONCRETE

- Ferrous Embedded items
- Rebars

- Non-Ferrous Embedded item
- Plastic/ PVC Pipes
- Voids



- Wires with electricity

IMPACTS ON THE WHOLE CONNECTION DESIGN ON TECHNICAL ASPECT

Concrete

- Damaged when heavily drilled
- Cracks & fissure may affect the capacity of the rebar

Adhesive

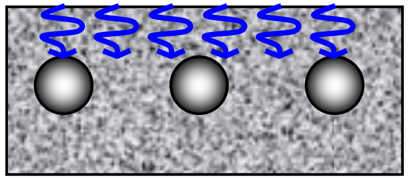
- Flow through the void inside
- Cannot assure the depth of rebar filled with adhesive

Rebar

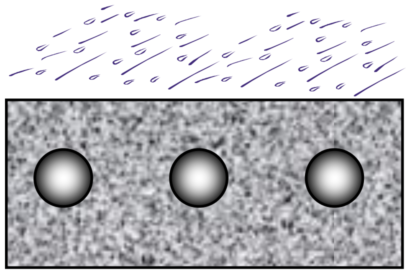
- Exposing existing rebar

Performance of Rebar will vary from design assumption

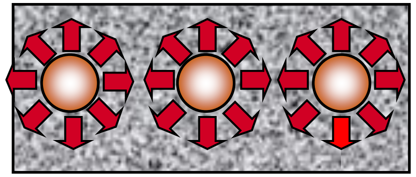
WHY DEPTH / CONCRETE COVER IS CRITICAL AND MUST BE VERIFED



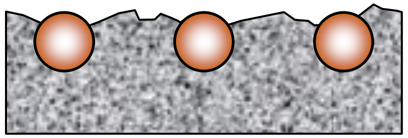
Workloads provoke small cracks in concrete surfaces. With insufficient concrete cover, cracks go down to rebar.



Humidity out of ambient air intrudes into structural member.

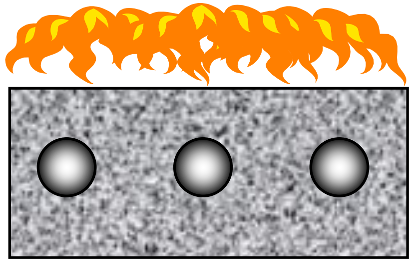


Rebar corrodes, expands and looses tensile strength.

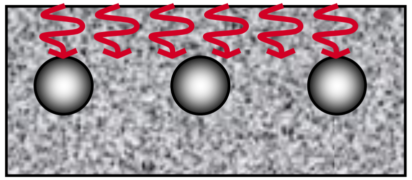


Concrete surface may blow off.

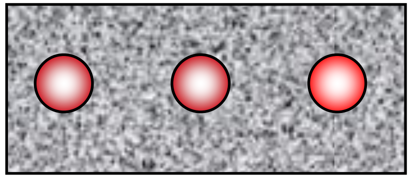
Preventing steel failures and thus collapses of the structure



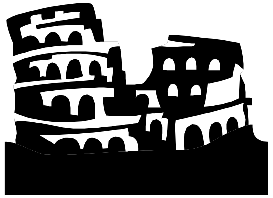
Concrete surface exposed to fire over longer period



Heat penerates concrete



Rebar heats up and loses strength (has lost most of its strength by about 500°C)



