PROFIS ENGINEERING

Masonry module

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BEng & Arch

THIS IS HILTI:

- Founded in 1941 in Schaan, Liechtenstein
- World market leader in fastening and demolition technologies for construction professionals
- Roughly 32,000 employees in more than 120 countries
- Roughly 280,000 customer interactions per day
- 100% family owned: all shares held by the Martin Hilti Family Trust

SOLUTIONS FOR CONSTRUCTION PROFESSIONALS

Drilling and demolition

- Drilling and chiseling
- Diamond systems

Cutting and grinding

- Cutting and grinding
- Diamond systems

Engineering

- Design
- Specifications
- Consulting

Measuring and aligning

- Distance measuring
- Leveling and aligning
- Detection

Fastening and installation

- Direct fastening
- Screw fastening technology
- Anchor technology
- Installation

Firestop and insulation

- Construction chemicals
- Firestop

Services

- Training and advice
- Quality and testing
- Logistics
- Finance and administration
- Engineering services
- Tool services

Software

AGENDA

1. Masonry as a base material
2. Anchor working principles and brickwork
3. Regulatory framework. Anchor portfolio
4. Design flow with ETA data available
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6. PROFIS Engineering: Masonry module overview

MASONRY

Masonry is the craft of building structures with brick, stone, or similar materials, which are often laid in and bound together by mortar.

Masonry is one of the oldest building technologies that remains popular to this day.

Great Chinese wall

Parthenon

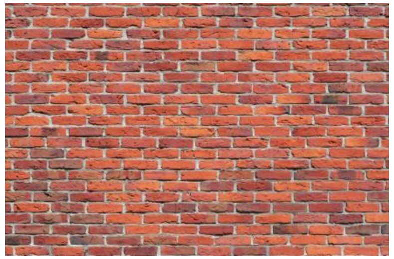
Giza pyramids

Coliseum

Maya temples

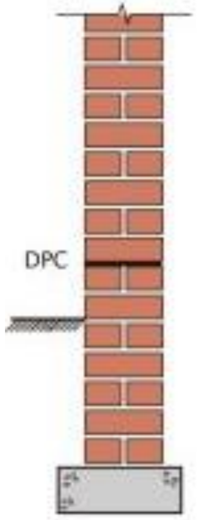
Babylonian walls

MAIN TYPES OF MASONRY

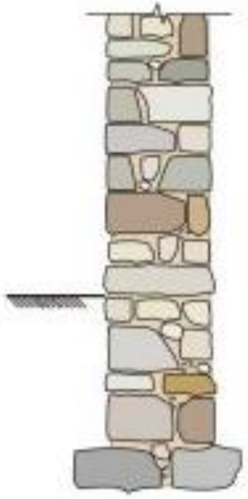
Stone	Clay	Concrete	Others
Rubble	**Adobe**	**Concrete bricks**	**Calcium Silicate**
Rough shaped	air dried, “mud brick”	Light / normal weight	aka sand lime brick
			
Ashlar	**Fired bricks**	**ACC**	
Shaped stones	“regular clay brick”	AAC autoclaved aerated concrete	
			Too heterogeneous, large scatter between various masonry units

STRUCTURAL ELEMENTS MAY CONSIST OF SEVERAL UNITS OF MASONRY

Single masonry unit

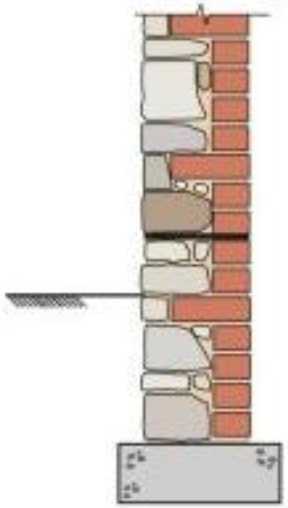


1 brick wall

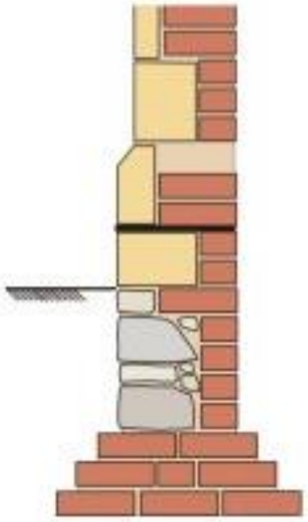


Rubble wall

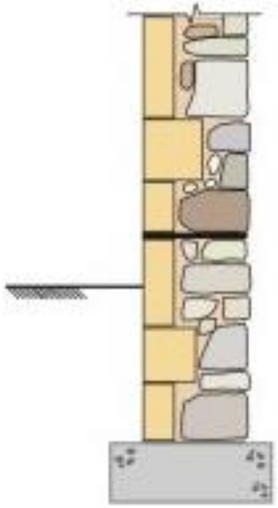
2+ masonry units



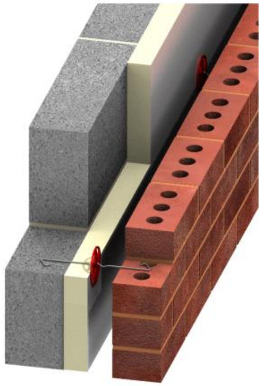
Rubble wall with brick cladding



Ashlar with brick backing



Ashlar with rubble backing



ACC + air lay + brick cladding

Preliminary detailed inspection of an element, covering both internal and external faces, needs to be done before anchor design and installation

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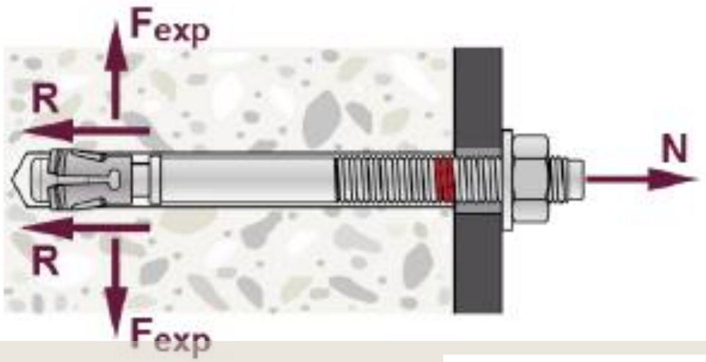
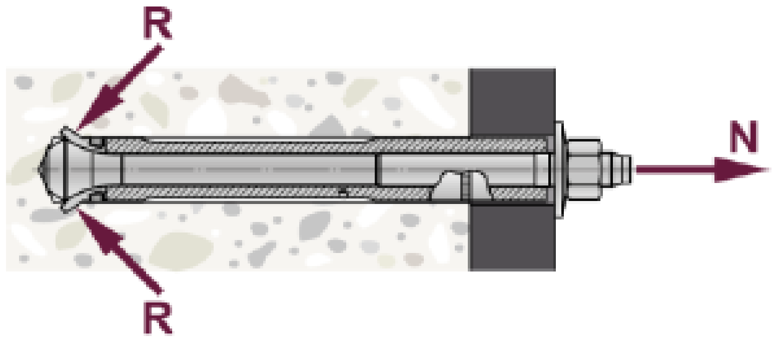
ANCHORS WORKING PRINCIPLES

