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# ETAG 029

GUIDELINE FOR
EUROPEAN TECHNICAL APPROVAL
of

# METAL INJECTION ANCHORS FOR USE IN MASONRY

Edition April 2013

This Guideline for European Technical Approval is established and published in accordance with Article 11 of the Construction Products Directive as a basis for the preparation and issue of European Technical Approvals (ETA) in accordance with Article 9.1 of the Construction Products Directive.

European Technical Approvals are issued by Approval Bodies authorised and notified in accordance with Article 10 of the Construction Products Directive. These bodies are organized in EOTA.

The European Technical Approval, according to the Construction Products Directive, is a favourable technical assessment of the fitness for use of a construction product and the technical specification of the assessed product, serving as basis for the CE marking of this product when and where a harmonised standard according to the Directive is not or not yet available.

Due to technical innovation and the progress of the state of the art, Guidelines for technical approval might not reflect the latest developments and experiences gained in approval procedures. The reader of this Guideline is therefore advised to check with an EOTA member whether there are further provisions which have to be taken into account in the use of the Guideline.



**This edition replaces edition June 2010 of ETAG 029**

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# 1 SCOPE OF THE ETAG

The ETAG "METAL INJECTION ANCHORS FOR USE IN MASONRY“ covers the assessment of post-installed injection anchors placed into pre-drilled holes in masonry and anchored by bonding and mechanical interlock.

The injection anchors are intended to be used for anchorages for which requirements for mechanical resistance and stability and safety in use in the sense of the Essential Requirements N° 1 (ER 1) and N° 4 (ER 4) and, where applicable N° 2 (ER 2) and N° 3 (ER 3), of the CPD [1] shall be fulfilled; failure of anchorages made with these products would cause an immediate risk to human life and/or possibly lead to considerable economic consequences. They are for fixing and/or supporting structural elements (which contribute to the stability of the works) or heavy units.

The fixture can be supported either statically determinate (one or two supports) or statically indeterminate (more than two supports).

The following annexes are full parts of the ETAG:
Annex A: Details of tests
Annex B: Recommendations for tests to be carried out on construction works (informative)
Annex C: Design methods for anchorages

## 1.1 Definition of the construction product

### 1.1.1 Types and operating principles

This ETAG applies to injection anchors consisting of a threaded rod, deformed reinforced bar, internal threaded socket, or other shapes and the mortar, placed into drilled holes in masonry and anchored by bonding the metal part to the sides of the drilled hole by means of mortar and by mechanical interlock (see Figure 1.1). For proper injection of the mortar, mesh sleeves made of metal or plastic are also covered in this ETAG (see Figure 1.2).

Injection anchors are supplied and used as a unit. However, if the metal parts are commercial standard parts supplied by another party than the approval holder (e.g. manufacturer of standard rods), specific conditions according to 4.3 have to be fulfilled.

### 1.1.2 Materials

This ETAG applies to anchors in which all the metal parts directly anchored in the masonry and designed to transmit the applied loads are made either of carbon steel, stainless steel or malleable cast iron.

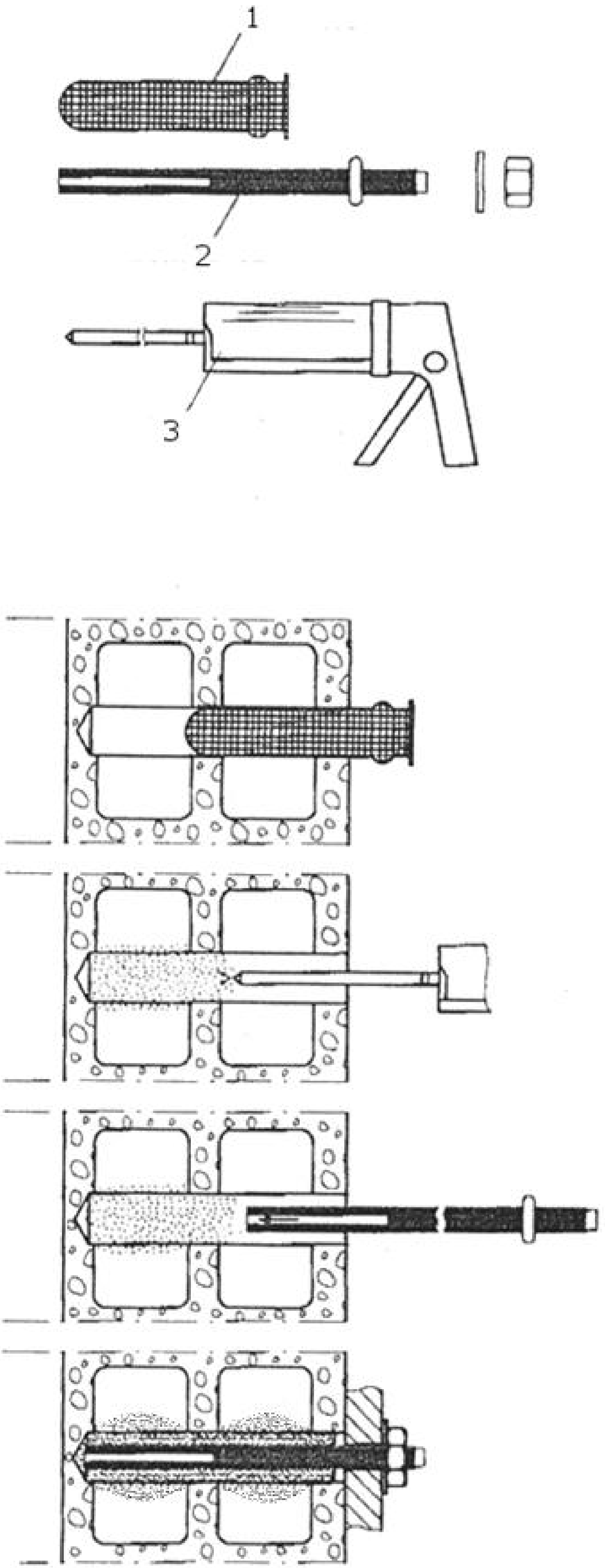
The bonding material may be manufactured from cementitious mortar, synthetic mortar or a mixture of the two including fillers and/or additives.

### 1.1.3 Dimensions

This ETAG applies to anchors with a minimum thread size of 6 mm (M6).
The minimum anchorage depth of the anchor min $h_{ef}$ shall be 50 mm.
The maximum anchorage depth shall be max $h_{ef} = h_{min}$ -30 mm.

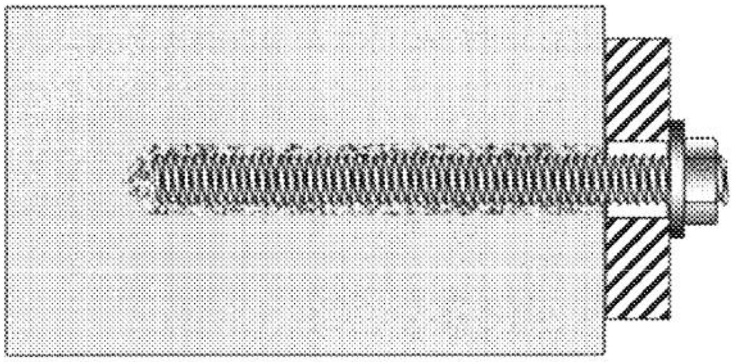
This ETAG applies to applications where the minimum thickness of the masonry members in which injection anchors are installed is at least $h_{min}$ = 80 mm.

Anchors with internal thread are covered only if they have a thread length of at least d + 5 mm after taking account of possible tolerances.

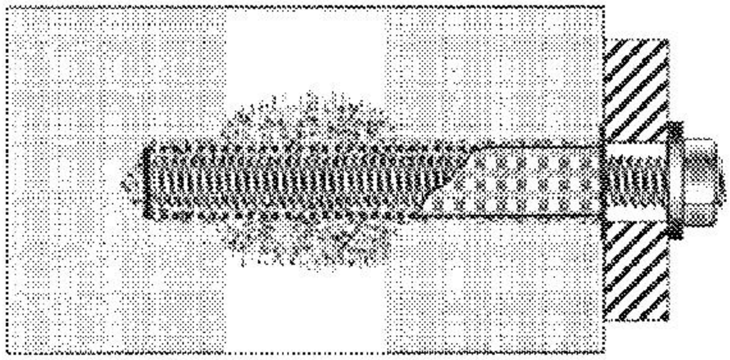



1. sieve sleeve
2. threaded rod with washer and hexagon nut
3. injection cartridge

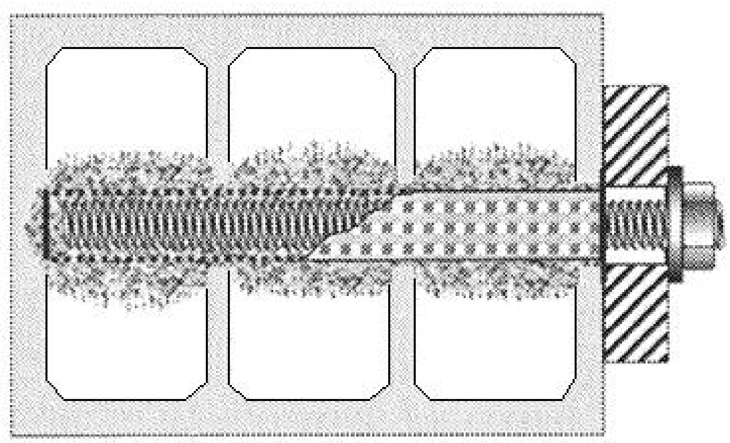
**Figure 1.1 – Example of injection anchors**



Threaded anchor rod set in solid brick using injection mortar



Threaded anchor rod set in perforated brick using injection mortar and mesh sleeve



Threaded anchor rod set in hollow block using injection mortar and mesh sleeve

**Figure 1.2 – Example of injection anchors**

### 1.1.4 Base material (masonry)

This ETAG applies to the use of injection anchors in masonry units of clay, calcium silicate, normal weight concrete and lightweight aggregate concrete (solid and hollow or perforated format blocks), autoclaved aerated concrete or other similar materials. As far as the specification of the different masonry units is concerned, EN 771-1 to 5:2011 [2] may be taken as reference. The design and construction of masonry structures in which the injection anchors are to be anchored shall be in accordance with EN 1996-1-1:2005 + AC:2009 [6] and the relevant national regulations.

Attention is drawn to the fact that the standards for masonry are not very restrictive with regard to details of units (e.g. type, dimensions and location of hollows, number and thickness of webs). Anchor resistance and load displacement behaviour, however, decisively depend on these influencing factors.

Usually solid masonry units do not have any holes or cavities other than those inherent in the material. However, solid units may have a vertical perforation or grip holes of up to 15 % of the cross section or frogs up to 20 % based on the volume of the brick. Therefore testing in solid material covers units with vertical perforation or grip holes of up to 15 % of the cross section or frogs up to 20 % based on the volume of the brick.

Masonry units consisting of hollow or perforated units have a certain volume percentage of voids which pass through the masonry unit. For the assessment of injection anchors anchored in hollow or perforated units it has also to be assumed that the anchor may be situated in solid material (e.g. joints, solid part of unit without holes) so that also tests in solid material may be required.

## 1.2 Intended use of the construction product

The injection anchors are intended to be used for anchorages for which requirements for mechanical resistance and stability and safety in use in the sense of the Essential Requirements N° 1 (ER1) and N° 4 (ER4) and, where applicable N° 2 (ER 2) and N° 3 (ER 3), of the CPD shall be fulfilled; failure of anchorages made with these products would cause an immediate risk to human life and/or possibly lead to considerable economic consequences. They are for fixing and/or supporting structural elements (which contribute to the stability of the works) or heavy units.

This ETAG applies only to anchors subject to static or quasi-static actions in tension, shear or combined tension and shear or bending. The anchors may be used in areas with very low seismicity according to EN 1998-1:2004 + AC:2009 [15].

This ETAG covers applications only where the masonry members in which the anchors are embedded are subject to static or quasi-static actions.

## 1.3 Assumed working life of the construction product

The provisions and the verification and assessment methods included or referred to in this ETAG have been written based upon the assumed working life of the injection anchors for the intended use of 50 years when installed in the works, provided that the injection anchors are subject to appropriate installation and use (see 4.3). These provisions are based upon the current state of the art and the available knowledge and experience.

"Assumed working life" means that, when an assessment following the ETAG provisions is made, and when this working life has elapsed, the real working life may be, in normal use conditions, considerably longer without major degradation affecting the Essential Requirements.

The indications of durability (linked to the working life) of the construction product cannot be interpreted as a guarantee given by the product manufacturer or his representative or the Approval Body issuing the ETA, but are regarded only as a means for choosing the appropriate products in relation to the expected economically reasonable working life of the works (see 5.2.2 of the Interpretative Documents).

## 1.4 Terminology

### 1.4.1 Common terms relating to the Construction Products Directive

For the meaning of these terms see EOTA document "Common terms used in Guidelines for European Technical Approval" published on the EOTA website.

### 1.4.2 Specific terms used in this ETAG

#### 1.4.2.1 General

| | | |
|---|---|---|
| Anchor | = | a manufactured, assembled component including bonding materials for achieving anchorage between the base material (masonry) and the fixture. |
| Anchor group | = | several anchors (working together) |
| Fixture | = | component to be fixed to the masonry |
| Anchorage | = | an assembly comprising base material (masonry), anchor or anchor group and component fixed to the masonry. |

#### 1.4.2.2 Anchors

The notations and symbols frequently used in this Guideline are given below. Further particular notation and symbols are given in the text.

| | | |
|---|---|---|
| $b$ | = | width of the member of the base material |
| $c$ | = | edge distance towards the free edge of the brick (edge of the wall or vertical joint not to be filled with mortar) |
| $c_{cr}$ | = | edge distance for ensuring the transmission of the characteristic resistance of a single injection anchor |
| $c_{min}$ | = | minimum allowable edge distance |
| $d$ | = | anchor bolt/thread diameter |
| $d_0$ | = | drill hole diameter |
| $d_{cut}$ | = | cutting diameter of drill bit |
| $d_{cut,m}$ | = | medium cutting diameter of drill bit |
| $d_f$ | = | diameter of clearance hole in the fixture |
| $d_{nom}$ | = | outside diameter of anchor |
| $h$ | = | thickness of masonry member (wall) |
| $h_{min}$ | = | minimum thickness of masonry member |
| $h_0$ | = | depth of cylindrical drill hole at shoulder |
| $h_1$ | = | depth of drilled hole to deepest point |
| $h_{ef}$ | = | effective anchorage depth |
| $h_{nom}$ | = | overall anchor embedment depth in the masonry |
| $l_{unit}$ | = | length of the masonry unit |
| $h_{unit}$ | = | height of the masonry unit |
| $s$ | = | spacing of the injection anchor |
| $s_{cr,N}$ | = | spacing for ensuring the transmission of the characteristic resistance of a single injection anchor |
| $s_{cr,II}$ | = | $s_{cr}$ II horizontal joint |
| $s_{cr,\perp}$ | = | $s_{cr}$ $\perp$ horizontal joint |
| $s_{min}$ | = | minimum allowable spacing |
| $T$ | = | torque moment |
| $T_{inst}$ | = | installation torque moment recommended by the manufacturer |
| $T_u$ | = | maximum torque moment during failure |
| $t_{fix}$ | = | thickness of fixture |
| $t$ | = | thickness of outer web of the brick |

#### 1.4.2.3 Base materials (masonry) and metal parts of anchor

| | | |
|---|---|---|
| $\rho$ | = | bulk density of masonry unit |
| $f_b$ | = | normalised mean compressive strength of masonry unit |
| $f_{b,test}$ | = | mean compressive strength of the test masonry unit at the time of testing |
| $f_{y,test}$ | = | steel tensile yield strength in the test |
| $f_{yk}$ | = | nominal characteristic steel yield strength |
| $f_{u,test}$ | = | steel ultimate tensile strength in the test |
| $f_{uk}$ | = | nominal characteristic steel ultimate strength |

#### 1.4.2.4 Loads/forces

| | | |
|---|---|---|
| F | = | force in general |
| N | = | normal force (+N = tension force) |
| V | = | shear force |
| M | = | moment |
| $N_{Rk}$, $V_{Rk}$ | = | characteristic anchor resistance (5 %-fractile of results) under tension and shear force, respectively |
| $N^h_{Sd}$ ($V^h_{Sd}$) | = | design value of tensile load (shear load) acting on the most stressed anchor of an anchor group |

#### 1.4.2.5 Tests

| | | |
|---|---|---|
| $F^t_{Ru}$ | = | ultimate load in a test |
| $F^t_{Ru,m}$ | = | mean ultimate load in a test series |
| $F^t_{Rk}$ | = | 5 %-fractile of the ultimate load in a test series |
| n | = | number of tests of a test series |
| v | = | coefficient of variation |
| $\delta(\delta_N, \delta_V)$ | = | displacement (movement) of the anchor at the masonry surface relative to the masonry surface in direction of the load (tension, shear) outside the failure area. The displacement includes the steel and masonry deformations and a possible anchor slip. |
| $\alpha$ | = | ratio of test value / reference value, for instance |

#### 1.4.2.6 Temperature terms

Service temperature range: Range of ambient temperatures after installation and during the lifetime of the anchorage.