Structure collapses

TYPICAL WORKFLOW ON POST-INSTALLED REBAR (PIR) INSTALLATION

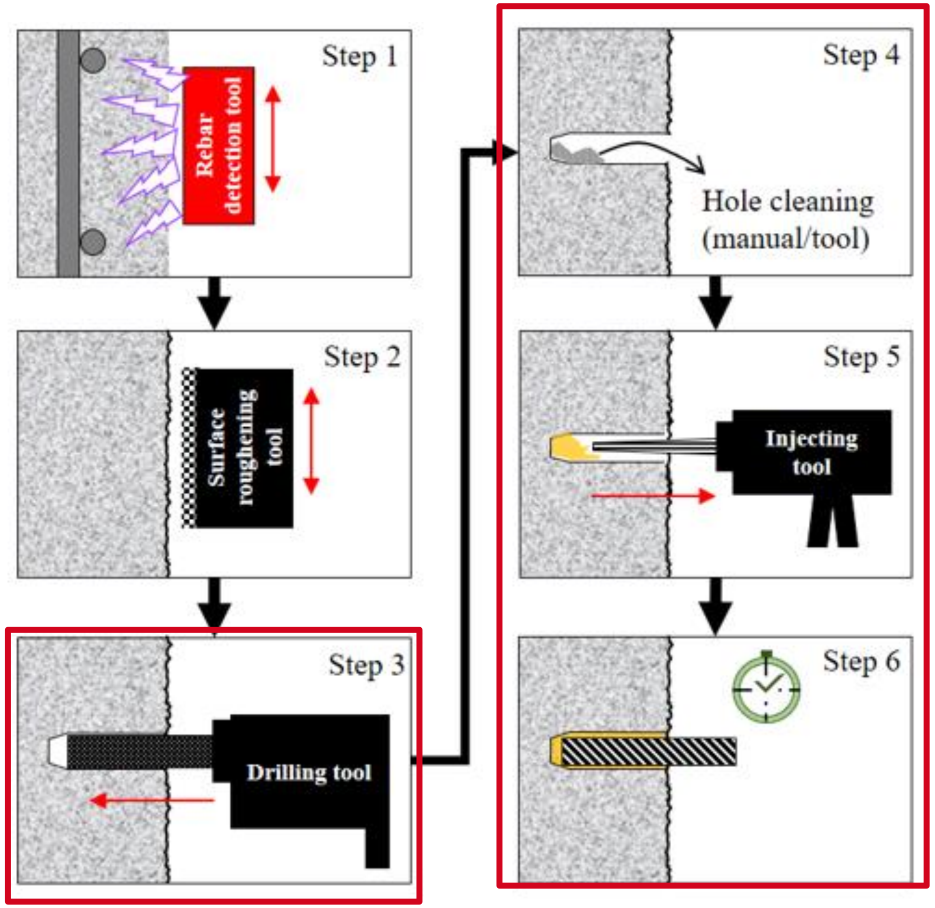
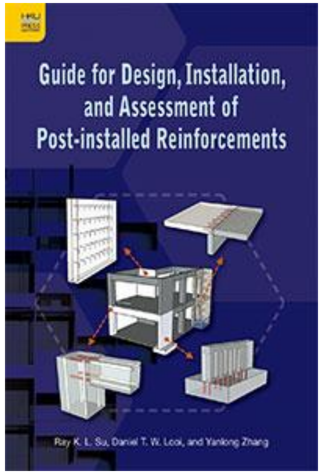


Fig. 3.1 Typical installation sequential procedure of post-installed rebar



WHAT IS GOING ON?

What's wrong in the installation process?

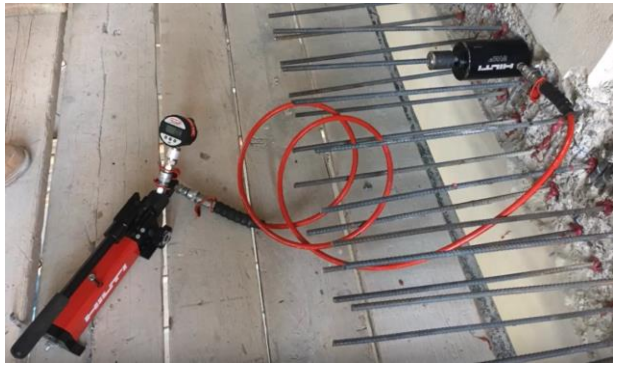
- Not enough repetition
- Wrong equipment
- Safety concerns

WHY CLEANING IS SO CRUCIAL?

CAUTION

No cleaning or improper cleaning of the borehole can lead to dramatic decrease of post-installed rebar resistance!