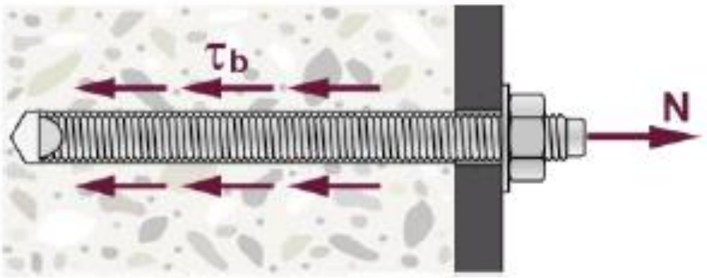
Expansion (friction)

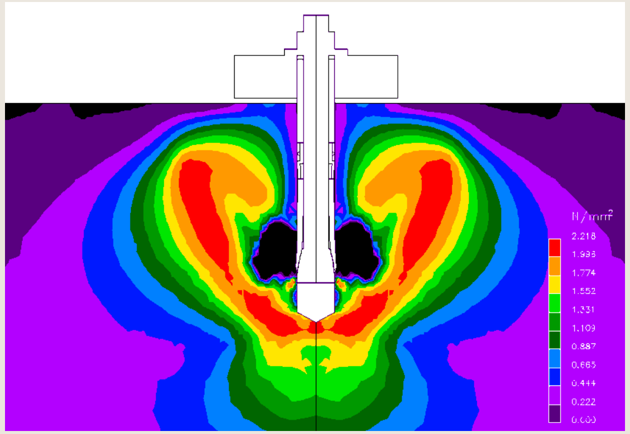


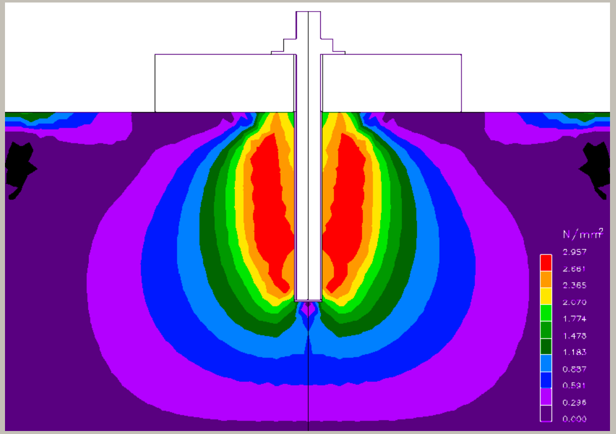
Mechanical interlock



Bonding







ANCHORS WORKING PRINCIPLES

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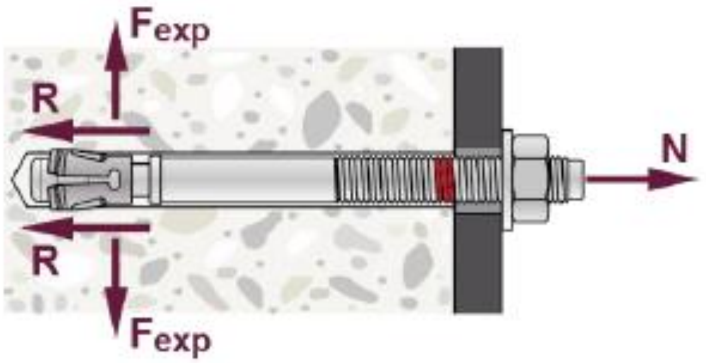
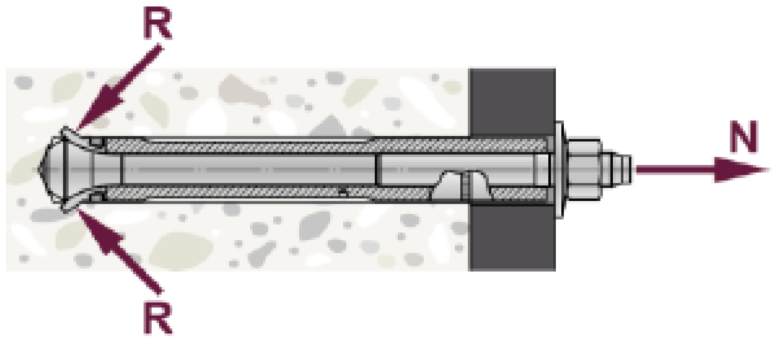
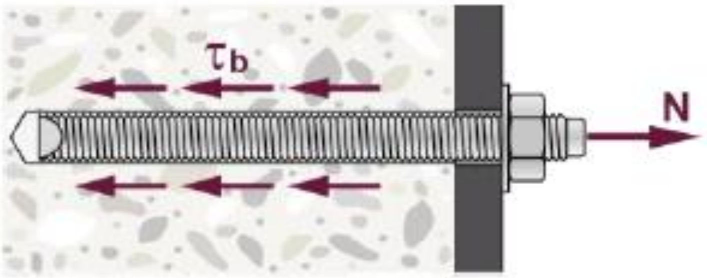


Mechanical interlock



Bonding

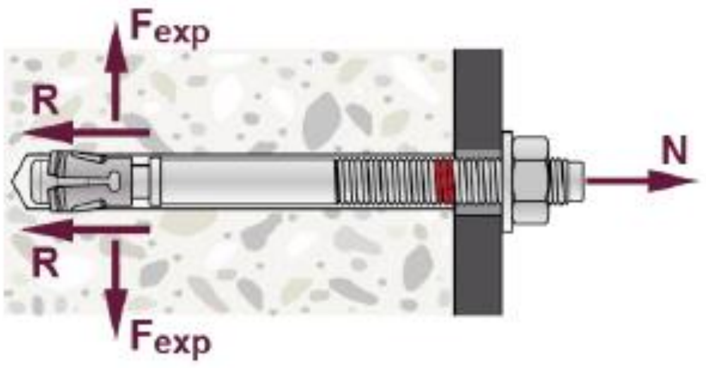


- Stress transfer localized along the length of expanding element / protruding element pressing on base material
- Smaller high stress areas lead to wider breakout cones

- Stress transfer along the effective embedment depth
- Even stress distribution with narrow cones

ANCHORS WORKING PRINCIPLES

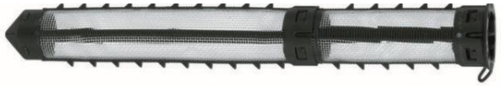
Expansion (friction)



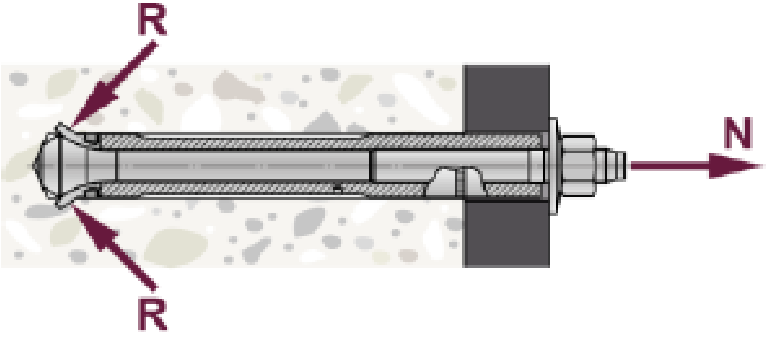
- Stress transfer localized along the length of extended element pressing on base materia
- Smaller high stress areas lead to wider brea