Short term temperature: Temperatures within the service temperature range which vary over short intervals, e.g. day/night cycles and freeze/thaw cycles.

Maximum short term temperature: Upper limit of the service temperature range.

Long term temperature: Temperature within the service temperature range, which will be approximately constant over significant periods of time. Long term temperatures will include constant or near constant temperatures, such as those experienced in cold stores or next to heating installations.

Maximum long term temperature: Specified by the manufacturer within the range of 0,6 times to 1,0 times the maximum short term temperature.

Normal ambient temperature: Temperature 21 °C ± 3 °C (for test conditions only)

Open time: The maximum time from end of mixing to when the insertion of the anchor into the bonding material shall be completed.

Installation ambient temperature range: The environmental temperature range of the base material allowed by the manufacturer for installation.

Anchor component installation temperature range: The temperature range of the bonding material and embedded part immediately prior to installation.

Curing time: The minimum time from the end of mixing to the time when the anchor may be torqued or loaded (whichever is longer). The curing time depends on the ambient temperature.

### 1.5 Procedure in the case of a significant deviation from the ETAG

The provisions of this ETAG apply to the preparation and issue of European Technical Approvals in accordance with Article 9.(1) of the CPD and Section 3.1 of the Common Procedural Rules.

In cases in which a certain provision of this ETAG is not or not fully applicable or a particular aspect of a product and/or intended use to be assessed is not or not sufficiently covered by the methods and criteria of the ETAG, the procedure of Article 9.(2) of the CPD and Section 3.2 of the Common Procedural Rules may apply with regard to the deviation or aspect concerned.

## 2 ASSESSMENT OF FITNESS FOR USE

### 2.1 Meaning of "fitness for use"

"Fitness for (the intended) use" of a construction product means that the product has such characteristics that

the ***works*** in which it is to be incorporated ***can***, if properly designed and built,

1. ***satisfy*** the Essential Requirements when and where such works are subject to regulations containing such requirements (CPD Article 2.(1)) and
2. ***be fit*** for their intended use, account being taken of economy, ***and*** in this connection ***satisfy*** the Essential Requirements for an economically reasonable working life, if normally maintained (see CPD Annex I, sentence 1 and 2).

### 2.2 Elements of the assessment of fitness for use

The assessment of the fitness of a construction product for its intended use includes:

- the identification of the characteristics of the product which are relevant to its fitness for use (in the following referred to as "regulatory characteristics");
- the establishment of methods for the verification and assessment of the regulatory product characteristics and the expression of the respective product performances;
- the identification of such regulatory characteristics to which the option "No Performance Determined" applies for the reason that in one or more Member States they are not relevant for the fulfilment of the requirements applicable to the works;
- the identification of such regulatory characteristics for which limit values (threshold values) have to be respected for technical reasons.

### 2.3 Relationship of requirements to the product characteristics and methods of verification and assessment

#### 2.3.1 Relationship of requirements to the product characteristics

The product characteristics, methods of verification and assessment criteria which are relevant for the fitness of injection anchors for the intended use referred to in 1.2 are given in Table 2.1.

**Table 2.1 – Product characteristics and methods of verification and assessment**

| No | Product characteristic | Option "No Performance Determined" | Method of verification and assessment | Expression of product performance |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| Essential Requirement 1: Mechanical resistance and stability | | | | |
| 1 | Suitability under normal site conditions:<br>Requirements for an acceptable load/displacement behaviour,<br>a certain ultimate load,<br>a certain limited scatter | No | 2.4.1 and<br>2.4.2 | Influence factors on the load bearing behaviour of the anchor in accordance with the criteria of 2.4.2 |
| 2 | Admissible service conditions:<br>- load bearing behaviour of the anchor for tension/shear/ combined tension and shear/ bending<br>- Required spacing and edge distance of the anchor<br>- Minimum spacing and minimum edge distance of the anchor<br>- Displacement for serviceability limit state of the anchor | No | 2.4.1 and<br>2.4.2 | 2.4.2.2.3<br>- Characteristic resistance for tension/shear/ combined tension and shear/ bending<br>- Characteristic spacing and edge distance of the anchor<br>- Minimum spacing and minimum edge distance of the anchor<br>- Displacement for serviceability limit state of the anchor |
| Essential Requirement 2: Safety in case of fire | | | | |
| 3 | Reaction to fire | Yes (Class F) | 2.5.1 | Anchorages satisfy requirements for Class A1 (see 2.5.1) |
| 4 | Resistance to fire | No | 2.5.2 | Evaluation of the couple anchor-concrete (anchorages) concerning resistance to fire by tests or calculations |
| Essential Requirement 3: Hygiene, health and environment | | | | |
| 5 | Content and/or release of dangerous substances | Yes | 2.6 | See the relevant chapter [2)] |
| Essential Requirement 4: Safety in use | | | | |
| 6 | The same criteria are valid as for Essential Requirement 1 | | | |
| Essential Requirement 5: Protection against noise | | | | |
| | None | | | |
| Essential Requirement 6: Energy economy and heat retention | | | | |
| | None | | | |
| General aspects relating to fitness for use [1)] | | | | |
| 7 | Suitability against environmental conditions | No | 2.7.1 | Resistance against environmental conditions |

[1)] Aspects of durability and economy of the works (see CPD, Annex 1, sentences 1 and 2) which are not dealt with under Essential Requirements 1 to 6. Such aspects are also referred to as "serviceability".

[2)] NPD option regarding ER3: For the meaning of the NPD option regarding ER3, see EOTA TR 034 "General Checklist for ETAGs/CUAPs/ETAs - Content and/or release of dangerous substances in products/kits" [18]

#### 2.3.2 Use categories

The Guideline applies to anchorages in respect of the following use categories:

##### 2.3.2.1 Use categories in respect of the base material:

Use category **b**: Metal injection anchors for use in **solid**[1)] **masonry**
Use category **c**: Metal injection anchors for use in **hollow or perforated masonry**
Use category **d**: Metal injection anchors for use in **autoclaved aerated concrete masonry**

Each use category shall be given in the approval separately.

**1)** Covers also units with vertical perforation or grip holes of up to 15 % cross section or frogs up to 20 % based on the volume of the brick

##### 2.3.2.2 Use categories in respect of installation and use:

Category **d/d** - **Installation and use** in structures subject to **dry**, internal conditions,
Category **w/d** - **Installation in** dry or **wet** substrate and **use** in structures subject to **dry**, internal conditions,
Category **w/w** - **Installation and use** in structures subject to dry or **wet** environmental conditions.

Each use category shall be given in the approval separately.

##### 2.3.2.3 Use categories in respect of the service temperature range:

The functioning of an injection anchor, including its ability to continue to withstand its design load with an appropriate safety factor and to limit displacements, shall not be adversely affected by temperatures in the base material near to the surface within a temperature range to be specified by the manufacturer which may be either:

**(Ta)** - 40 °C to + 40 °C (max short term temperature + 40 °C and max long term temperature + 24 °C)
**(Tb)** - 40 °C to + 80 °C (max short term temperature + 80 °C and max long term temperature + 50 °C)
**(Tc)** on manufacturer's request with - 40 °C to T1 (short term: T1 > + 40 °C, long term: 0,6 T1 to 1,0 T1)

Injection anchors are not affected by service temperatures down to - 40 °C. If there is no experience for unknown bonding materials on their performance at - 40 °C then normal pull-out tests at – 40 °C will be required.

The performance shall not be adversely affected by short term temperatures within the service temperature range or by long term temperatures up to the maximum long term temperature.

Performance at the maximum long term temperature and maximum short term temperature is checked by tests described in 2.4.1.1.2

### 2.4 Product characteristics which are relevant for the fitness for use relating to Mechanical Resistance and Stability (ER 1)

#### 2.4.1 Method of verification (General)

The tests involved in the assessment of injection anchors fall into 3 categories:

(1) Tests for confirming their suitability (see 2.4.1.1)
(2) Tests for evaluating the admissible service conditions (see 2.4.1.2)
(3) Tests for checking durability (see 2.7.1)

The details of tests are given in Annex A.

It is assumed that for each injection anchor size there is only one anchorage depth. If the injection anchors are intended to be installed with two or more anchorage depths the tests have to be carried out at each depths.

#### 2.4.1.1 Tests for suitability

The purpose of the suitability tests is to establish whether an anchor is capable of safe, effective behaviour in service including consideration of adverse conditions both during site installation and in service.

The types of suitability tests, test conditions, the number of required tests and the criteria applied to the results shall be taken in accordance with Table 2.4.2. Detailed information about special tests is given in the chapters after the table.

**Table 2.4.1 – Base material for suitability tests for injection anchors to be used in masonry**

| | Purpose of test | Base material for use categories **b** and **c** | | Base material for use category **d** |
|---|---|---|---|---|
| | | Solid clay | Solid calcium silicate | Autoclaved aerated concrete |
| 1a<br>1b | Installation safety | x | x | x |
| 2a | Functioning, effect of increased temperature | x | x | x |
| 2b<br>2c | Functioning, effect of installation temperature | (1) | | x |
| 3 | Functioning under repeated loads | (1) | | x |
| 4a | Functioning under sustained loads<br>(normal temperature) | (1) | | x |
| 4b | Functioning under sustained loads<br>(max. long term temp.) | (1) | | x |
| 5 | Maximum torque moment | Tests in all types of bricks as applied for | | |
| 6 | Functioning under freeze/thaw condition | (1) (2) | | |
| 7 | Checking durability of the bonding material | C20/25 | | |

Notes to Table 2.4.1

(1) Tests in solid clay masonry units or solid calcium masonry units, resulting from reference tests according to Table 2.4.4, line 1 (the maximum resistance is decisive). If the same injection system is already assessed in accordance with ETAG 001-5: Edition 2002. Amendment 2012 [17], the results of the relevant suitability tests (reduction factors) can also be used for anchors for use in masonry.

(2) Tests in freeze-thaw resistant base material (see also 2.4.1.1.6).

**Table 2.4.2 – Suitability tests for injection anchors to be used in masonry**

| | Purpose of test | Ambient base material Tempe-rature | Minimum number of tests for anchor size (2) | | | | | Criteria | | Test procedure suitability tests described in |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | s | i | m | i | l | load/dis. behaviour | req. α (1) | |
| 1 | Installation in<br>(a) dry substrate | normal | 5 | - | 5 | - | 5 | 2.4.2 (c) | ≥ 0,8 | 2.4.1.1.1a) |
| | (b) wet substrate (3) | normal | 5 | - | 5 | - | 5 | 2.4.2 (c) | ≥ 0,8 | 2.4.1.1.1b) |
| 2 | Functioning, effect of temperature (4)<br>(a) increased temperature | +50 °C(5)<br>+80 °C(5) | | | 5<br>5 | | | 2.4.2 (c) | ≥ 1,0<br>≥ 0,8 (6) | 2.4.1.1.2 |
| | (b) low temperature | (4) | | | 5 | | | | ≥ 1,0 | |
| | (c) minimum curing time | normal | | | 5 | | | | ≥ 0,9 | |
| | *More detailed description analogous Section 2.4.1.1.2.* | | | | | | | | | |
| 3 | Functioning under repeated loads | normal | - | - | 5 | - | - | 2.4.2 (c) | ≥ 1,0 | 2.4.1.1.3 |
| 4 | Functioning under sustained loads | normal<br>+ 50 °C(5) | - | - | 5 | - | - | 2.4.2 (c) | ≥ 0,9 | 2.4.1.1.4 |
| 5 | Maximum torque moment | normal | 5 | 5 | 5 | 5 | 5 | | | 2.4.1.1.5 |
| 6 | Functioning under freeze/thaw condition (7) | normal | - | - | 5 | - | - | 2.4.2 (c) | ≥ 0,9 | 2.4.1.1.6 |
| 7 | Checking durability of the bonding material | see 2.7.1.2 | | | | | | | | |

Notes to Table 2.4.2

(1) If requirement is not met, corresponding provisions are given in 2.4.2.1

(2) Anchor size: s = smallest; i = intermediate; m = medium; l = largest
If installation with sieve sleeve in solid bricks (or solid parts of bricks) is allowed in the ETA, the tests shall be done with sieve sleeve otherwise the tests shall be performed without sieve sleeve.

(3) This test is not required for use category **d/d** (dry)

(4) Minimum installation temperature as specified by the manufacturer; normally 0 °C to + 5 °C

(5) For temperature range (Tb), for other temperature ranges see 2.3.2.3

(6) Reference values from the tests with maximum long term temperature +50 °C for temperature range (Tb), for other temperature ranges see 2.3.2.3

(7) For use category **w/w** only

#### 2.4.1.1.1 Installation in dry or wet substrate

**(a) Installation in dry substrate**

Confined tension tests in dry solid masonry according to Annex A, A.5.4 a). These tests have to be performed for all use categories.

**(b) Installation in wet substrate**

Confined tension tests in wet solid masonry according to Annex A, A.5.4 b). These tests may be omitted for use category d/d.

#### 2.4.1.1.2 Influence of temperature on characteristic resistances

**(a) Effect of increased temperature**

The confined tension tests shall be carried out according to Annex A, A.5.5 a) for the different temperature ranges given in 2.3.2.3.

**(b) Effect of low installation temperature**

The confined tension tests shall be carried out at the end of the curing time while maintaining the temperature of the test member at the specified lowest installation temperature ± 2 K. Details of the tests are described in Annex A, A.5.5 b).

**(c) Minimum curing time at normal ambient temperature**

Perform tension tests according to Annex A, A.5.5 c) at normal ambient temperature at the corresponding minimum curing time specified by the manufacturer.