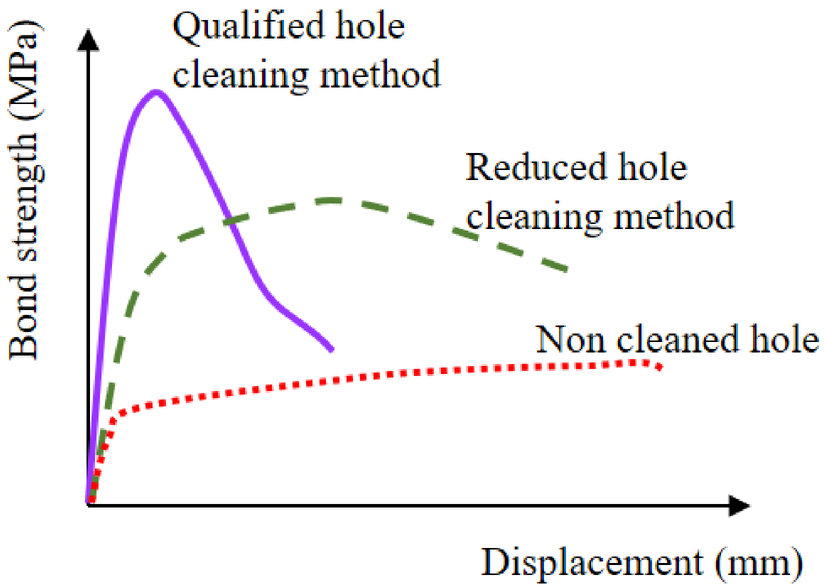
Pull-out Test



Hammer drilled borehole

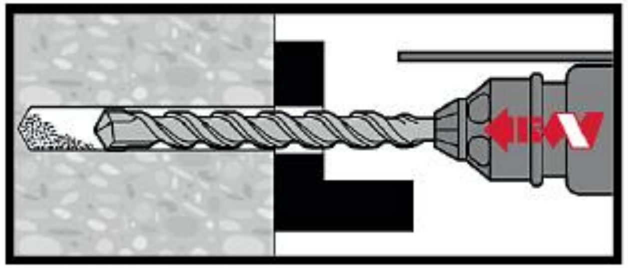
Diamond drilled borehole

Represntation of impacts from cleaning on bond strength



* Ilustrative (depends on mortar type, concrete class, etc.)

HOW DOES CLEANING AFFECT REBAR PERFORMANCE?



Dust & debris settle at the bottom of drill hole

Dust & debris still adhere on the interior surface

ULS equation for basic anchorage length

$$Design\ Force = Capacity\ of\ Rebar$$

$$\sigma_{sd} * (Sectional\ Area\ of\ Rebar) = f_{bd} * (Contact\ Area\ with\ adhesive)$$

$$\sigma_{sd} * \pi \left(\frac{\emptyset}{2}\right)^2 = f_{bd} * (\pi \emptyset l_{b,rqd})$$

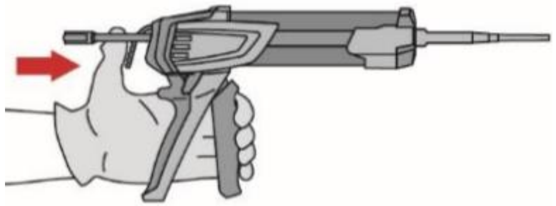
$$l_{b,rqd} = \frac{\Phi}{4} \times \frac{\sigma_{sd}}{f_{bd}}$$

Dust reduces the bond strength between rebar and concrete **but not catered in Eqn**

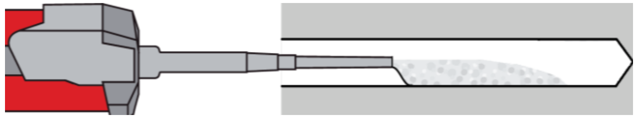
Is the bonding strength as ideal as we assumed?

HOW CAN WE ENSURE 100% FILLING VOLUME INSIDE THE DRILL HOLE?

Traditional Method



Manual Dispenser



Nozzle with no accessories

- Poor distribution of chemical into the drill hole
- Half fill in horizontal application
- Difficult to maintain consistency in ceiling application
- Air bubbles/ voids present

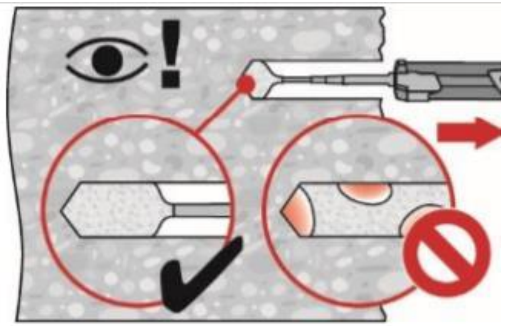
Innovative Solution

Electrical Dispenser

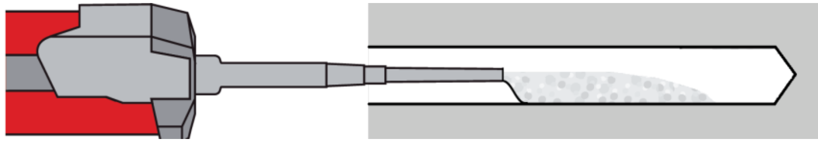
Extension tube and Piston Plug

- Consistent distribution of chemical into the drill hole
- Fully spread chemicals

HOW DOES INJECTION AFFECT REBAR PERFORMANCE?



Air bubbles



Horizontal application

ULS equation for basic anchorage length

$$Design\ Force = Capacity\ of\ Rebar$$

$$\sigma_{sd} * (Sectional\ Area\ of\ Rebar) = f_{bd} * (Contact\ Area\ with\ adhesive)$$

$$\sigma_{sd} * \pi \left(\frac{\emptyset}{2}\right)^2 = f_{bd} * \left(\pi \emptyset l_{b,rqd}\right)$$

$$l_{b,rqd} = \frac{\phi}{4} \times \frac{\sigma_{sd}}{f_{bd}}$$

Void reduces the area of contact between adhesive and rebar **but not catered in Eqn**

Is the filling of adhesive as ideal as we expected?

THANK YOU