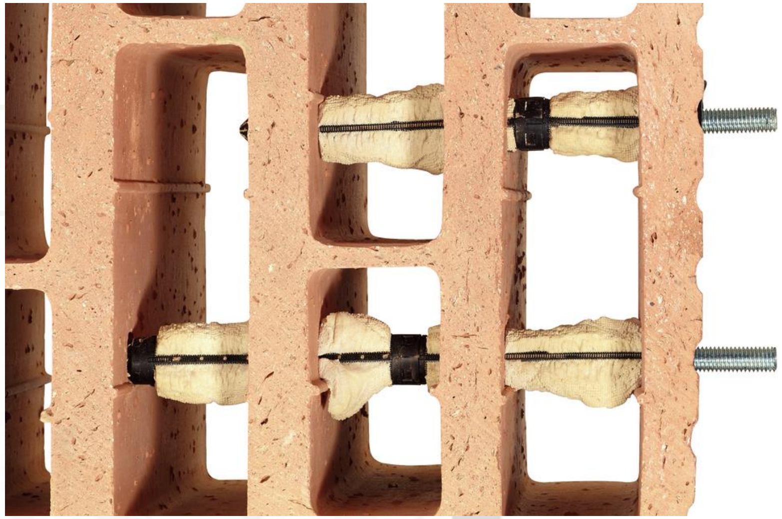
narrow cones

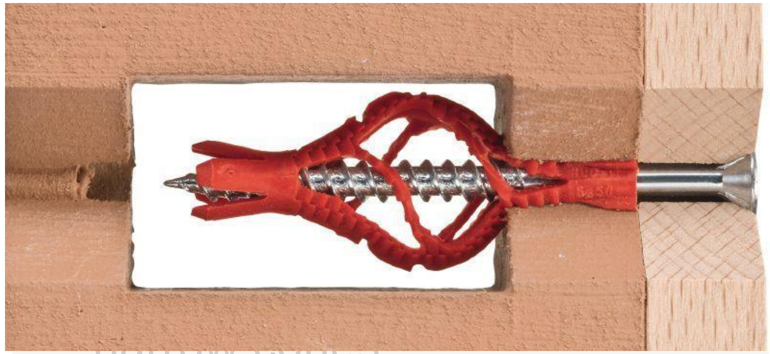
ANCHORS WORKING PRINCIPLES



Mechanical interlock





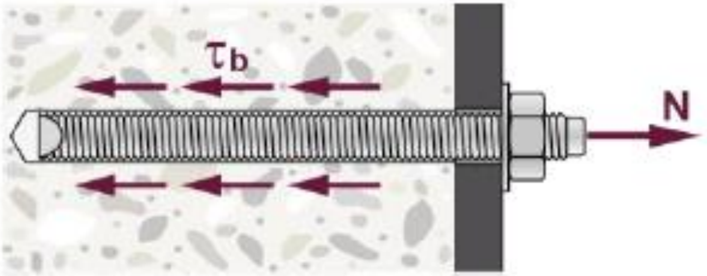


- S… ng the length of expanding element / e… on base material
- S… ad to wider breakout cones

ANCHORS WORKING PRINCIPLES

Expansion (friction)

Bonding



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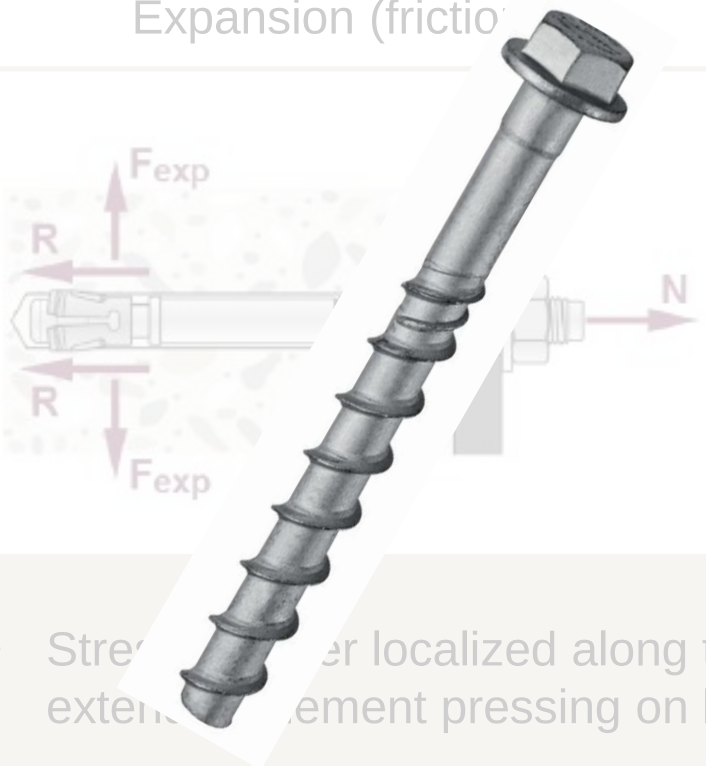
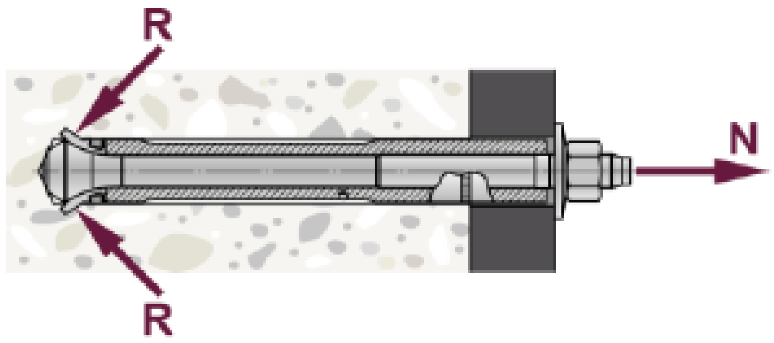
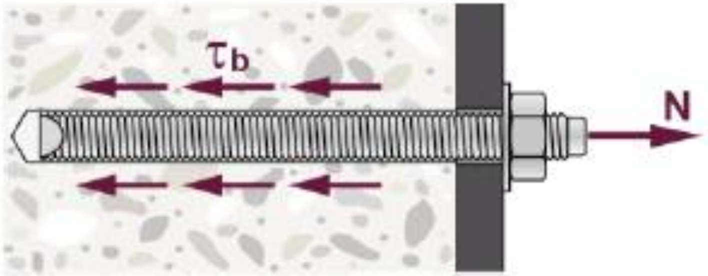
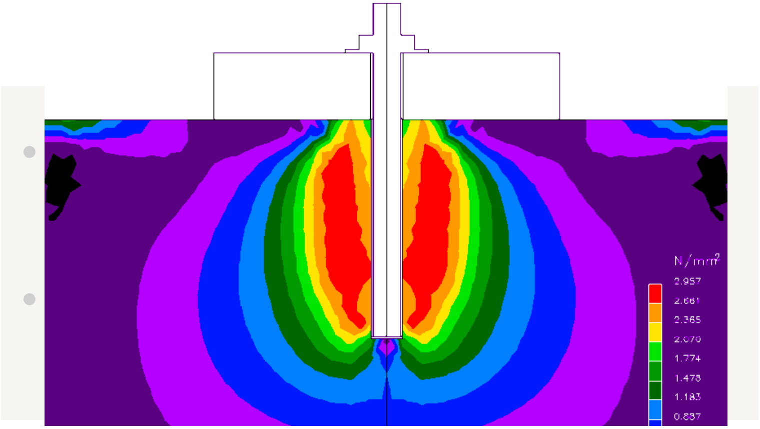
ANCHORS WORKING PRINCIPLES