#### 2.4.1.1.3 Repeated loading

The injection anchor is subjected to $1 \times 10^5$ load cycles with a maximum frequency of approximately 6 Hz. After completion of the load cycles the anchor shall be unloaded, the displacement measured and a tension test performed according to Annex A. Details of the tests are described in Annex A, 5.6.

#### 2.4.1.1.4 Sustained loading

The test is performed at normal temperature (T = + 21 °C ± 3 °C) for temperature range (Ta), (Tb) and (Tc) and at maximum long term temperature for temperature range (Tb) and (Tc) [T = + 50 °C at minimum for temperature range (Tb)].

The anchor shall be installed at normal temperature and subjected to a tension (sustained) load. After completion of the sustained load test the anchor shall be unloaded, the displacement measured and immediately after unloading a tension test performed. Details of the tests are described in Annex A, A.5.7.

#### 2.4.1.1.5 Maximum torque moment

The torque moment shall be measured with a calibrated torque moment transducer. The torque moment shall be increased until failure of the injection anchor. Details of the tests are described in Annex A, A.5.8.

#### 2.4.1.1.6 Functioning under freeze/thaw conditions

In general the tests are carried out for injection anchors with a service condition in wet substrate only. The tests are performed in freeze-thaw resistant base material. The tests may also be carried out in freeze-thaw resistant concrete C50/60; in this case the corresponding reference tests are required in concrete under normal conditions as well.

The displacements shall be measured during the temperature cycles.

After completion of 50 cycles, carry out a tension test at normal ambient temperature. Details of the tests are described in Annex A, A.5.9.

### 2.4.1.2 Tests for evaluating the admissible service conditions

For determination of the admissible service conditions, the tests given in Table 2.4.3 shall be carried out.

If existing information is available from the manufacturer and the corresponding test report contains all relevant data, then the Approval Body may reduce the number of tests for admissible service conditions, making use of this existing information. However, it will be considered in the assessment only if the results are consistent with comparable test results available to the Approval Body.

All tests for determination of admissible service conditions shall be carried out according to Annex A in the base material for which the injection anchor is intended to be used.

The minimum edge distance $c_{min}$ and minimum spacing $s_{min}$ shall be given by the manufacturer and shall be confirmed by the corresponding tests.

The determined characteristic resistances for the approval are valid only for the bricks and blocks which are used in the tests regarding base material (masonry or aerated concrete), size of units, compressive strength and configuration of the voids. Therefore the following information has to be given in the test report and in the approval:

*Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EN 1996-1-1:2005 + AC:2009 [6].*

As far as the specification of the different masonry units is concerned, EN 771-1 to 5:2011 [2] may be taken as reference.

In hollow or perforated masonry, anchorages in the end side of a wall (reveal) are covered only, if the tests include this setting position. Therefore this information has to be given in the test reports and in the approval.

**Table 2.4.3 – Tests for admissible service conditions for injection anchors for use in masonry**

| | Purpose of test | Load direc-tion | Distances | Member thickness h | Remarks | Number of tests | | | Test procedure described in Annex A |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | s | m | l | |
| 1 | Reference tension tests for suitability tests (1) | N | $c \geq c_{cr}$(3) | $\geq h_{min}$ | Test with single anchors | 5 | 5 | 5 | Annex A, A.5.1, A.5.2 |
| 2 | Characteristic resistance for tension loading not influenced by edge and spacing effects (2) | N | $c \geq c_{cr}$(3) | $\geq h_{min}$ | Test with single anchors (4) | 5 | 5 | 5 | Annex A, A.5.1, A.5.2 |
| 3 | Characteristic resistance for shear loading not influenced by edge and spacing effects (2) | V | $c \geq c_{cr}$(3) | $\geq h_{min}$ | Test with single anchors (4) | 5 | 5 | 5 | Annex A, A.5.1, A.5.3 |
| Optional tests | | | | | | | | | |
| 4 | Characteristic resistance for tension loading at minimum edge distance (5) | N | $c = c_{min}$ | $= h_{min}$ | Test with single anchors at the edge of test member | 5 | 5 | 5 | Annex A, A.5.1, A.5.2 |
| 5 | Characteristic resistance for shear loading at minimum edge distance (6) | V | $c = c_{min}$ | $= h_{min}$ | Test with single anchors at the edge of test member | 5 | 5 | 5 | Annex A, A.5.1, A.5.3 |
| 6 | Characteristic resistance for tension loading at minimum spacing (7) | N | $s = s_{min}$<br>$c = c_{min}$ | $= h_{min}$ | Test with double / quadruple anchor group (8) at the edge of test | 5 | 5 | 5 | Annex A, A.5.1, A.5.2 |
| 7 | Characteristic resistance for shear loading at minimum spacing (7) | V | $s = s_{min}$<br>$c = c_{min}$ | $= h_{min}$ | Test with double / quadruple anchor group (8) at the edge of test member | 5 | 5 | 5 | Annex A, A.5.1, A.5.3 |

Notes to Table 2.4.3

(1) Reference tension tests for determination of the results of the suitability tests. They have to be carried out on the same masonry units regarding base material, size of units and compressive strength as used for the corresponding suitability tests. They have to be performed with the same anchor configuration (e.g. size, sieve sleeve) as used for the corresponding suitability tests.

If the results of the reference tests are smaller than the results of the tests for characteristic resistance, the reference tests shall be considered for evaluating of the characteristic resistance.

(2) The tests shall be carried out at the most unfavourable setting position in the brick of hollow or perforated masonry, which give the lowest characteristic resistance of the anchor. For example, if hollow brick consists of thick webs or shells, the anchor shall be tested in the hole as well as in the massive parts of the brick.

For the intended use in plastered masonry (the joints are not visible) additional tests in joints not filled with mortar are necessary, if the drilling diameter is smaller than 15 mm. If such products are not tested and assessed, the relevant ETA shall allow the use only if the setting position in a joint only can be excluded (e.g. removal of the plaster around the installation position).

(3) For characteristic edge distances the following distances may be used (standard values):

Anchorages in solid masonry and AAC: $c_{cr} = 1{,}5\ h_{ef}$
Anchorages in hollow or perforated masonry: $c_{cr} = \max(100\ \text{mm};\ 6\ d_0)$

If the manufacturer accepts these standard values $c_{cr}$ as the minimum value $c_{min}$, tests on the free edge can be omitted.

(4) For determination of a group of two or four injection anchors the following spacing may be used (standard values):

Anchorages in solid masonry and AAC: $s_{cr} = 3{,}0\ h_{ef}$
Anchorages in hollow or perforated masonry: $s_{cr,II} = l_{unit}$ ($s_{cr}$ II horizontal joint)
$s_{cr,\perp} = h_{unit}$ ($s_{cr} \perp$ horizontal joint)

If the manufacturer accepts these standard values $s_{cr}$ as the minimum value $s_{min}$, tests with anchor groups can be omitted.

(5) Tension tests with single anchors near the free edge of a wall to determine the characteristic resistance depending on the minimum edge distance $c_{min}$. These tests can be omitted, if for $c_{min}$ the value $c_{cr}$ is accepted.

(6) Shear tests with single anchors in direction to the free edge of a wall to determine the characteristic resistance depending on the minimum edge distance $c_{min}$. This test can be omitted, if the resistance calculated according to Annex C, C.5.2.2.5 is accepted.

(7) The spacing $s_{min}$ may also be evaluated by appropriate tests with an anchor group of two anchors with $s_{min,II}$ and/or $s_{min,\perp}$ and/or with an anchor group of four anchors with $s_{min,II}$ and/or $s_{min,\perp}$.
$s_{min}$ shall be given in the approval (spacing of a group of anchors in the tests)

The spacing $s_{min}$ shall be greater than the following values:

Anchorages in solid masonry and AAC: $s_{min} \geq \max(50\ \text{mm};\ 3\ d_0)$
Anchorages in hollow or perforated masonry: $s_{min} \geq \max(75\ \text{mm};\ 5\ d_0)$
This test may be omitted if for $s_{min}$ the value $s_{cr}$ is accepted.

(8) Double and/or quadruple anchor group depend on the application of the manufacturer. The tested configuration will be given in the ETA.

### 2.4.2 Method of assessing and judging (general)

This sub-clause details the assessing and judging of the injection anchors related to the intended use, using the verification methods of 2.4.1.

**(a) 5%-fractile of the ultimate loads**

The 5%-fractile of the ultimate loads measured in a test series is to be calculated according to statistical procedures for a confidence level of 90 %. If a precise verification does not take place, a log normal distribution and an unknown standard deviation of the population shall be assumed.

$$F_{5\%} = \bar{F}\,(1 - k_s \cdot v) \qquad (2.4.1)$$

e.g.: n = 5 tests: $k_s = 3{,}40$
n = 10 tests: $k_s = 2{,}57$

**(b) Conversion of ultimate loads to take account of masonry and steel strength**

Masonry unit strength:

In some cases it can be necessary to convert the results of a test series to correlate with a unit strength different from that of the test unit. In the case of unit failure, this conversion shall be carried out according to Equation (2.4.2)

$$F_{Ru}\,(f_b) = F_{Ru}^{t} \cdot \left( \frac{f_b}{f_{b,test}} \right)^{\alpha} \qquad (2.4.2)$$

with:

$F_{Ru}\,(f_b)$ = failure load at unit compressive strength $f_b$
$\alpha$ = 0,5 for masonry units of clay or concrete and solid unit of calcium silicate
$\alpha$ = 0,75 for masonry units of perforated calcium silicate (in this connection the range in the unit strength in the tests is limited to ± 100 % of the nominal strength of the unit for the characteristic resistance)
$f_{b,test}$ = mean compressive strength of the masonry unit at the time of testing with $f_{b,test} > f_b$ (if $f_{b,test} < f_b$, then $f_{b,test}$ or the next smaller strength class $f_b$ shall be given in the approval)

In the case of pull-out failure the influence of the unit strength on the failure load shall be established. In the absence of better information, Equation (2.4.2) may be used as an approximation.

Autoclaved aerated concrete units strength:

General:
The tests results shall be converted as far as compressive strength and dry density are concerned.

Compressive strength:
For AAC blocks the characteristic compressive strength shall be determined from the declared value of compressive strength according to EN 771-4: using the factor of 0,9.

$$f_{ck} = 0{,}9\, f_{c,decl}$$

Dry density:
As reference values of dry density the following minimum values of dry density shall be used for low and high strength AAC for conversion of the test results:

low strength AAC: $\rho_{min} = 350\ kg/m^3$
high strength AAC: $\rho_{min} = 650\ kg/m^3$

Conversion of test results:
The test results obtained for low and high strength AAC shall be converted using the following Equation:

$$F_{Ru}^{t_K} = F_{Ru}^{t}\ \frac{\rho_{min}^{3/4} \cdot f_{ck}}{\rho_{test}^{3/4} \cdot f_{c,test}} \quad (kN) \qquad (2.4.3)$$

From the above, the 5 %-fractile for the ultimate load shall be derived.

Characteristic failure load (ultimate load) of the different strength of AAC:
For the strength between low and high strength AAC the characteristic failure loads shall be determined by linear interpolation of the converted test results.

Steel strength:

In case of steel failure the failure load shall be converted to the nominal steel strength by Equation (2.4.4)

$$F_{Ru}(f_{uk}) = F_{Ru}^{t} \cdot \frac{f_{uk}}{f_{u,test}} \tag{2.4.4}$$

with:

$F_{Ru}(f_{uk})$ = failure load at nominal characteristic steel ultimate strength

**(c) In all tests the following criteria shall be met:**

(1) In all tension tests the load-displacement curves shall show a steady increase (see Figure 2.4); uncontrolled slip of injection anchors is not allowed.

Solid masonry units (bond between steel element, injection mortar and masonry)

Uncontrolled slip occurs when the mortar with the embedded part is pulled out of the drilled hole (because then the load displacement behaviour depends significantly on irregularities of the drilled hole). The corresponding load when uncontrolled slip starts is called load at loss of adhesion $N_{u,adh}$. For the requirement on the load-displacement curves with respect to uncontrolled slip the following evaluation shall be done:

$N_{u,adh}$ shall be evaluated for every test from the measured load displacement curve. In general the load at loss of adhesion is characterised by a significant change of stiffness, see Figure 2.4 a. If the change in stiffness at a defined load is not so obvious e.g. the stiffness is smoothly decreasing, than the load at loss of adhesion shall be evaluated as follows:

1) Compute the tangent to the load-displacement curve at a load 0,3 $N_u$ ($N_u$ = peak load in test). In general the tangent stiffness can be taken as the secant stiffness between the points 0/0 and 0,3 $N_u/\delta_{0,3}$ ($\delta_{0,3}$ = displacement at N = 0,3 $N_u$).
2) Divide the tangent stiffness by a factor of 1,5.
3) Draw a line through the point 0/0 with the stiffness as calculated in 2).
4) The point of intersection between this line and the measured load-displacement curve gives the load $N_{u,adh}$ where the adhesion fails, see Figure 2.4 b.

If there is a peak in the load-displacement curve to the left side of this line which is higher than the load at intersection then $N_{u,adh}$ is taken as the peak load, see Figure 2.4 c.

If there is a very stiff load-displacement curve at the beginning ($\delta_{0,3} \leq 0{,}05$mm) then the drawing of the line for the calculation can be shifted to the point (0,3 $N_u/\delta_{0,3}$ ), see Figure 2.4 d.

For all tests, the factor $\alpha_1$ shall be calculated according to Equation (2.4.5a):

$$\alpha_1 = \frac{N_{u,adh}}{0{,}5 \cdot N_{Ru}} \tag{2.4.5a}$$

with:
$N_{u,adh}$ = load at loss of adhesion as defined above
$N_{Ru}$ = maximum load of single test

The minimum value of $\alpha_1$ of all tests is decisive. If the value of $\alpha_1$ is less than 1,0 then the characteristic resistance $N_{Rk,p}$ shall be reduced according to 2.4.2.2.3.

The evaluation of the load at loss of adhesion is not required when failure occurs between mortar and embedded part along the entire embedment depth (see definition of uncontrolled slip). In this case the factor $\alpha_1$ may be taken as 1,0.

Hollow or perforated masonry units and solid masonry with open structure (porous) material (mechanical interlock of the mortar with parts of the masonry)

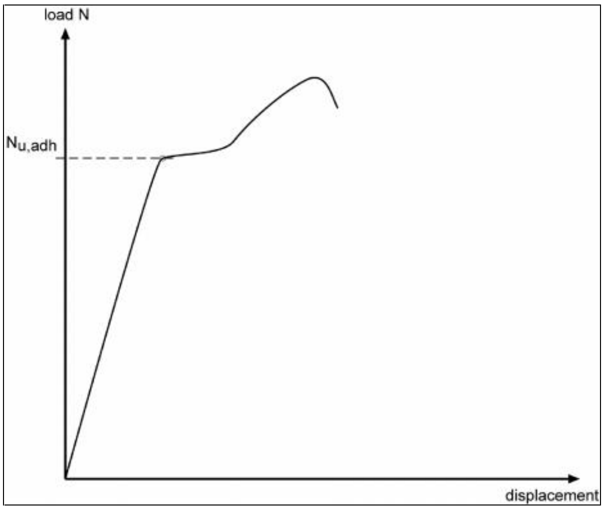
Uncontrolled slip is characterised by a significant change of stiffness according to Figure 2.5. The corresponding load when uncontrolled slip starts is called $N_1$.