Expansion (frictio	Mechanical interlock	Bonding









- Stre … er localized along the length of expanding element / exte … ement pressing on base material
- Smaller high stress areas lead to wider breakout cones

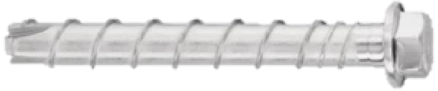
WHAT ANCHORS WORK IN MASONRY?

Undercut anchors (HDA, HSC, …)

Expansion anchors (HST3, HSA, …)

Drop-in anchors (HKD, …)

Screw anchors (HUS4, HUS3, …)



Plastic anchors (HRD, …)

Resin anchors (HIT-HY 270, HIT-HY 170 …)

Medium- and heavy-duty steel anchors **are not the best fit** for masonry due to the way they transfer loads in the base material (undercut and expansion)

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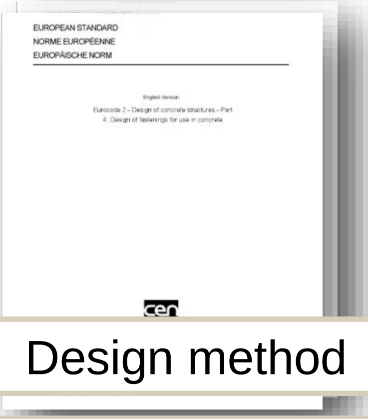
HILTI

REGULATORY FRAMEWORK



Product qualification	↔	Technical data	↔	Design method
EAD – European Assessment Document		ETA – European Technical Assessment		Eurocode ↑ EOTA Technical reports
• What essential characteristics of a product must be known • How to test for the essential characteristics and evaluate results		• Essential characteristic values • Field of application of a product, installation requirements …		• How to design and calculate

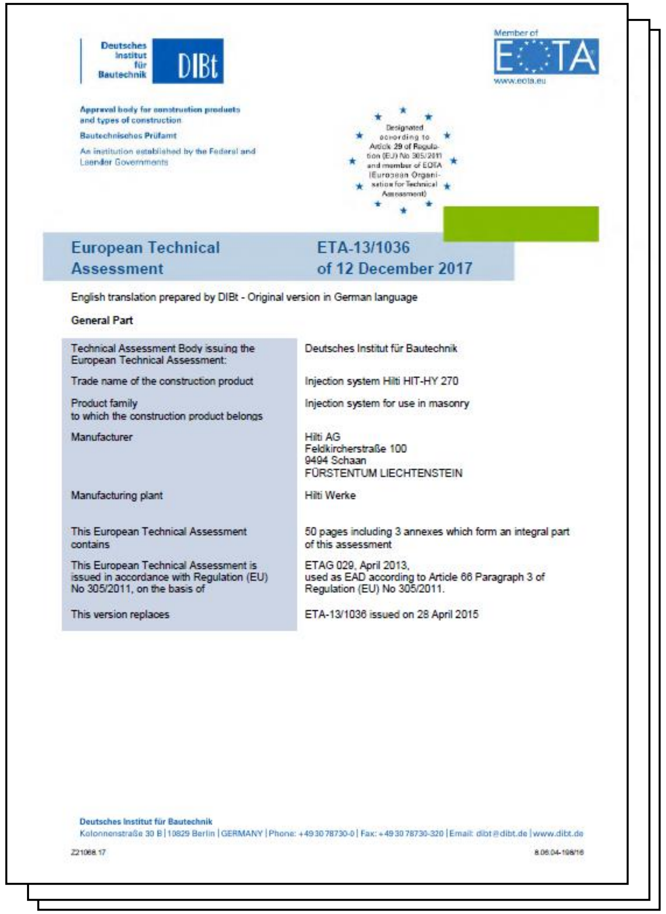
REGULATORY FRAMEWORK. FIXTURES IN MASONRY

	Chemical anchors	Plastic anchors
Product qualification	EAD 330076-00-0604	ETAG020 Annex A
Technical data	ETA	ETA
Design method	EOTA TR054	ETAG020 Annex C
Guideline for on-site tests assessment	EOTA TR053	ETAG020 Annex B

ETA approved anchors	Anchors with Hilti Test Data*
 **HIT-HY 270, HIT-HY 170**	 **HIT-1 CE, HIT-MM Plus**
 **HRD**	 **HUD / HPS**
	 **HUS 4 / HUS**

Fixtures in masonry covered by the anchor ETA can be designed by the official design method **without** on-site tests.

HIT-HY 270: ETA AND HILTI TEST DATA


Deutsches Institut für Bautechnik DIBt

Member of EOTA www.eota.eu

Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

Designated according to Article 29 of Regulation (EU) No 305/2011 and member of EOTA (European Organisation for Technical Assessment)

European Technical Assessment | ETA-13/1036 of 12 December 2017

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	Injection system Hilti HIT-HY 270
Product family to which the construction product belongs	Injection system for use in masonry
Manufacturer	Hilti AG Feldkircherstraße 100 9494 Schaan FÜRSTENTUM LIECHTENSTEIN
Manufacturing plant	Hilti Werke
This European Technical Assessment contains	50 pages including 3 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	ETAG 029, April 2013, used as EAD according to Article 66 Paragraph 3 of Regulation (EU) No 305/2011.
This version replaces	ETA-13/1036 issued on 28 April 2015

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Z21068.17 8.06.04-198/16

- **ETA –** European Technical Assessment covers the purpose and the field of application of a product, contains product specific characteristic data, installation requirements and other details
- HIT-HY 270 **ETA** covers **12 types of masonry**, based on independent tests
- Hilti also provides **technical data** for **26** other types of masonry, based on **Hilti tests**

Fixtures in masonry covered by ETA can be designed by the official design method without on-site tests.

CHARACTERISTIC ANCHOR RESISTANCE DEPENDS ON INSTALLATION PARAMETERS

Table B2: Overview brick types and properties

Brick type	Picture	Brick size [mm]	Compressive strength $f_{b,ETA}$ [N/mm²]	Bulk density [kg/dm³]	Annex
Solid clay brick EN 771-1		≥ 240x115x52	12 / 20 / 40	2,0	C3/C4
Solid clay brick EN 771-1		≥ 240x115x72	10 / 20	2,0	C5/C7

Characteristic resistances for all anchor combinations (see Table B3)

Table C8: Tension resistance at edge distance c ≥ 50 mm

Use category			**w/w = w/d**		**d/d**	
Service temperature range			**Ta**	**Tb**	**Ta**	**Tb**
Anchor type and size	h_{ef} [mm]	f_b [N/mm²]	$N_{Rk,p} = N_{Rk,b}$ [kN]			
All anchor	≥ 50	10	1,5 (1,5*)			
		20	2,0 (2,0*)			
	≥ 80	10	2,5 (3,0*)			
		20	3,5 (4,0*)			

* CAC cleaning only

The anchor resistance for tension and shear is affected by:

1. Brick mean compression strength

2. Moisture present at installation / use:

- **d/d** – installation and use at dry indoor conditions
- **w/d** – installation in wet conditions and use at dry indoor conditions
- **w/w** – installation and use at dry or wet outdoor conditions

3. In-service temperature range:

Ta – from -40°C to +40°C (+24°C/+40°C);

Tb – from -40°C to +80°C (+50°C/+80°C)

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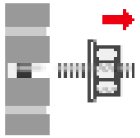
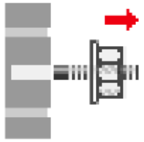
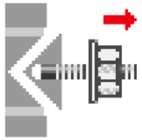
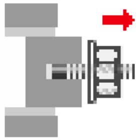
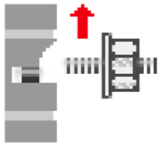
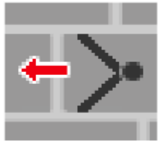
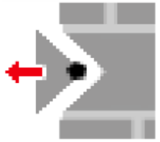
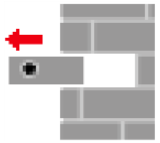
ANCHOR FAILURE MODES IN MASONRY

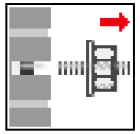
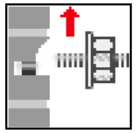
Tension	
(1) Steel failure	
(2) Pull-out failure	
(3) Brick breakout failure	
(4) Pull-out of one brick	

Shear	
(5) Steel failure	
(6) Local brick failure	
(7) Brick edge failure	
(8) Push out of one brick	

Combination check

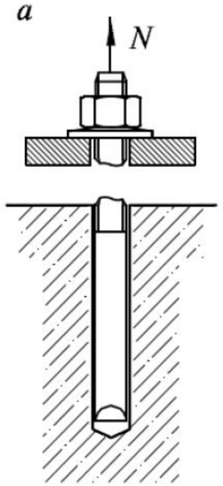
DEFINING RESISTANCE

Failure mode	**(1)** Steel failure (tension) **(5)** Steel failure (shear)

Evaluation for: highest loaded anchor

Tension: $N^{h}_{Sd} \leq N_{Rk,s} / \gamma_{Ms}$

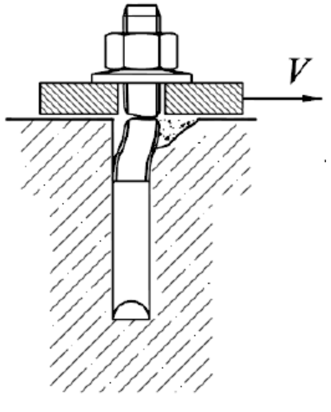


For threaded rods:

$N_{rk,s} = A_s \cdot f_{uk}$

Shear: $V^{h}_{Sd} \leq V_{Rk,s} / \gamma_{Ms}$

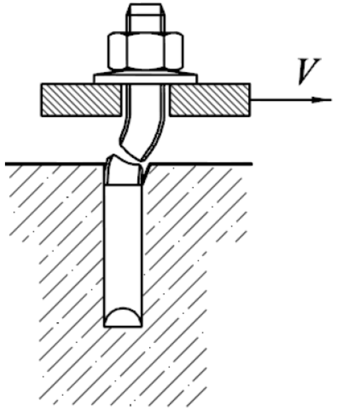
a) No lever arm



For threaded rods:

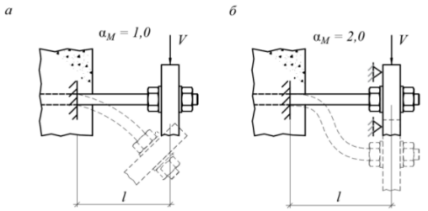
$V_{Rk,s} = 0{,}5 \cdot A_s \cdot f_{uk}$

б) With lever arm



$V_{Rk,s} = \alpha_M \cdot M_{Rk,s} / l$

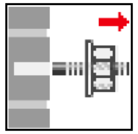
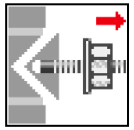
α_M – restraint level factor



γ_{Ms} , $N_{rk,s}$, $V_{rk,s}$ and $M_{rk,s}$ taken from anchor ETA. Stand-off not permitted without grouting or plaster

DEFINING RESISTANCE

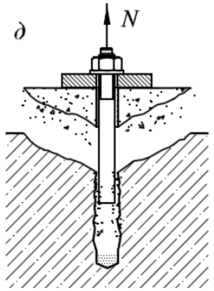
Failure mode	**(2)** Pull-out failure (tension) **(3)** Brick breakout failure (tension)

Evaluation for: highest loaded anchor + group of anchors

Pull-out:

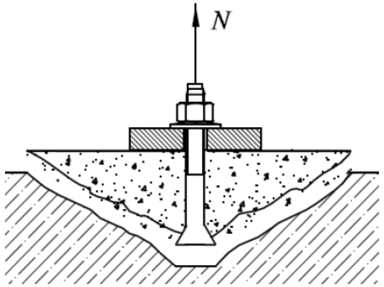
$N^h_{Sd} \leq \alpha_j \cdot N_{Rk,p} / \gamma_{Mm}$



Brick break out:

$N_{Sd} \leq \alpha_j \cdot N_{Rk,b} / \gamma_{Mm}$

$N_{Sd}^g \leq \alpha_j \cdot N^g_{Rk} / \gamma_{Mm}$



γ_M , $N_{Rk,p}$, $N_{Rk,b}$ taken from anchor ETA.
ETA provides one figure for $N_{Rk,p} = N_{Rk,b}$.