For all tests, the factor $\alpha_1$ shall be calculated according to Equation (2.4.5b):

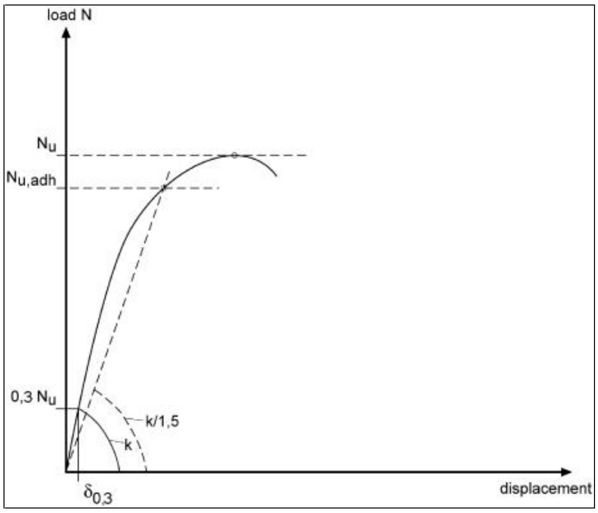
$$\alpha_1 = \frac{N_1}{0{,}5 \cdot N_{Ru}} \qquad (2.4.5b)$$

with: $N_1$ = load at which uncontrolled slip of the anchor occurs (see Figure 2.5)
$N_{Ru}$ = maximum load of single test

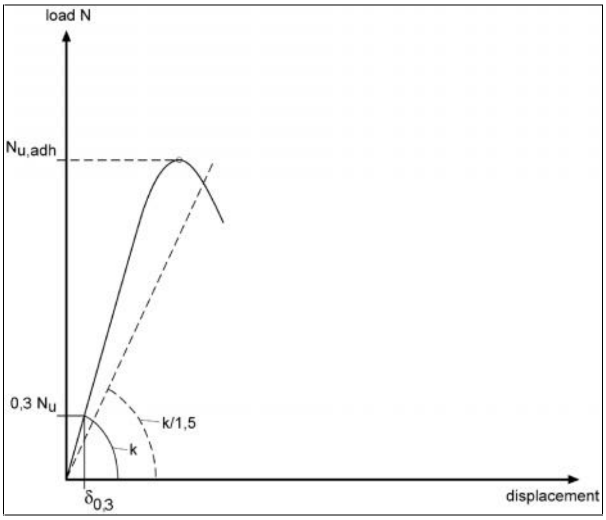
The minimum value of $\alpha_1$ of all tests is decisive. If the value of $\alpha_1$ is less than 1,0 then the characteristic resistance $N_{Rk,p}$ shall be reduced according to 2.4.2.2.3.



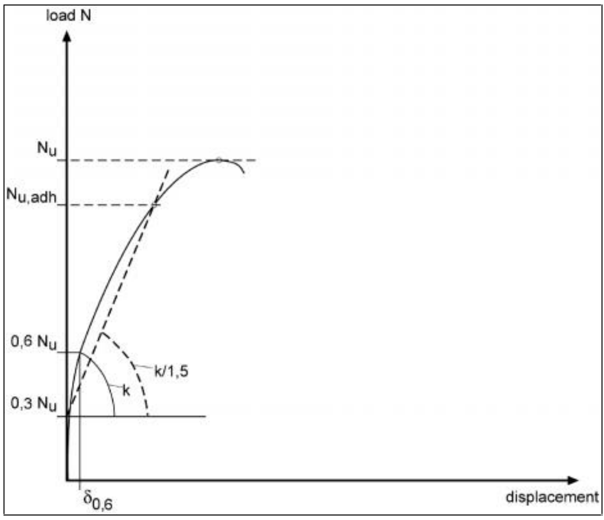

a) load at loss of adhesion by a significant change of stiffness




b) evaluation of load at loss of adhesion




c) evaluation of load at loss of adhesion




d) evaluation of load at loss of adhesion

**Figure 2.4 – Examples of load-displacement curves (solid masonry)**

N1

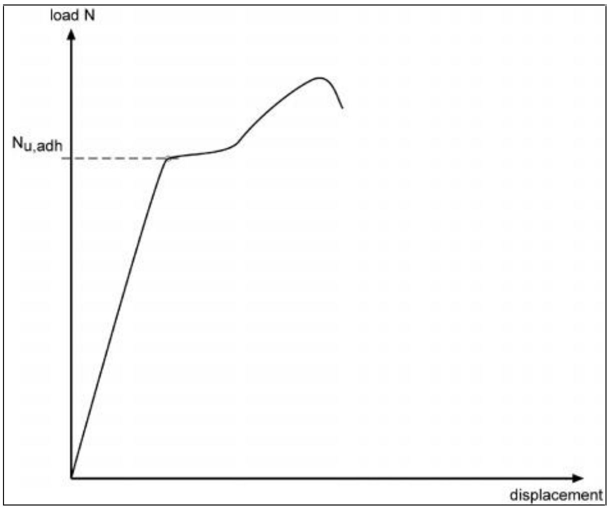



**Figure 2.5 – Example of load-displacement curve (hollow or perforated masonry)**

(2) In general, in each test series, the coefficient of variation of the ultimate load shall be smaller than v = 30 % in the suitability tests and v = 20 % in the admissible service condition tests.

If the coefficient of variation of the ultimate load in the suitability test is greater than 30 %, then the following $\alpha_V$-value has to be taken into account:

$$\alpha_V = \frac{1}{1+0{,}03\cdot(v[\%]-30)} \leq 1{,}0 \qquad (2.4.6)$$

If the coefficient of variation of the ultimate load in the admissible service condition test is greater than 20 %, then the following $\alpha_V$-value has to be taken into account:

$$\alpha_V = \frac{1}{1+0{,}03\cdot(v[\%]-20)} \leq 1.0 \qquad (2.4.7)$$

(3) If in the tests under shear loading displacements higher than 20 mm occur, then the load at a displacement of 20 mm shall be evaluated.

### 2.4.2.1 Additional criteria valid for suitability tests

In the suitability tests the factor $\alpha$ shall be larger than the value given in Table 2.4.2:

$$\alpha = \text{lesser value of } \frac{N^t_{Ru,m}}{N^r_{Ru,m}} \qquad (2.4.8)$$

$$\text{and } \frac{N^t_{Rk}}{N^r_{Rk}} \qquad (2.4.9)$$

with:

$N^t_{Ru,m}$ ; $N^t_{Rk}$ = mean value or 5 %-fractile, respectively, of the ultimate loads in a test series

$N^r_{Ru,m}$ ; $N^r_{Rk}$ = mean value or 5 %-fractile, respectively, of failure loads in the reference tests.

Reference tests have to be carried out on the same masonry units regarding base material, size of units and compressive strength as used for the corresponding suitability tests.

Equation (2.4.9) is based on test series with a comparable number of test results in both series. If the number of tests in the two series is very different, then Equation (2.4.9) may be omitted when the coefficient of variation of the test series is smaller than or equal to the coefficient of variation of the reference test series or if the coefficient of variation in the suitability tests is v ≤ 15 %.

If the criterion for the required value of $\alpha$ (see Table 2.4.2) is not met in a test series, then the factor $\alpha_2$ shall be calculated.

$$\alpha_2 = \frac{\alpha}{req.\alpha} \qquad (2.4.10)$$

with:

$\alpha$ lowest value according to Equation (2.4.8 or 2.4.9) in the test series

req. $\alpha$ required value of $\alpha$ according to Table 2.4.2

### 2.4.2.1.1 Installation in dry or wet substrate

The required $\alpha$ in the tests is $\geq$ 0,8. If the requirements concerning $\alpha$ are not fulfilled, $\alpha_2$ shall be calculated according to Equation (2.4.10).

### 2.4.2.1.2 Influence of temperature on characteristic resistances

**a) Effect of increased temperature**

The required $\alpha$ for the tests at maximum long term temperature is:

req.$\alpha \geq$ 1,0 for temperature ranges (Tb) (T = + 50 °C) and (Tc) (0,6 T1 to 1,0 T1, chosen by the manufacturer)

The required $\alpha$ for the maximum short term temperature are:

req.$\alpha \geq$ 0,8 of the results of maximum long term temperature (24 °C for temperature range Ta)
req.$\alpha \geq$ 0,8 of the results of maximum long term temperature (50 °C for temperature range Tb)
req.$\alpha \geq$ 0,8 of the results of maximum long term temperature (0.6T1 to 1.0T1 temperature chosen by the manufacturer for temperature range Tc)

If the requirements concerning $\alpha$ are not fulfilled in the tests at the maximum long term or maximum short term temperature, $\alpha_2$ shall be calculated according to Equation (2.4.10).

**b) Effect of low installation temperature**

The required $\alpha$ for the tests at the minimum installation temperature is 1,0.

If this condition is not fulfilled, then the minimum installation temperature shall be increased and the tests at minimum installation temperature shall be repeated until the condition is fulfilled.

**c) Minimum curing time at normal ambient temperature**

The mean failure loads and the 5% fractile of failure loads measured in tests at the normal ambient temperature and corresponding minimum curing time shall be at least 0,9 times to the values measured in reference tests with a "long curing time" in the tests for admissible service conditions. The "long curing time" is the maximum curing time normally used in admissible service condition tests (24 hours for resins, 14 days for cementitious-mortars).

If this condition is not fulfilled, then the minimum curing time at normal ambient temperature shall be increased and the corresponding tests shall be repeated or the characteristic resistance for pull-out failure given in the ETA reduced according to Equation (2.4.10).

### 2.4.2.1.3 Repeating loading

The increase of displacements during cycling shall stabilise in a manner indicating that failure is unlikely to occur after some additional cycles. This condition may be assumed as fulfilled if the displacements after cycling at max N of the test are smaller than the mean value of the displacements at overcoming loss of adhesion in the reference tests.

If the above condition on the displacement is not fulfilled, the tests have to be repeated with a lower maximum load (max N) until this condition is fulfilled. Then the characteristic resistance $N_{Rk}$ shall be reduced by the factor max N (applied) / max N (required).

The required $\alpha$ for the pull-out tests subsequent to the cycling loading is 1,0. If this condition is not fulfilled, $\alpha_2$ shall be calculated according to Equation (2.4.10).

#### 2.4.2.1.4 Sustained loading

The displacements measured in the tests have to be extrapolated according to Equation (2.4.11) (Findley approach) to 50 years (tests at normal ambient temperature), or 10 years (tests at maximum long term temperature.

The curve fitting shall start with the displacement measured after approximately 100 h.

$$s(t) = s_o + a \cdot t^b \qquad (2.4.11)$$

$s_o$ = initial displacement under the sustained load at t = 0 (measured directly after applying the sustained load)

a, b = constants (tuning factors), evaluated by a regression analysis of the deformations measured during the sustained load tests

The extrapolated displacements shall be less than the mean value of the displacements at the load at overcoming loss of adhesion in the reference tests.

If this condition is not fulfilled, the tests have to be repeated with a lower load $N_p$ until the requirement is fulfilled and the characteristic resistance shall be reduced by the factor $N_p$ (applied) / $N_p$ (required).

The failure loads measured in the pull-out tests subsequent to the sustained loading at normal temperature shall be compared with the failure loads measured in the reference tension tests (Table 2.4.3, line 1).

The failure loads measured in the pull-out tests subsequent to the sustained loading at maximum long term temperature shall be compared with the failure loads measured in the suitability tests at maximum long term temperature (Table 2.4.2, line 2(a)).

The required $\alpha$ is 0,9. If this condition is not fulfilled for residual capacity after sustained loading at normal temperature and maximum long term temperature, $\alpha_2$ shall be calculated according to Equation (2.4.10).

#### 2.4.2.1.5 Maximum torque moment

The installation of the injection anchor shall be practicable without steel failure, turn-through in the hole or failure of the anchorage.

This condition may be assumed to be fulfilled if the following conditions are met. The ratio of the maximum torque moment $T_u$ during failure to the installation moment $T_{inst}$ recommended by the manufacturer shall be determined for every test. The 5 %-fractile of the ratio for all tests shall be at least 2,1. The conversion to the nominal masonry strength may be omitted for these determinations.

#### 2.4.2.1.6 Functioning under freeze/thaw conditions

The rate of displacement increase shall be reduced with increasing number of freeze/thaw cycles to a value almost equal to zero.

### 2.4.2.2 Criteria for admissible service conditions tests

#### 2.4.2.2.1 General

In all tension tests, the requirement for the load/displacement curves shall satisfy the requirements laid down in 2.4.2 c (1). The requirements on the coefficient of variation of the ultimate loads are given in 2.4.2 c (2).

#### 2.4.2.2.2 Characteristic resistance of a single anchor for the different conditions

The characteristic resistances of the injection anchor for the different failure modes under tension and shear loading shall be evaluated by the corresponding tests to get the required values for the design method according to Annex C.

#### 2.4.2.2.3 Characteristic resistance of a single anchor in the ETA

The characteristic resistances of single anchors without spacing effects under tension loading shall be calculated as follows:

$$N_{Rk,p} = N_{Rk,b} = N_{Rk,0} \cdot \min^{1)} (\min \alpha_1 ; \min \alpha_{2,\ line\ 1,3,4,6}) \cdot \min \alpha_{2,\ line\ 2} \cdot \min \alpha_3 \cdot \min \alpha_{V,N} \qquad (2.4.12)$$

*1) The lowest value of min* $\alpha_1$ *or min* $\alpha_{2,\ line\ 1,3,4,6}$ *is used .*

with:

| | | |
|---|---|---|
| $N_{Rk,p}$ | = | characteristic resistance of pull out failure of the anchor |
| $N_{Rk,b}$ | = | characteristic resistance of brick break out failure |
| $N_{Rk,0}$ | = | minimum characteristic resistance evaluated from the results of tests according to Table 2.4.3, line 2 and Table 2.4.3, line 4 |
| min $\alpha_1$ | = | minimum value $\alpha_1$ (reduction factor from the load/displacement behaviour) according to Equation (2.4.5) of all tests ($\leq$ 1,0) |
| min $\alpha_{2,line\ 2}$ | = | minimum value $\alpha_2$ (reduction factor from the ultimate loads in the suitability tests) according to Equation (2.4.10) of suitability tests according to Table 2.4.2, line 2 (temperature) ($\leq$ 1,0) |
| min $\alpha_{2,line\ 1,3,4,6}$ | = | minimum value $\alpha_2$ (reduction factor from the ultimate loads in the suitability tests) according to Equation (2.4.10) of suitability tests according to Table 2.4.2, line 1, 3, 4 and 6 ($\leq$ 1,0) |
| min $\alpha_{V,N}$ | = | minimum value $\alpha_V$ to consider a coefficient of variation of the ultimate loads in the suitability and admissible service condition tension tests (according to Table 2.4.3, line 1, 2, 4 and 6) larger than 30 % or 20 %, respectively, Equations (2.4.6) and (2.4.7). |
| min $\alpha_3$ | = | minimum value $\alpha_3$ (reduction factor from the durability behaviour) according to Equation (2.7.1) of all tests ($\leq$ 1,0) |

The characteristic resistances of single anchors without spacing effects under shear loading shall be calculated as follows:

$$V_{Rk,b} = V_{Rk,0} \cdot \min \alpha_1 \cdot \min \alpha_{V,V} \qquad (2.4.13)$$

with:

| | | |
|---|---|---|
| $V_{Rk,b}$ | = | characteristic resistance of local brick failure independent of the failure mode |
| $V_{Rk,0}$ | = | minimum characteristic resistance evaluated from the results of tests according to Table 2.4.3, line 3 and Table 2.4.3, line 5 |
| min $\alpha_1$ | = | minimum value $\alpha_1$ (reduction factor from the load/displacement behaviour) according to Equation (2.4.5) of all tests ($\leq$ 1,0) |
| min $\alpha_{V,V}$ | = | minimum value $\alpha_{V,V}$ to consider a coefficient of variation of the ultimate loads in the admissible service condition shear tests (according to Table 2.4.3, line 3, 5 and 7) larger than 20 %, Equations (2.4.7). |

In case of steel failure in the tests according to Table 2.4.3, line 3, $V_{Rk,s}$ (characteristic resistance of steel failure of the anchor) according to Equation (2.4.13) shall be considered additionally. The minimum value of $V_{Rk,s}$ according to Equation (C.5.5) and $V_{Rk,s}$ according to Equation (2.4.13) shall be given in the approval.

The value of the characteristic resistance ~~$F_{Rk}$~~ $N_{Rk,p}$, $N_{Rk,b}$, $V_{Rk,s}$, $V_{Rk,b}$ shall be rounded down to the following numbers:

0,3 / 0,4 / 0,5 / 0,6 / 0,75 / 0,9 / 1,2 / 1,5 / 2 / 2,5 / 3 / 3,5 / 4 / 4,5 / 5 / 5,5 / 6 / 6,5 / 7 / 7,5 / 8 / 8,5 / 9 / 9,5 / 10 / 10,5 / 11 / 11,5 / 12 kN

The determined characteristic resistances for the approval are valid only for the bricks and blocks which are used in the tests regarding base material, size of units, compressive strength and configuration of the voids. Therefore the following information has to be given in the test report and in the approval:

*Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EC 6*.

The characteristic resistance of the injection anchor may be determined by "job site tests" according to Annex B, if the anchor has an approval with characteristic values for the same type of base material (e.g. clay, calcium silicate, lightweight aggregate or autoclaved aerated concrete) as is present on the construction works. Furthermore job site tests for use in solid masonry are possible only if the injection anchor has an approval for use in solid masonry and job site tests for use in hollow or perforated masonry are possible only if the metal injection anchor has an approval for use in hollow or perforated masonry.

If the characteristic resistance of the injection anchor may be determined by "job site tests" according to Annex B, the $\beta$ factor to consider the different influences of the product shall be calculated as follows and shall be given in the ETA.

$$\beta = \min(\min \alpha_1 ; \min \alpha_{2,\text{ line }1,3,4,6}) \cdot \min \alpha_{2,\text{ line }2} \cdot \min \alpha_3 \cdot \min \alpha_{V,N} \qquad (2.4.14)$$

$\min \alpha_1$, $\min \alpha_{2,\text{line }2}$, $\min \alpha_{2,\text{line }1,3,4,6}$, $\min \alpha_{V,N}$, $\min \alpha_3$ see Equation (2.4.12)

#### 2.4.2.2.4 Displacement behaviour

As a minimum, the displacements under short and long term tension and shear loading shall be given in the approval for a tension or shear load F which corresponds to the value according to Equation (2.4.13).

$$F = \frac{F_{Rk}}{\gamma_F \cdot \gamma_M} \qquad (2.4.15)$$

with:

- $F_{Rk}$ = characteristic resistance $N_{Rk,p}$, $N_{Rk,b}$ for displacements under tension load acc. to 2.4.2.2.3
- $F_{Rk}$ = characteristic resistance $V_{Rk,s}$ or $V_{Rk,b}$ for displacements under shear load acc. to 2.4.2.2.3
- $F_{Rk}$ = characteristic resistance according to 2.4.2.2.3
- $\gamma_F$ = 1,4
- $\gamma_M$ = corresponding material partial safety factor

The displacements under short term tension loading ($\delta_{NO}$) are evaluated from the tests with single anchors without edge or spacing effects according to Table 2.4.3, line 2. The value derived shall correspond to the 95 %-fractile for a confidence level of 90 %.

The long term tension loading displacements $\delta_{N\infty}$ may be assumed to be equal to 2,0 times the value $\delta_{NO}$.

The displacements under short term shear loading ($\delta_{VO}$) are evaluated from the corresponding shear tests with single anchors. The value derived shall correspond to the 95 %-fractile for a confidence level of 90 %.

The long term shear loading displacements $\delta_{V\infty}$ may be assumed to be equal to 1,5 times the value $\delta_{VO}$.

Under shear loading, the displacements might increase due to a gap between fixture and anchor. The influence of this gap is taken into account in design.

#### 2.4.2.2.5 Characteristic resistance of an anchor group in the ETA

The characteristic resistances of a double or quadruple anchor group under tension loading shall be calculated as follows:

$$N_{Rk}^{g} = \alpha_{g,N} \cdot N_{Rk} \qquad (2.4.16)$$

with:

- $N_{Rk}^{g}$ = characteristic resistance of the anchor group under tension loading and under defined spacing $s_{min,II}$ and/or $s_{min,\perp}$ and under defined edge distances $c_{min}$, given in the approval
- $N_{Rk}$ = $N_{Rk,p}$ or $N_{Rk,b}$ according to Equation (2.4.12)
- $\alpha_{g,N}$ = smaller value of $\frac{N_{Ru,m}^{t,g}}{N_{Ru,m}^{r}}$ and $\frac{N_{Rk}^{t,g}}{N_{Rk}^{r}}$,
  group factor for tension loading, shall be rounded to 0,05
  ≤ 2 (for double anchor groups)
  ≤ 4 (for quadruple anchor groups)

$N_{Ru,m}^{t,g}$ ; $N_{Rk}^{t,g}$ = mean value or 5 %-fractile of the ultimate loads of an anchor group in a test series according to Table 2.4.3, line 6

$N_{Ru,m}^{r}$ ; $N_{Rk}^{r}$ = mean value or 5 %-fractile of ultimate loads of a single anchor in the relevant reference test according to Table 2.4.3, line 2 (if $c_{min} = c_{cr}$) or line 4 (if this optional test is performed)

The characteristic resistances of a double or quadruple anchor group under shear loading shall be calculated as follows:

$$V_{Rk}^{g} = \alpha_{g,V} \cdot V_{Rk} \quad (2.4.17)$$

with:

$V_{Rk}^{g}$ = characteristic resistance of the anchor group under shear loading and under defined spacing $s_{min,II}$ and/or $s_{min,\perp}$ and under defined edge distances $c_{min}$, given in the approval

$V_{Rk}$ = $V_{Rk,b}$ according to Equation (2.4.13)

$\alpha_{g,V}$ = smaller value of $\frac{V_{Ru,m}^{t,g}}{V_{Ru,m}^{r}}$ and $\frac{V_{Rk}^{t,g}}{V_{Rk}^{r}}$,

group factor for shear loading, shall be rounded to 0,05
≤ 2 (for double anchor groups)
≤ 4 (for quadruple anchor groups)

$V_{Ru,m}^{t,g}$ ; $V_{Rk}^{t,g}$ = mean value or 5 %-fractile of the ultimate loads of an anchor group in a test series according to Table 2.4.3, line 7

$V_{Ru,m}^{r}$ ; $V_{Rk}^{r}$ = mean value or 5 %-fractile of ultimate loads of a single anchor in the relevant reference test according to Table 2.4.3, line 3 (if $c_{min} = c_{cr}$) or line 5 (if this optional test is performed)

In general, a linear interpolation between the characteristic resistance of a single anchor and the characteristic resistance of an anchor group depending on the spacing is not allowed. If there are sufficient test results with anchor groups in the same masonry units available, which show a clear dependency between the load-bearing capacity and the anchor spacing and/or the edge distance, it is possible to evaluate them and to take them into account in the approval.

## 2.5 Verification methods relating to Safety in Case of Fire (ER 2)

### 2.5.1 Reaction to fire

The reaction to fire performance of the anchor shall be in accordance with laws, regulations and administrative provisions applicable to the anchor in its intended end use application. This performance shall be expressed in the form of classification specified in accordance with the relevant EC decision and the appropriate CEN classification standards.

The metal parts of injection anchors and the cementitious mortar are assumed to satisfy the requirements for Class A1 of the characteristic reaction to fire, in accordance with the provisions of EC Decision 96/603/EC (as amended) without the need for testing on the basis of its listing in that Decision.

The bonding material (synthetic mortar, cementitious mortar or a mixture of the two including fillers and/or additives) is located between the metal anchor rod and the wall of the drilled hole in the end use. The thickness of the mortar layer is about 1 to 2 mm and most of the mortar is material classified class A1 according to EC Decision 96/603/EC. Therefore it may be assumed that the bonding material (synthetic mortar or a mixture of synthetic mortar and cementitious mortar) in connection with the injection anchor in the end use application do not make any contribution to fire growth or to the fully developed fire and they have no influence to the smoke hazard.

In the context of this end use application of the anchorages the bonding material can be considered to satisfy any reaction to fire requirements.

### 2.5.2 Resistance to fire

The resistance to fire performance of the assembled system of which the anchor form part shall be in accordance with laws, regulations and administrative provisions applicable to the assembled system of which the anchor form part in its intended end use application. This performance shall be expressed in the form of a classification specified in accordance with the relevant EC decision and the appropriate CEN classification standards.

The suitability of a injection anchor for use in a system that is required to provide a specific fire resistance class, shall be assessed according to the EOTA Technical Report N° 020 "Evaluation of anchorages in concrete concerning Resistance to Fire" [7].

## 2.6 Verification methods relating to Hygiene, Health and the Environment (ER 3)

The applicant shall either:

- submit the chemical constitution and composition of the materials and components of the product to the Approval Body which will observe strict rules of confidentiality
  or
- submit a written declaration to the Approval Body stating whether or not and in which concentration the materials and components of the product contain substances which have to be classified as dangerous according to Directive 67/548/EEC and Regulation (EC) No 1272/2008 and listed in the "Indicative list on dangerous substances" of the EGDS, taking into account the installation conditions of the construction product and the release scenarios resulting from there.

The use of recycled materials shall always be indicated, because this could lead to the implementation of further assessment and verification methods.

The information concerning the presence of dangerous substances listed in Council Directive 67/548/EEC and Regulation (EC) No 1272/2008 regulated at European level and listed in the "Indicative list on dangerous substances" of the EGDS and/or of other dangerous substances, shall be circulated as part of the evaluation report by the issuing Approval Body to the other Approval Bodies, under strict conditions of confidentiality.

### 2.6.1 Method of verification (Release of dangerous substances)

The product and/or constituents of the product listed in the EOTA TR 034: "General Checklist for ETAGs/CUAPs/ETAs – Content and/or release of dangerous substances in products/kits", which have to be considered will be verified by the given methods taking into account the installation conditions of the construction product and the release scenarios resulting from there. Regulations related to placing the product on the market may also need to be taken into account.

Regarding the release scenarios referred to in the EOTA TR 034, the use category IA2 (Product with no direct contact to (e.g. covered products) but possible impact on indoor air) have to be considered.

### 2.6.2 Method of assessing and judging (Release of dangerous substances)

The product and/or constituents of the product listed in the EOTA TR 034: "General Checklist for ETAGs/CUAPs/ETAs – Content and/or release of dangerous substances in products/kits", which have to be considered will be verified by the given methods taking into account the installation conditions of the construction product and the release scenarios resulting from there. Regulations related to placing the product on the market may also need to be taken into account.

The content of cadmium contained in zinc coatings shall be declared by the applicant.

Note (to be implemented in the ETA):

For dangerous substances falling under the scope of the CPD for which:

- no assessment and verification methods are given (or cannot be found in TR 034) or
- “no performance determined” is declared or
- the chosen verification and assessment method does not comply with the regulatory requirement of a particular Member State

there might be the necessity for an additional assessment.

## 2.7 Verification methods relating to Durability

### 2.7.1 Method of verification

#### 2.7.1.1 Tests for checking durability of the metal parts (corrosion)

No special tests are required.

The durability of the coating of the metal part that ensures the suitability and the bearing behaviour of the anchor shall be shown. Furthermore it shall be shown that the coating does not negatively affect the durability of the bonding material. No special test conditions can be given in this Guideline for checking the durability of any coating because this depends on the type of coating. Any appropriate tests shall be decided on by the responsible Approval Body. Zinc coatings (electroplated or hot dip galvanised) need not be subjected to testing if used under dry internal conditions

#### 2.7.1.2 Tests for checking durability of the bonding material

The durability of the bonding material (except for cementitious mortar) shall be verified by slice tests. With slice tests, the sensitivity of installed anchors to different environmental exposures can be shown. The slice tests shall be carried out in concrete. The slice test is described in Annex A, A.5.10 in detail.

Slice tests in an alkaline liquid are required only for applications in use category w/w according to section 2.3.2.2 if the injection anchor is installed in:

- masonry from normal weight or lightweight concrete masonry units
- joints of masonry made from clay or calcium silicate units filled with non carbonated cementitious mortar

Slice tests may be omitted for applications in:

- masonry made from normal weight or lightweight concrete masonry units if the characteristic resistance is calculated according to Equation (2.4.12) with $\alpha_3 = 0,3$
- joints of masonry units made out of clay or calcium silicate filled with cementitious mortar, if the characteristic resistance of the anchor for the corresponding masonry unit given in the ETA is $N_{Rk} \leq N_{Rk}$ (concrete brick) with $N_{Rk}$ (concrete brick) calculated according to Equation (2.4.12) with $\alpha_3 = 0,5$ or the mortar is carbonated over the embedment depth of the anchor.
  Carbonated mortar may be assumed if the structure is sufficiently old (e.g. $\geq$ 15 years)

### 2.7.2 Method of assessing and judging

#### 2.7.2.1 Durability of the metal parts

The assessment/testing required with respect to corrosion resistance will depend on the specification of the injection anchor in relation to its use. Supporting evidence that corrosion will not occur is not required if the steel parts of the metal injection anchor are protected against corrosion, as set out below:

Injection anchors intended for use in structures subject to dry, internal conditions:

> No special corrosion protection is necessary for steel parts as coatings provided for preventing corrosion during storage prior to use and for ensuring proper functioning (e.g. a zinc coating with a minimum thickness of 5 microns) is considered sufficient.

Injection anchors for use in structures subject to external atmospheric exposure or exposure in permanently damp internal conditions:

> The metal parts of the anchors shall be made of an appropriate grade of stainless steel. The grade of stainless steel suitable for the various service environments (marine, industrial, etc.) shall be in accordance with existing rules. Grade A4 of ISO 3506-1 and 2:2009 [4] or equivalent may be used under internal and external or other environmental conditions if no particularly aggressive conditions exist.

Injection anchors for use in structures subject to external atmospheric exposure or exposure in permanently damp internal conditions or particularly aggressive conditions:

> If the anchor is to be used in particularly aggressive conditions such as permanent or alternate immersion in seawater or the splash zone of seawater, chloride atmosphere of indoor swimming pools or atmosphere with extreme chemical pollution (e.g. in desulphurization plants or road tunnels, where de-icing materials are used) stainless steel material 1.4529, 1.4565 and 1.4547 according to EN 10088-5 [5] can be used.

Where a form of protection (material or coating) other than those mentioned above is specified, it will be necessary to provide evidence in support of its effectiveness in the defined service conditions; with due regard to the aggressiveness of the conditions concerned.

If an anchor involves the use of different metals, these shall be electrolytically compatible with each other. In dry internal conditions, carbon steel is compatible with malleable cast iron.

Assessment of the durability of the coating is based on the type of coating and the intended conditions of use (i.e. dry internal or external conditions).