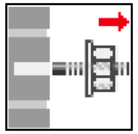
Main factors:

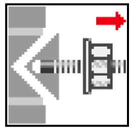
- Geometry of the fixture – anchor spacing and edge distances
- Cleaning of the drill hole
- Installation conditions – wet / dry
- Temperature range for use
- Vertical joints composure
- Factors for anchor group

DEFINING RESISTANCE

Failure mode

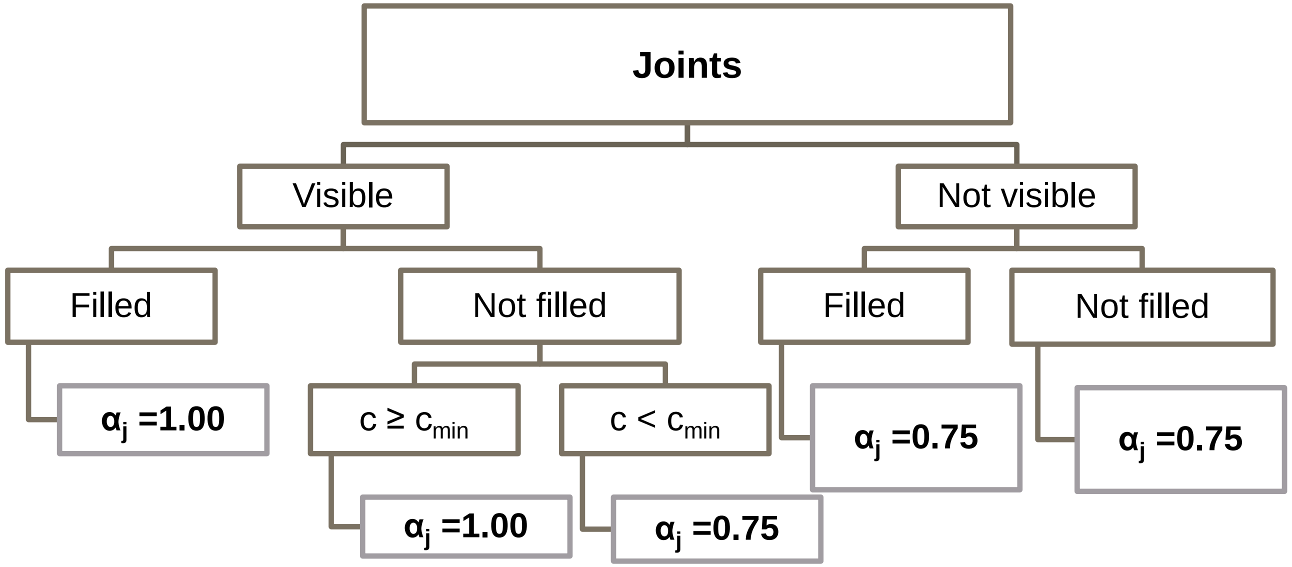
(2) Pull-out failure (tension)
(3) Brick breakout failure (tension)\





Joints composure factors:

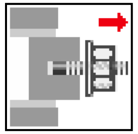
$$N_{Sd} \leq \alpha_j \cdot N_{Rk,p} / \gamma_{Mm}$$
$$N_{Sd} \leq \alpha_j \cdot N_{Rk,b} / \gamma_{Mm}$$



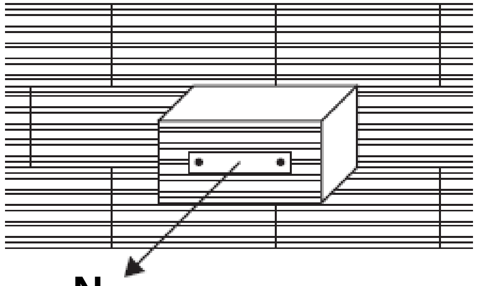
Note:
For not filled joints **c** is the distance to the closest joint. For this case **c** could be lower than $\mathbf{c_{min}}$, but the distance to the edge of the wall can not be **<$\mathbf{c_{min}}$** .

DEFINING RESISTANCE

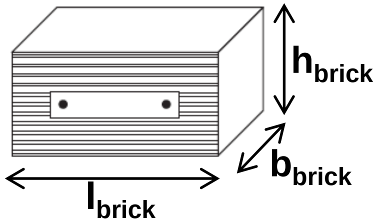
Failure mode	(4) Pull out of one brick (tension)



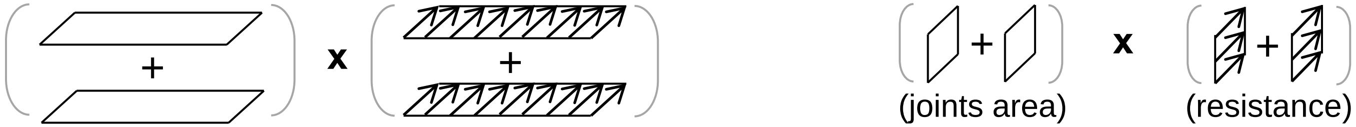
Evaluation for: full load for an anchor or a group of anchors



$N_{Sd} \leq N_{Rk,pb} / \gamma_{Mm}$

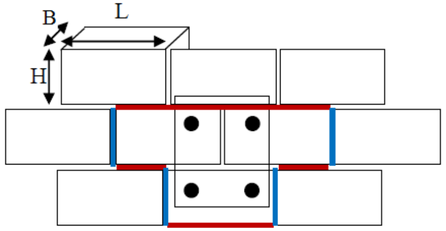


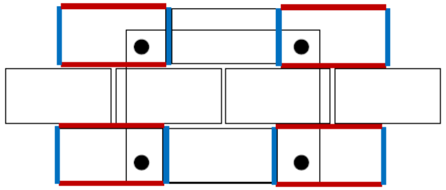
$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} \cdot (0{,}5 \cdot f_{vko} + 0{,}4 \cdot \sigma_d) + b_{brick} \cdot h_{brick} \cdot f_{vko}$



Resistance of **horizontal joints**

Resistance of **vertical joints**
(only for filled joints)

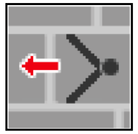


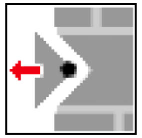


σ_d = design compression stress (top surface of the brick)
f_{vko} = initial shear, defined by masonry type and mortar (EN 1996-1-1, table 3.4)

DEFINING RESISTANCE

Failure mode	**(6)** Local brick failure (shear) **(7)** Brick edge failure (shear)

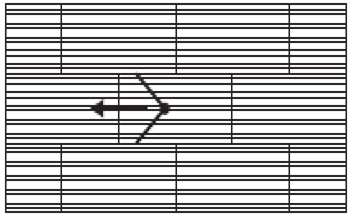




Evaluation for: closet to the edge anchor

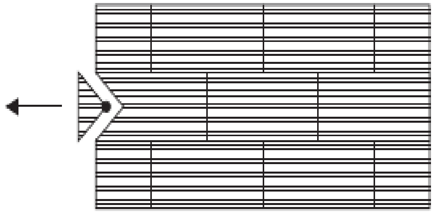
Local brick failure

$$V_{Sd} \leq \alpha_{j,b} \cdot V_{Rk,b} / \gamma_{Mm}$$
$$V_{Sd}^{g} \leq \alpha_{j,b} \cdot V^{g}_{Rk} / \gamma_{Mm}$$



Brick edge failure

$$V_{Sd} \leq \alpha_{j,c} \cdot V_{Rk,c} / \gamma_{Mm}$$
$$V_{Sd}^{g} \leq \alpha_{j,x} \cdot V^{g}_{Rk} / \gamma_{Mm}$$



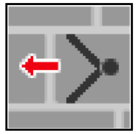
$V_{Rk,b}$, $V_{Rk,c}$, γ_M taken from anchor ETA

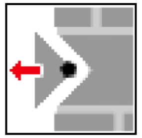
Main factors:

- Geometry of the fixture – anchor spacing and edge distances
- Cleaning of the drill hole
- Installation conditions – wet / dry
- Temperature range for use
- Vertical joints composure
- Factors for anchor group

DEFINING RESISTANCE

Failure mode	**(6)** Local brick failure (shear) **(7)** Brick edge failure (shear)





Joints composure factors:

$$V_{Sd} \le \alpha_{j,b} \cdot V_{Rk,b} / \gamma_{Mm}$$
$$V_{Sd} \le \alpha_{j,c} \cdot V_{Rk,c} / \gamma_{Mm}$$

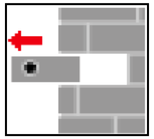
- **Joints**
  - Visible
    - Filled
      - $\alpha_{j,b}$=1.00, $\alpha_{j,c}$=1.00
    - Not filled
      - **Free edge**
  - Not visible
    - Filled
      - t=2-5 мм
        - $\alpha_{j,b}$=0.75, $\alpha_{j,c}$=1.00
      - t>5 мм
        - **Free edge**
    - Not filled
      - No solution

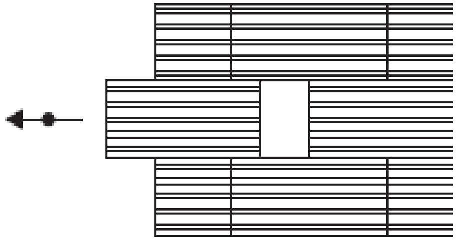
Note:

- For visible and not visible filled joints with thickness t=2-5 мм”, **c** is the distance to the edge of the wall
- For not filled joints and not visible filled joints with thickness t>5 мм”, **c** is the distance to the closets filled joint
- For all cases the edge distance must be $c<c_{min}$

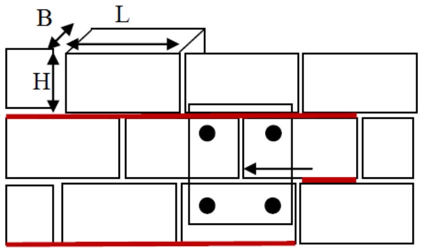
DEFINING RESISTANCE

Failure mode | **(8)** Brick push out (shear)

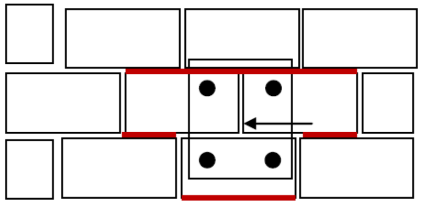




For filled vertical joints

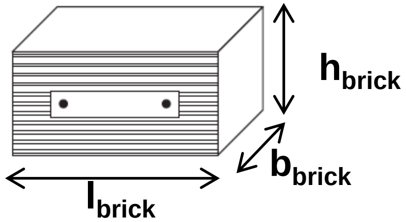


For not filled vertical joints

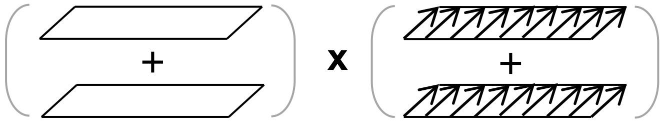


Evaluation for: full load for an anchor or a group of anchors

$$V_{Sd} \leq V_{Rk,pb} / \gamma_{Mm}$$



$$V_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} \cdot (0{,}5 \cdot f_{vko} + 0{,}4 \cdot \sigma_d)$$

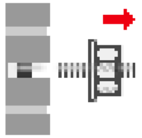
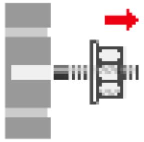
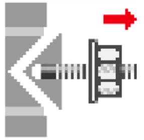
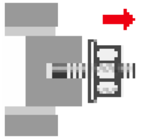


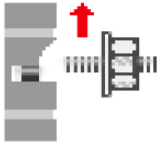
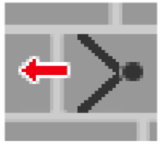
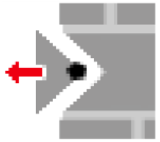
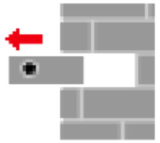
(joints area) (resistance)

Resistance of **horizontal joints**

σ_d = design compression stress (top surface of the brick)
f_{vko} = initial shear, defined by masonry type and mortar (EN 1996-1-1, table 3.4)

DEFINING RESISTANCE

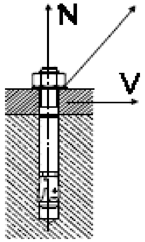
Tension	
(1) Steel failure	
(2) Pull-out failure	
(3) Brick breakout failure	
(4) Pull-out of one brick	

Shear	
(5) Steel failure	
(6) Local brick failure	
(7) Brick edge failure	
(8) Push out of one brick	

Lowest resistance [N, кН]

Lowest resistance [V, кН]

Combination check



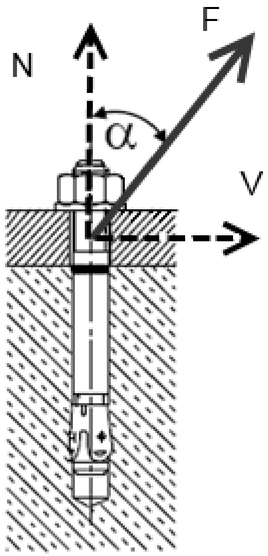
DEFINING RESISTANCE

Check for combined tension and shear

Utilization factors under combined tension and shear:

$$\beta_V = \frac{V_{Sd}}{V_{Rd}}; \beta_V \leq 1.0$$

$$\beta_N = \frac{N_{Sd}}{N_{Rd}}; \beta_N \leq 1.0$$



Combination check:

$\beta_V + \beta_N \leq 1.2$ – for solid brick

$\beta_V + \beta_N \leq 1.0$ – for hollow brick

Once all checks are done – the anchor resistance is provided

DESIGN FLOW: MAIN QUESTION

Is my masonry covered by my anchor ETA?

Masonry is covered by an ETA if:
The brick name is on the standard bricks list in the ETA – it is made from the same material; it has equal or higher compression strength and equal or bigger dimensions (for hollow bricks – same dimensions of hollows).

YES	NO
Calculation by TR054 with ETA data	**On-site tests are needed before the design can proceed**

AGENDA

1. Masonry as a base material
2. Anchor working principles and brickwork
3. Regulatory framework. Anchor portfolio
4. Design flow with ETA data available
5. Design flow with no ETA data: specifying site tests
6. PROFIS Engineering: Masonry module overview

ON-SITE TEST MATRIX

Base material	Anchor type	Purpose of on-site test	Type of on-site test	Test execution & evaluation method
Masonry standard	Chemical (incl. rebar)	**DETERMINE RESISTANCE**	**Destructive [Pull-out]** simplified [1] or statistical [2] evaluation	**according to TR, ETAG, British Standard (BS)**
Masonry non-standard	Mechanical		**Non-destructive** simplified evaluation	**according to TR, ETAG, British Standard (BS)**
Concrete standard	Plastic	**VERIFY SETTING QUALITY**	**Non-destructive** assessment	**according to TR, ETAG, British Standard (BS)**
Concrete non-standard				

THE TEST METHOD DEFINES THE NEXT STEPS OF ANCHOR DESIGN

Test method defines:

1. The number of anchors to be tested
2. The test load
3. Test results evaluation process

Masonry is covered by an ETA if:
The brick name is on the standard bricks list in the ETA – it is made from the same material; it has equal or higher compression strength and equal or bigger dimensions (for hollow bricks – same dimensions of hollows).