**Note:** Bolts or screws made of galvanised steel with high steel strength (>1 000 N/mm²; property class >10.9) may be sensitive to brittle fracture. Therefore the risk of brittle fracture has to be considered in the assessment of such products. Commercial standard rods made of galvanised steel should be used with property class 8.8 at most.

#### 2.7.2.2 Durability of the bonding material

In the slice tests according to Annex A, A.5.10 it shall be shown that:

- the bond strength of the slices stored in an alkaline liquid is at least as high as that of the bond strength of the comparison tests on slices stored under normal conditions and
- the bond strength of the slices stored in sulphurous atmosphere media is not smaller than 0,9 times of the bond strength of the comparison tests on slices stored under normal conditions.

To show compliance with this requirement of the slice tests the factor $\alpha_3$ shall be calculated according to Equation (2.7.1).

$$\alpha_3 = \frac{\tau_{um(stored)}}{\tau_{um,dry}} \qquad (2.7.1)$$

with:

$\tau_{um(stored)}$ = mean bond strength of the slices stored in the corresponding atmosphere (alkaline fluid or in sulphurous),

$\tau_{um,dry}$ = mean bond strength of the comparison tests on slices stored under normal condition

The bond strength in the slice tests shall be calculated according to Equation (2.7.2)

$$\tau_u = \frac{N_u}{\pi \cdot d \cdot h_{sl}} \qquad (2.7.2)$$

with:

$N_u$ = measured maximum load
d = diameter of the embedded part
$h_{sl}$ = thickness of slice, measured values

If the value $\alpha_3$ is less than 1,0 for the tests in alkaline fluid and 0.9 for tests in sulphurous atmosphere then the characteristic resistance $N_{Rk}$ shall be reduced according to 2.4.2.2.3.

# 3 EVALUATION AND ATTESTATION OF CONFORMITY AND CE MARKING

## 3.1 System of attestation of conformity

According to the communication of the European Commission, the system of attestation of conformity laid down in Commission Decision 97/177/EC dated 17 February 1997 of the OJ L 073 dated 14 March 1997, is given in Table 3.1.

**Table 3.1 – System of attestation of conformity applicable to "Metal injection anchors for use in masonry"**

| Product | Intended use | Level(s) or class(es) | Attestation of conformity system |
|---|---|---|---|
| Metal injection anchors for use in masonry | For fixing and/or supporting to masonry, structural elements (which contributes to the stability of the works) or heavy units | | 1 |

The system of attestation of conformity referred to above is defined as follows:

System 1: Certification of the conformity of the product by a notified certification body on the basis of:

(a) Tasks for the manufacturer:

- (1) factory production control;
- (2) further testing of samples taken at the factory by the manufacturer in accordance with a prescribed test plan;

(b) Tasks for the notified body:

- (3) initial type-testing of the product;
- (4) initial inspection of factory and of factory production control;
- (5) continuous surveillance, assessment and approval of factory production control.

## 3.2 Tasks and responsibilities of the manufacturer and notified body

### 3.2.1 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of "Metal injection anchors for use in masonry" in the procedure of attestation of conformity are laid down in Table 3.2.

Table 3.2 is an example only; the control plan depends on the individual manufacturing process and has to be established between notified body and manufacturer for each product.

**Table 3.2 – Control plan for the manufacturer; cornerstones**

| No | Subject/type of control | Test or control method | Criteria, if any | Minimum number of samples | Minimum frequency of control |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| **Factory production control (FPC)**<br>[**including testing of samples in accordance with a prescribed test plan**] | | | | | |
| 1 | Metal part / dimensions and tolerances | Measuring or optical | Laid down in control plan | 3 | Every shift or 8 hours of production per machine |
| 2 | Metal part / material properties e.g. tensile strength or hardness, elastic limit, elongation on rupture | e.g. tensile test, hardness testing Brinell or Vickers | Laid down in control plan | 3 | Every shift or 8 hours of production per machine |
| 3 | Metal part / coating | Measuring of thickness | Laid down in control plan | 3 | Every shift or 8 hours of production per machine |
| 4 | Mortar / components / mass | Mass | Laid down in control plan | 3 | Every shift or 8 hours of production per machine |
| 5 | Mortar / condition | | Laid down in control plan | 2 | Every shift or 8 hours of production per machine |
| 6 | Mortar / density | | Laid down in control plan | 2 | Every shift or 8 hours of production per machine |
| 7 | Mortar / viscosity | | Laid down in control plan | 2 | Every shift or 8 hours of production per machine |
| 8 | Fingerprint of bonding material | | | | Each batch |

### 3.2.2 Tasks for the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of attestation of conformity for "Metal injection anchors for use in masonry" are laid down in Table 3.3.

**Table 3.3 – Control plan for the notified body; cornerstones**

| No | Subject/type of control | Test or control method | Criteria, if any | Minimum number of samples | Minimum frequency of control |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| **Initial type-testing of the product (ITT)** | | | | | |
| 1 | Initial type testing will be available as part of the required assessment for issuing European Technical Approvals unless there are changes in the production line or plant.<br>In such cases the ITT has to be agreed between the Approval Body and the notified body. | - | - | - | - |
| **Initial inspection of factory and factory production control (FPC)** | | | | | |
| 2 | Ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the injection anchor. | - | Laid down in control plan | - | 1 |
| **Continuous surveillance, judgment and assessment of factory production control (FPC)** | | | | | |
| 3 | Verifying that the system of factory production control and the specified automated manufacturing process are maintained taking account of the control plan. | - | Laid down in control plan | - | 1/year |

### 3.3 CE marking and accompanying information

According to Council Directive 93/68/EEC the CE marking consists of the letters "CE" in the form laid down in the Directive, followed by the identification number of the notified certification body.

The packaging or the delivery tickets associated with the product shall contain the CE marking and the following accompanied information:

- the name and address of the producer (legal entity responsible for the manufacture),
- the last two digits of the year in which the CE marking was affixed,
- the number of the EC certificate of conformity for the product,
- the number of the European Technical Approval,
- the number of the ETAG,
- size of the anchor,
- use category.

Example of CE marking and accompanying information:

| | |
|---|---|
| CE | Letters "CE" |
| 1234 | Identification number of notified certification body |
| Any Company<br>Street 1, City,<br>Country | Name and address of the producer (legal entity responsible for the manufacture) |
| 10 | Two last digits of year of affixing CE marking |
| 1234-CPD-0321 | Number of EC certificate of conformity |
| ETA-06/2135 | Number of European Technical Approval |
| ETAG 029 | ETAG number |
| M10 / Use category b,c and w/w | Size / use category |

### 3.4 Marking of the product

Every injection anchor shall be clearly identifiable before installation[1)] and shall be marked by:

- the name or identifying mark of the producer
- the injection anchors identity (commercial name)
- the intended use (durability use, e.g. an additional mark for stainless steel anchors to distinguish them from non-stainless steel anchors). The intended use may be included in the injection anchor identity.
- the minimum anchorage depth or the maximum admissible thickness of the fixture
- if an injection anchor is designed for use at more than one anchorage depth while maintaining the same thread diameter, the anchorage depths available and used shall be discernible after installation of the injection anchor.

[1)] For use of commercial standard rods see 4.3

# 4 ASSUMPTIONS UNDER WHICH THE FITNESS FOR THE INTENDED USE IS ASSESSED

## 4.1 Design method for anchorages

The assessment of the injection anchor shall be made assuming that one of the design methods given in Annex C is used. However, if an alternative design method shall be proposed, the Approval Body shall judge this design method and the relevance of the assessment, in particular the relevance of the tests to be undertaken.

The overall assumption shall be made that the design and dimensioning of anchorages is based on technical considerations and in particular the following:

- Preparation of verifiable calculation notes and drawings for determining the relevant masonry in the region of the anchorage, the loads to be transmitted and their transmission to the supports of the structure.

- Consideration not only of direct loads but also the important additional loads caused by restraint of intrinsic (e.g. shrinkage) or extrinsic deformation (e.g. by temperature variations) in the injection anchor, in the fixture or in the base material together with verification of the distribution of loads in these structures and assemblies.

- It is to be ensured that the use category applies and the strength class, density etc. of the base material is not lower than that to which the characteristic loads apply.

## 4.2 Packaging, transport, storage of the product

Any special transport conditions shall be stated on accompanying documents.

Any special storage conditions shall be stated on packaging including:

Storage temperature range,
Restrictions such as keeping away from heat and direct sunlight,
Expiry date.

## 4.3 Installation of the product in the works

The loading capacity and reliability of anchorages are greatly affected by the manner in which the injection anchors are installed. The manufacturer's installation instructions therefore form a fundamental part of the assessment of the fitness for use of an injection anchor.

This Guideline takes account of a reasonable degree of imperfection in relation to installation and thus control methods on site after installation will in general not be necessary. This assumes, however, that gross errors on site will be avoided by use of instructions and correct training of the installers and supervision on site.

The anchor shall be used only as supplied by the manufacturer without exchanging the components of an anchor. Commercial standard threaded rods, washers and hexagon nuts may also be used if the following requirements are fulfilled:

1. Material, dimensions and mechanical properties of the metal parts (rod, washer, nut) according to the specifications given in the ETA
   *Remark: The ETA has to contain all details of the metal parts.*
   *The material of stainless steel is given according to EN 10088:2009 [5], the mechanical properties according to EN ISO 898-1 and 2:2009 [8] (galvanised steel) and according to EN ISO 3506-1 and 2:2009 [4] (stainless steel).*

2. Confirmation of material and mechanical properties of the metal parts by inspection certificate 3.1 according to EN 10204:2004 [9]; the documents shall be stored.

3. Marking of the rod with the envisaged embedment depth. This may be done by the manufacturer of the rod or the person on the job site.

Installation instructions shall typically include the following:

- Before placing an injection anchor, the checks to be made to ensure that the use category applies.
- Plaster or similar materials shall be removed, unless there is information from the planning engineer that this layer was taken into account.
- Holes to be drilled perpendicular (maximum deviation 5°) to the surface unless specifically required otherwise by the manufacturer's instructions.
- Normally hard metal hammer-drill bits in accordance with ISO or National Standards shall be used.
- All special drill bits (e.g. stopdrills or diamond core drill bits) required in accordance with manufacturer's installation instructions to be in compliance with the manufacturer's specifications. This may be checked by comparing the drill bit manufacturer's declared performance and characteristics against the specifications of the anchor manufacturer.
- Instructions for hole cleaning shall specify in detail the type of cleaning equipment to be used, e.g. the volume of blow out pump and diameter and material of brush, together with the precise cleaning procedure including the number and order of blowing/brushing actions.
- Injection anchors to be installed ensuring not less than the specified embedment depth. The edge distance and spacing to be kept to the specified values, no minus tolerances to be allowed.
- Remark to the different installation temperature

  *Temperature limits*

  The following temperature limits shall be specified:

  Installation ambient temperature range

  Bonding material installation temperature range.

  *Operational time limits*

  Open time and curing time shall be stated in relation to the relevant temperature limits, e.g.:

  Open time related to bonding material installation temperature

  Curing time in relation to installation ambient temperature

  If tables are used to indicate times-versus-temperature ranges, they shall be inclusive so that the relevant time is clear for all temperatures within the appropriate range. An accepted example is given in the following:

| | Installation ambient temperature °C | Curing time (minutes) |
|---|---|---|
| E.g. | 5 to ≤ 15 | 120 min |
| | >15 to 25 | 60 min |

The following example is not accepted:

| Installation ambient temperature °C | Curing time (minutes) |
|---|---|
| 5 | 120 min |
| 15 | 60 min |

When curing times are stated it shall be made clear that this is the earliest time that the injection anchor may be torqued or loaded. A longer waiting time may be recommended for proof of ultimate load tests on site; if so, this shall be stated.

Finally it is assumed that the necessary information and appropriate specifications for correct installation are available on site and that the person responsible transmits all the necessary information to the installer. It is to be further assumed that installation is carried out by trained personnel under the supervision of the person responsible for technical matters on site. Where pictograms are used, their meaning shall be clear and unambiguous. If necessary, text in the appropriate language shall be added to clarify the meaning.

## 5 IDENTIFICATION OF THE CONSTRUCTION PRODUCT

In order to ensure that the injection anchor samples used for the initial assessment conform to the specification referred to in the approval, it is necessary to identify their relevant specifications and characteristics which can influence their functioning, performance or durability.

Identification tests are for verifying the characteristics of the injection anchors, including dimensions, constituent materials, anti-corrosion protection and the marking of the injection anchors and various components.

Wherever possible, checks shall be carried out on finished components. Where dimensions or other factors prevent testing to a recognized standard, e.g. tensile properties where the required ratio of length to diameter does not exist in the finished component, then the tests shall still be carried out on the finished component if practicable, in order to produce results for comparison purposes. Where this is not possible, tests shall be carried out on the raw material; however, it shall be noted that where the production process changes the characteristics of the material, then a change to the production process can render the results of these tests invalid.

A minimum number of each component depending on factors such as the production process and the bag size is to be taken and dimensions measured and checked against the drawings provided by the manufacturer. The tolerances specified for all components shall be complied with and the dimensions of these elements shall conform to the appropriate ISO or European Standards where relevant.

The results obtained shall be assessed to ensure that they are within the manufacturer's specification.

The product which is the subject of the European Technical Approval shall be identified by:

- Testing of product characteristics as laid down in the following.
- Fingerprinting.
- Formulation.
- Manufacturing process parameters.
- Calculations, detailing, drawings.

**Metal parts:**
During tests on the constituent materials of the components of the metal parts, the following properties shall be determined: tensile strength, elastic limit, elongation at rupture, hardness. The measured values shall be compared with minimum values or strength classes indicated in ISO or European Standards. The manner in which the components are fabricated shall also be checked (e.g. cold-forming, quenching, hardening). For the testing of carbon steel screws, bolts, nuts, reference can be made to ISO 898-1 and 2. For the testing of stainless steel screws, bolts, nuts reference can be made to ISO 3506-1 and -2. For quenched components, the surface hardness and case depth are to be determined. Hardness testing shall be by either the Brinell or Vickers methods. Wherever possible, the material declaration, according to the relevant material standard, shall be provided.

**Bonding material:**
All components of the bonding materials shall be described in a chemically unambiguous way and be identified by standard tests (e.g. fingerprinting tests). All component amounts shall be specified either by mass, volume or percentage, with appropriate tolerances.

The following characteristics shall be specified where relevant in accordance with ISO, European or national standards, together with any others as appropriate.

**1 <u>Organic Bonding agents</u>**

Resin, hardener and additives shall be identified by the following tests:

- density
- viscosity
- ignition loss and ash content
- conventional dry extract
- grain size analysis
- tensile strength
- bending strength
- compressive strength
- open time
- reactivity (gel or setting time) (this may be tested with a standardised formulation, not necessarily that specified for the bonding anchor)

In addition, the following tests are necessary:

Resin and hardener cured by polyaddition mechanism
**Epoxies**
- epoxy index (equivalent)
- amine equivalent

**Polyurethanes**
- hydroxyl equivalent
- isocyanate equivalent

Resin and hardener cured by polymerisation
**Unsaturated polyester, vinylester (epoxymethacrylates) and vinylesterurethanes (urethanmethacrylates)**
- hardener (catalyst) content of peroxide

**Methylmethacrylates (MMA)**
- hardener, content of peroxide

Filler
- specification of filler material (e.g. tested by density) including type
- specification of filler shape (e.g. fibre, balls, ...)
- grain size analysis

**2 Inorganic bonding agents**

- material specification by chemical analysis
- active binder batching
- grain size analysis
- density
- dry extract
- setting test
- shrinkage and swelling test
- bend and compressive strength at 7 and 28 days
- ignition loss and ash content

Filler, additives
- specification of filler material and additives
- specification of filler shape

# 6 FORMAT OF ETAS ISSUED ON THE BASIS OF THE ETAG

## 6.1 Definition of the anchor and its intended use

- Definition
- Intended use
  - Use categories in respect of the base material
  - Use categories in respect of installation and use
  - Use categories in respect of to the service temperature range
- Assumed working life

## 6.2 Characteristics of the anchor with regard to safety in use and methods of verification

- Definition of the base material which was used in the tests (type of material, strength, density, hole dimensions, dimensions of the brick)
- Minimum allowable edge distance and minimum allowable spacing
- Characteristic edge distance and characteristic spacing
- In addition to the specific clauses relating to dangerous substances contained in the European Technical Approval, there may be other requirements applicable to the products falling within its scope (e.g. transposed European legislation and national laws, regulations and administrative provisions). In order to meet the provisions of the EU Construction Products Directive, these requirements need also to be complied with, when and where they apply.

Note: For dangerous substances falling under the scope of the CPD for which:

- no assessment and verification methods are given (or cannot be found in TR 034) or
- “no performance determined” is declared or
- the chosen verification and assessment method does not comply with the regulatory requirement of a particular Member State

there might be the necessity for an additional assessment.

### 6.3 Evaluation and attestation of conformity and CE marking

- System of attestation of conformity
- Responsibilities
- CE-marking

### 6.4 Assumptions under which the fitness of the product for the intended use was favourably assessed

- Manufacturing
  The ETA is issued for the product on the basis of agreed data/information, deposited with the Approval Body which identifies the product that has been assessed and judged. Changes to the product/production process, which could result in this deposited data/information being incorrect, shall be notified to the Approval Body before the changes are introduced. The Approval Body will decide whether or not such changes affect the ETA and consequently the validity of the CE marking on the basis of the ETA and if so whether further assessment/alterations to the ETA, shall be necessary.
- Design of anchorages
  The anchorages are designed in accordance with the ETAG 029, Annex C.
- Installation

## 7 REFERENCE DOCUMENTS

[1] Directive relating to construction products (CPD): Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (89/106/EEC) taking account of the modified provisions (93/68/EEC)

[2] EN 771-1 to 5:2011: Specification for masonry units

[3] EN 12602:2008: Prefabricated reinforced components of autoclaved aerated concrete

[4] ISO 3506-1 and 2:2009: Mechanical properties of corrosion-resistant stainless-steel fasteners – Part 1: Bolts, screws and studs; Part 2: Nuts

[5] EN 10088-4 and 5:2009: Stainless steels – Part 4: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes; Part 5: Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes

[6] EN 1996-1-1:2005 + AC:2009: Design of masonry structures. Part 1-1: General rules for reinforced and unreinforced masonry structure

[7] EOTA: TR 020: Evaluation of Anchorages in Concrete concerning Resistance to Fire

[8I ISO 898-1 and 2:2009: Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified properly classes – coarse thread and fine pitch thread; Part 2: Nuts with specified properly classes – coarse thread and fine pitch thread

[9] EN 10204:2004: Metallic products – Types of inspection documents

[10] ISO 5468:2006: Rotary and rotary impact masonry drill bits hard metal tips – Dimensions

[11] EN 1990:2002 + A1:2005 / AC:2010: Eurocode 0: Basis of Structural Design

[12] EN 1991-1-1:2002 + AC:2009: Eurocode 1: Actions on Structures – Part 1-1: General actions – Densities, self-weight, imposed loads for building

[13] EN ISO 6988:1994: Metallic and other non-organic coatings – sulphur dioxide test with general condensation of moisture

[14] EOTA: ETAG 001, Annex A: Edition 1997, Amendment November 2006: Guideline for European technical approval of metal anchors for use in concrete, Annex A: Details of test

[15] EN 1998-1:2004 + AC:2009: Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings

[16] EN 772-1:2011: Methods of test for masonry units – Part 1: Determination of compressive strength

[17] EOTA: ETAG 001, Part 5: Edition 2002, Amendment November 2012: Guideline for European technical approval of metal anchors for use in concrete, Part 5: Bonded Anchors

[18] EOTA TR 034 "General Checklist for ETAGs/CUAPs/ETAs - Content and/or release of dangerous substances in products/kits”

European Organisation for Technical Approvals
Europäische Organisation für Technische Zulassungen
Organisation Européenne pour l'Agrément Technique

# ETAG 029

Edition April 2013

GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL

of

# METAL INJECTION ANCHORS FOR USE IN MASONRY

## Annex A: DETAILS OF TESTS



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## TABLE OF CONTENTS

## Introduction

If details are not given in the following, these details shall be taken from ETAG 001, Annex A: Edition 1997, Amendment November 2006 [14].

## A.1 Test samples

Samples shall be chosen to be representative of normal production as supplied by the manufacturer, including sleeve, threaded rod, deformed reinforced bar, internal threaded socket, or other shapes and the mortar.

Sometimes the tests are carried out with samples specially produced for the tests before issuing the European Technical Approval. If so, it shall be verified that the metal injection anchors subsequently produced conform in all respects, particularly suitability and bearing behaviour, with the anchors tested.

## A.2 Test members

### A.2.1 General

This ETAG applies to the use of injection anchors in masonry units of clay, calcium silicate, normal weight concrete, lightweight aggregate concrete, autoclaved aerated concrete (AAC) or other similar materials. The tests shall be performed in single units or in a wall. If tests are done in a wall, the thickness of the joints shall be about 10 mm and the joints shall be completely filled with mortar of strength class M2.5 with a strength $\leq$ 5 N/mm$^2$. If tests are performed with a mortar strength greater than M2.5 then the minimum mortar strength shall be given in the European Technical Approval. The units for test members of AAC may be glued together.

The walls may be lightly pre-stressed (about 0,2 N/mm$^2$ compressive pre-stressing) in the vertical direction to allow handling and transportation of the wall. The pre-stressing force should be applied in the quarter points of the wall in order to achieve a uniform distribution of stress in the wall.

If the tests are carried out in single units, the single units may also be lightly pre-stressed (about 0,2 N/mm$^2$ compressive pre-stressing).

### A.2.2 Test member for solid masonry material (use category b)

The unit shall have a compressive strength between 20 and 40 N/mm$^2$, unless where masonry units with a smaller compressive strength are given in the ETA, the test member shall then have the corresponding compressive strength.

All suitability tests and the tests according to this Guideline, Table 2.4.3, line 1 and 2 for admissible service conditions shall be performed with single injection anchors approximately in the centre of the unit under tension loading. The shear tests according to this Guideline, Table 2.4.3, line 3, shall be performed with single injection anchors approximately in the centre of the unit or in the wall under shear loading not influenced by edge effects. The tension tests according to this Guideline, Table 2.4.3, line 4 and the shear tests according to this Guideline, Table 2.4.3, line 5 shall be performed at the free edge of a unit (tests in units) or the wall (tests in a wall) with an edge distance $c=c_{min}$.

The determined characteristic resistance given in the European Technical Approval is valid only for the unit sizes which are used in the tests or for larger sizes.

### A.2.3 Test member for hollow or perforated bricks and hollow blocks (use category c)

Hollow or perforated bricks and hollow blocks shall be made of clay or calcium silicate, normal weight concrete or lightweight concrete. The location of the injection anchor with respect to the perforation shall be chosen such that the smallest anchor resistance can be expected.

The tension tests according to this Guideline, Table 2.4.3, line 4 and the shear tests according to this Guideline, Table 2.4.3, line 5 shall be performed at the free edge of a unit (tests in units) or the wall (tests in a wall) with an edge distance $c=c_{min}$.

The determined characteristic resistance given in the European Technical Approval is valid only for bricks and blocks which have been used in the tests regarding base material, size of the units, compressive strength and configuration of the voids.

### A.2.4 Test member for autoclaved aerated concrete (use category d)

A.2.4.1 Requirements for test specimens

At the time of testing the autoclaved aerated concrete (AAC) test specimens shall meet the following conditions:

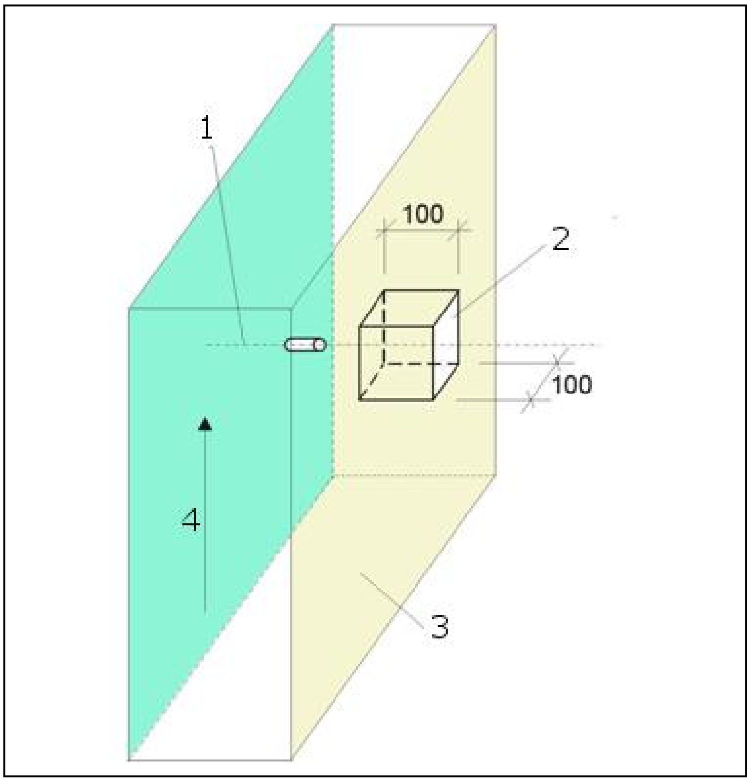
| | | |
|---|---|---|
| Low strength AAC | | |
| mean dry density | $\rho_m$ (kg/m³) | ≥ 350 |
| mean compressive strength | $f_{c,m}$ (N/mm²) | 1,8 to 2,8 |
| High strength AAC | | |
| mean dry density | $\rho_m$ (kg/m³) | ≥ 650 |
| mean compressive strength | $f_{c,m}$ (N/mm²) | 6,5 to 8,0 |

A.2.4.2 Definition of test specimens/samples

Test specimens: Testing of injection anchors is carried out on single units or walls with units mortared or glued together.

Samples: Samples (cubes/cylinders) are taken from the test specimen for determination of the material characteristics (see Figure A.2.4).
(cube: 100 x 100 x 100 mm); (cylinder: diameter 100 mm, height 100 mm)

The sample for determination of the material characteristic shall be taken from the same height as the position of the anchor relating to the direction of rise of the aerated concrete specimen, because the strength differs depending on the height of the direction of rise.




1. position of anchor
2. sample (cube)
3. test specimen
4. direction of rise

Dimensions in mm

**Figure A.2.4 – Taking of samples for autoclaved aerated concrete (AAC)**

A.2.4.3 Material characteristics

For determination of the material characteristics the following conditions apply:

Test specimens shall be taken from each batch (cycle of production) on delivery from the manufacturing plant and from each pallet on delivery from the retailer. Test specimens shall always be taken from series production. The direction of rise shall be discernible on the test specimen.

At the beginning of testing the test specimens shall be at least 4 weeks old. The moisture content of the concrete during the time of testing shall be $\leq$ 30 M% measured on the sample (cube/cylinder) or AAC block. The test specimens shall be stored in the test laboratory or under comparable conditions such that air can gain access on all sides. The clear distance between test specimens and from the floor shall be at least 50 mm.

Determination of the material characteristics (compressive strength, dry density) and moisture content is always carried out on the sample (cube/cylinder) or an AAC block. The characteristics shall be determined on at least 5 samples (cube/cylinder) or blocks. The compressive strength shall be determined as the mean value. Testing of the compressive strength is performed in the direction of metal injection anchor setting (see Figure A.2.4).

## A.3 Anchor installation

The injection anchors shall be installed in accordance with the installation instruction supplied by the manufacturer, unless explicitly required differently for a specific test. In tension and shear tests a torque shall not be applied to the anchor. Only in torque tests are the anchors torqued to failure. Torque shall be applied to the anchor by a torque wrench having traceable calibration. The measuring error shall not exceed 5 % of the applied torque throughout the whole measurement range.

For the installation safety tests special conditions are specified in this Guideline.

The holes for injection anchors shall be perpendicular to the surface of the member.

In the tests, the drilling tools and the type of drilling specified by the manufacturer shall be used. A drilling machine with a reasonable mass shall be used.

If hard metal hammer-drill bits are required, these bits shall meet the requirements of the standards (e.g. ISO 5468) with regard to dimensional accuracy, symmetry, symmetry of insert tip, height of tip and tolerance on concentricity. The diameter of the cutting edges as a function of the nominal drill bit diameter is given in Table A.3.1. In all tests (suitability tests and tests for admissible service conditions) the cylindrical hole is drilled with a medium diameter ($d_{cut,m}$) of the drill bit.

**Table A.3.1 – Cutting diameter of hard metal hammer-drill bits**

| Nominal drill bite diameter $d_0$ (mm) | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Size of test drill bit related to nominal drill bit diameter (mm) | +0,4<br>+0,15 | + 0,45<br>+ 0,2 | | + 0,5<br>+ 0,2 | | | | + 0,55<br>+ 0,2 | | | |
| Medium cutting diameter of drill bit $d_{cut,m}$ (mm) | 6,25 | 8,3 | 10,3 | 12,3 | 14,3 | 16,3 | 18,3 | 20,3 | 22,35 | 24,35 | 30,35 |

## A.4 Test equipment

Tests shall be carried out using measuring equipment having traceable calibration. The load application equipment shall be designed to avoid any sudden increase in load especially at the beginning of the test. The measuring error of the load shall not exceed 2 % throughout the whole measuring range.

Displacements shall be recorded continuously (e.g. by means of displacement electrical transducers) with a measuring error not greater than 0,02 mm.

For the tension tests, two test methods are distinguished: unconfined tests (see Figure A.4.1) and confined tests (see Figure A.4.2). Unconfined tests allow an unrestricted formation of the rupture cone of the base material. For this reason the clear distance between the support reaction and an injection anchor shall be at least 2 $h_{ef}$ (tension test) or 2 $c_1$ (shear tests with edge influence). In shear tests without edge influence where steel failure is expected, the clear distance may be less than 2 $c_1$. In confined tests, cone failure is eliminated by transferring the reaction force close to the anchor into the base material.

During tension tests (see A.5.2) the load shall be applied concentrically to the injection anchor. To achieve this, hinges shall be incorporated between the loading device and the injection anchor or between the loading device and fixture (tests with double anchor groups).