YES	NO
Calculation by TR054 with ETA data	**On-site tests are needed before the design can proceed**

Test by TR053:

Following calculation is available on PROFFIS Engineering (only tension test needed)

Test by other publications:

Following calculation is an engineering judgement / should be done by a corresponding design method

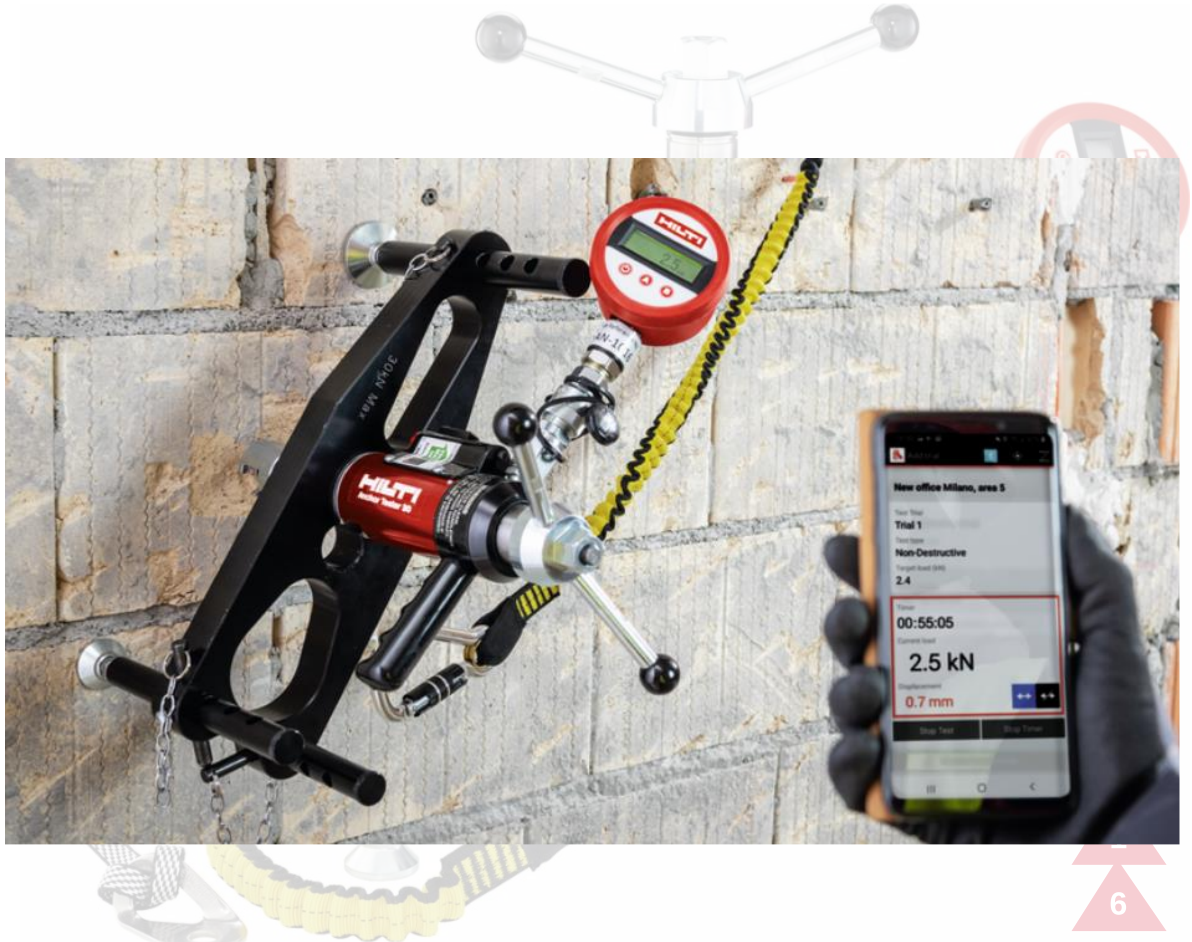
Purpose of tests, test load and number of anchors to be tested **must be specified** by responsible engineer

A TESTING RIG IS A MECHANICAL TOOL THAT DEFORMS JUST AS ANYTHING ELSE

1. Leg hinges x3
2. Leg fixators x3
3. Bolt testing adaptor x1
4. Top hat adaptor x1
5. Bridge x1
6. Areas of base material under legs x3

Testing rig deformations can affect test results. When dealing with critical cases seek professional support.

A TESTING RIG IS A MECHANICAL TOOL THAT DEFORMS JUST AS ANYTHING ELSE



1. Leg hinges x3
2. Leg fixators x3
3. Bolt testing adaptor x1
4. Top hat adaptor x1
5. Bridge x1
6. Areas of base material under legs x3

Note: When testing anchors in masonry, the legs of a rig must not rest on the brick the anchor is installed into, as it may interfere with brick pull out failure mode.

Testing rig deformations can affect test results. When dealing with critical cases seek professional support.

AGENDA

JOIN US FOR THE UPCOMING EVENTS: PROFIS ENGINEERING SERIES

March 19th 10:00 AM (GMT)

PROFIS Engineering – BET (Baseplate Engineering Training)

Dive deeper into steel-to-concrete connections under EN1992-4 with CBFEM analysis

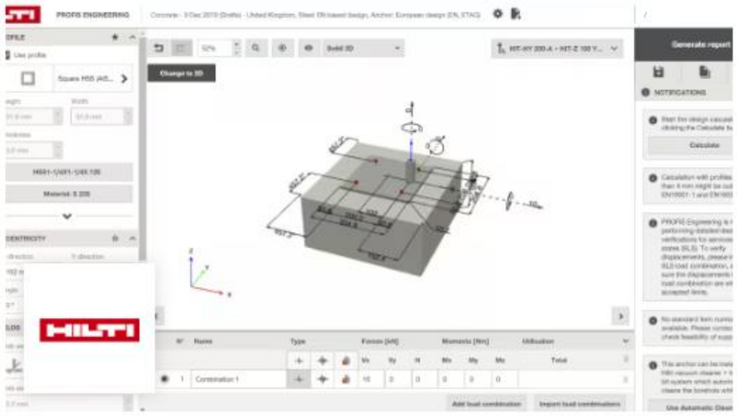
April 3rd 10:00 AM (GMT)

PROFIS Engineering – Supplementary reinforcement

Utilise the software to design and calculate connections relying on supplementary reinforcement

April 30th 10:00 AM (GMT)

PROFIS Engineering – Basic Training



Learn the PROFIS Engineering basics and time saving tricks you may not have seen before

THANK YOU!

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