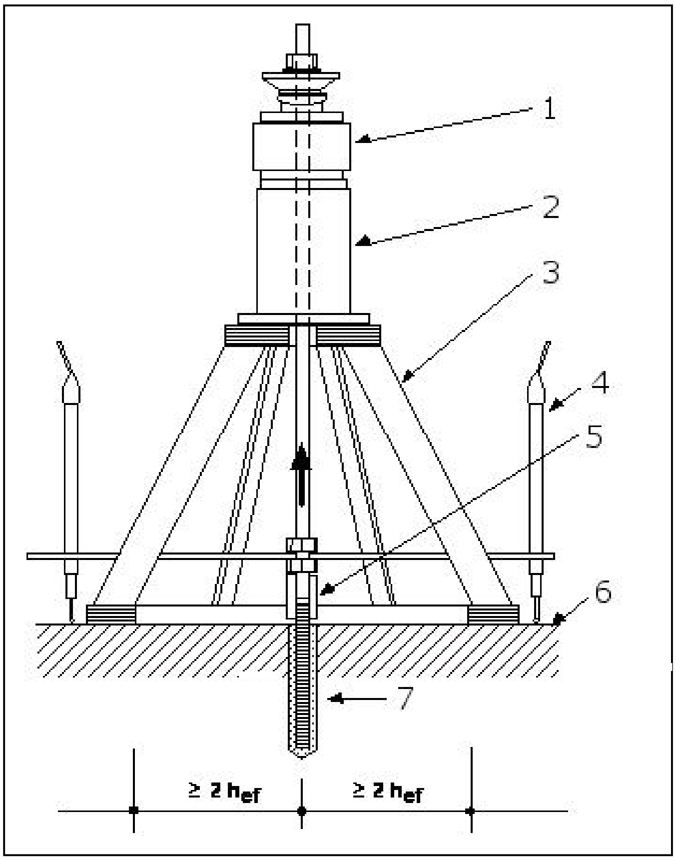
In shear tests (see A.5.4 and Figure A.4.3), the load shall be applied parallel to the surface of the base material. The height of the fixture shall be approximately equal to the outside diameter of the anchor. The diameter of the clearance hole in the fixture shall correspond to the sizes given in Table A.4.1. To reduce friction, smooth sheets (e.g. PTFE) with a maximum thickness of 2 mm shall be placed between the fixture and the test member.

During shear tests the load shall be applied such that pull out failure of the anchor or pry out failure is also covered. To achieve this, hinges shall be incorporated between the loading device and the fixture.

In torque tests the torque moment during installation until failure is measured. For this a calibrated torque moment transducer with a measuring error < 3 % throughout the whole measuring range shall be used.

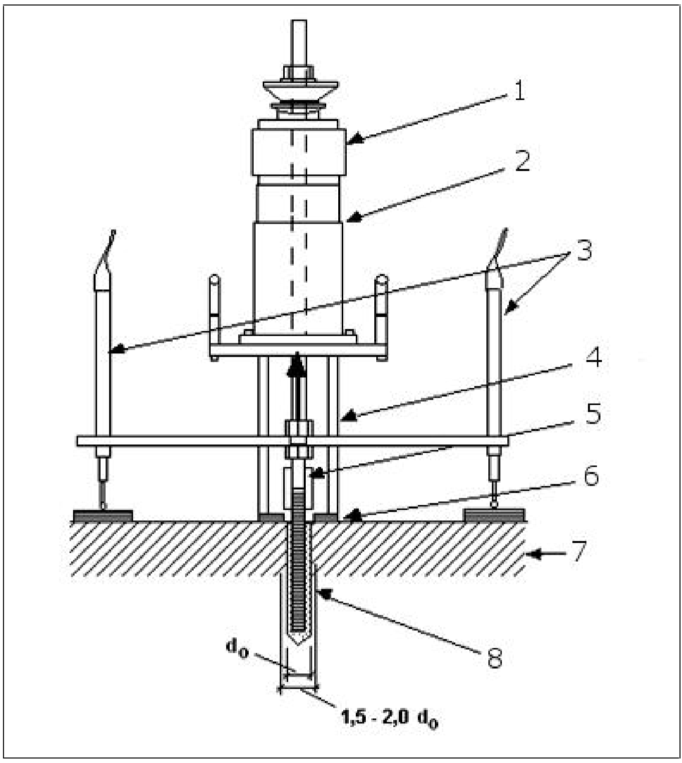
**Table A.4.1 – Diameter of clearance hole in the fixture**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| External diameter d or $d_{nom}$ (mm) | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 30 |
| Diameter of clearance hole in the fixture $d_f$ (mm) | 7 | 9 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 33 |



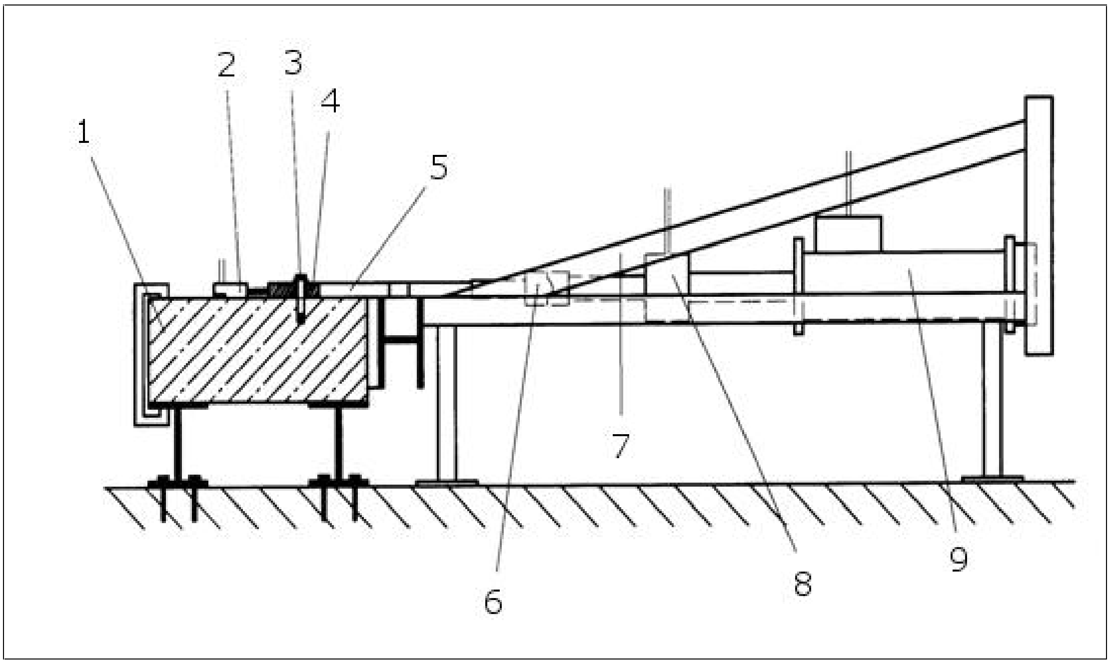

1 load cell
2 load cylinder
3 support
4 displacement transducer
5 socket
6 test member
7 injection anchor

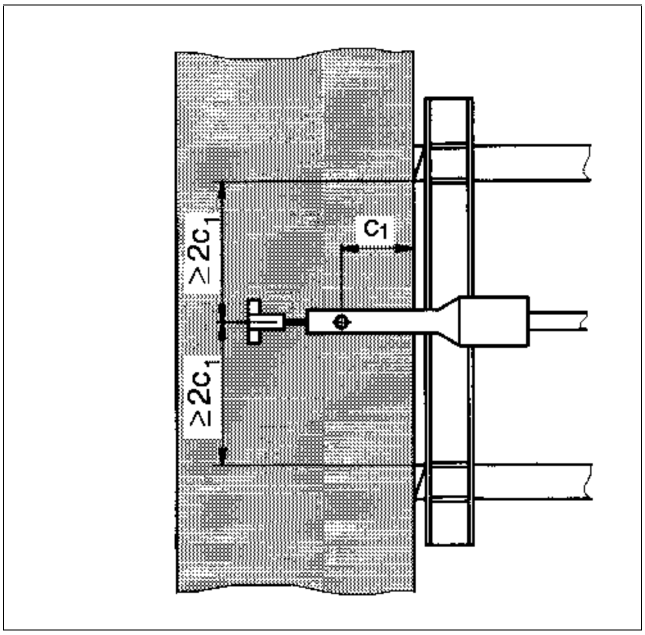
**Figure A.4.1 – Example of a tension test rig for unconfined tests**




1 load cell
2 load cylinder
3 displacement transducer
4 support
5 socket
6 steel plate
7 test member
8 injection anchor

**Figure A.4.2 – Example of a tension test rig for confined tests**




1 test member

2 displacement transducer

3 anchor

4 fixture

5 loading plate

6 universal joint

7 support

8 load cell

9 load cylinder

**Figure A.4.3 – Example of a shear test rig**

## A.5 Test procedure

### A.5.1 General

The injection anchors shall be installed in accordance with the installation instructions supplied by the manufacturer, except where deviations are specified in this Guideline. The drill holes shall be drilled using $d_{cut,m}$ drill bits. If the approval is to cover more than one drilling technique, then tests where drilling has an influence shall be carried out for all drilling techniques.

The tests for determination of **admissible service conditions** shall be carried out in the base material for which the injection anchor is intended to be used at normal ambient temperature (+21 °C $\pm$ 3 °C). The tests shall be carried out at the most unfavourable setting position in the brick of the hollow or perforated masonry, which give the lowest characteristic resistance of the anchor (exception: tests with minimum edge distance according to Table 2.4.3, line 4 of this Guideline). If the anchor is to be placed in the underside of a slab made of bricks, in the test the anchor shall be installed upwards in a vertical direction. The tests shall be carried out as unconfined tension tests.

The **reference tension tests** shall be carried out for determination of the results of the suitability tests. They have to be carried out with the same masonry units regarding base material, size of units and compressive strength as are used for the corresponding suitability tests. The tests shall be carried out as confined tension tests in the same way as the corresponding suitability tests.

The **suitability tests** shall be carried out in the base material according to 2.4.1.1. The anchors shall be installed according to the installation instructions of the manufacturer (except the installation safety tests, see A.5.4) in a horizontal direction in the centre of the brick. The tension tests shall be carried out as confined tension tests.

For all tests the load shall be increased in such a way that the peak load occurs after 1 to 3 minutes from commencement. Load and displacement shall be recorded either continuously or at least in about 100 intervals (up to peak load). The tests may be carried out with load or displacement control. In case of displacement control, the test shall be continued after the maximum load up to at least 75 % of the maximum load to be measured (to allow the drop of the displacement curve).

### A.5.2 Tension test

After installation, the injection anchor is connected to the test rig and loaded to failure. The displacements of the anchor relative to the surface of the test member shall be measured by use of either one displacement transducer on the socket of the test rig or at least two displacement transducers on either side (unconfined test: at a distance of $\geq 2{,}0\ h_{ef}$ from the anchor); the mean value shall be recorded in the latter case.

The anchors of an anchor group shall be connected by a rigid fixture. The tension load shall be applied centrally to the fixture. The connection between the fixture and the load jack shall be hinged to permit differential anchor displacement to occur.

When testing injection anchors at the free edge of a test member, the test rig shall be placed such that an unrestricted failure towards the edge is possible. It may be necessary to support the test rig outside the test member.

### A.5.3 Shear test

After installation, the injection anchor is connected to the test rig without gap between the anchor and the loading plate. The tension rod shall be attached to the fixture with a hinge. Then it is loaded to failure.

The displacements of the anchor relative to the base material shall be measured in the direction of the load application, for example by use of a displacement transducer fixed behind the injection anchor (seen from the direction of load application) on the base material.

When testing anchors at an edge, the test rig shall be arranged such that an unrestricted brick edge failure may occur.

### A.5.4 Installation in dry or wet substrate

**(a) Installation in dry substrate**

These tests have to be done for all use categories. Confined tension tests in dry solid bricks (dry conditions according to EN 772-1:2011, 7.3.2 [16].

Drill downwards to the depth required by the manufacturer.

Clean the hole with the hand pump and brush supplied by the manufacturer, using two blowing and one brushing operations in the order prescribed in the manufacturer's installation instructions. This test procedure is valid only if the manufacturer's installation instructions specify hole cleaning with at least four blowing and two brushing operations. If the instructions specify less than this, then the above requirement (2 blows + 1 brush) shall be reduced proportionately and the number of blows/brushes shall be lowered to the next whole number. Therefore where the manufacturer's installation instructions recommend two blowing and one brushing operations, the suitability tests shall be carried out without the brushing operation.

If precise instructions for hole cleaning are not provided by the manufacturer's installation instructions, then the tests are carried out without hole cleaning.

Install the embedded part in accordance with the manufacturer's installation instructions and carry out tension tests.

**(b) Installation in wet masonry**

These tests may be omitted for use category d/d (dry).

Confined tension tests in wet solid bricks.

Hole cleaning and installation according to A.5.4 (a). However the substrate in the area of anchorage shall be water saturated when the hole is drilled, cleaned and the embedded part is installed.

If bricks are put under water for one day (at least for 24 hrs) water saturated substrate will be achieved.

### A.5.5 Influence of temperature on characteristic resistances

**a) Effect of increased temperature**

The confined tension tests shall be carried out at the following temperatures for the different temperature ranges given in 2.3.2.3 of this Guideline:

*Temperature range **(Ta)** maximum short term temperature up to +40 °C:*

Tests are performed with the maximum short term temperature at +40 °C. The maximum long term temperature at approximately +24 °C is checked by the tests at normal ambient temperature.

*Temperature range **(Tb)** maximum short term temperature up to +80 °C:*

Tests are performed with the maximum short term temperature at +80 °C and with the maximum long term temperature at +50 °C.

*Temperature range **(Tc)** on manufacturer's request:*

Test are performed with the maximum short term temperature and the maximum long term temperature specified by the manufacturer within the range of 0,6 times to 1,0 times the maximum short term temperature and at temperatures between +21 °C and maximum short term temperature with an increment of ≤ 20 K.

Anchor size: medium diameter

*Test method:*

Install anchors at normal ambient temperature according to manufacturer's installation instructions.

Raise the test member temperature to the required test temperature at a rate of approximately 20 K per hour. Cure the test member at this temperature for 24 hours.

While maintaining the temperature of the test member in the area of the embedded part at a distance of 1d from the substrate surface at ± 2 K of the required value, carry out the confined tension test.

Number of tests: ≥ 5 tests per temperature.

**b) Effect of low installation temperature**

Anchor size: medium diameter

*Test method:*

Drill and clean the hole according to the manufacturer's installation instructions then cool the test member to the lowest installation ambient temperature specified by the manufacturer, and the bonding material and embedded part to the lowest anchor component installation temperature specified by the manufacturer. Install the anchor and maintain the temperature of the test member at the lowest installation ambient temperature for the curing time quoted by the manufacturer at that temperature.

Carry out confined tension tests at the end of the curing time while maintaining the temperature of the test member in the area of the embedded part at a distance of 1d from the substrate surface at the specified lowest installation temperature ± 2 K.

Number of tests: ≥ 5 tests

**c) Minimum curing time at normal ambient temperature**

Perform tension tests at normal ambient temperature at the corresponding minimum curing time specified by the manufacturer.

Number of tests: ≥ 5 tests

### A.5.6 Tests under repeated loading

The injection anchor is subjected to 1 x $10^5$ load cycles with a maximum frequency of approximately 6 Hz. During each cycle the load shall be varied as a sine curve between max N and min N according to equation (A.5.1) and (A.5.2). The displacements shall be measured during the first loading up to max N and either continuously or at least after 1, 10, 100, 1 000, 10 000 and 100 000 load cycles.

max N $= 0{,}4 \cdot N_{Ru,m}$ (A.5.1)

min N $= 0{,}2 \cdot N_{Ru,m}$ (A.5.2)

$N_{Ru.m}$ = mean ultimate load in the test series according to Table 2.4.3, line 2 of this Guideline.

After completion of the load cycles the anchor shall be unloaded, the displacement measured and a confined tension test performed.

### A.5.7 Tests under sustained loading

The test is performed at normal temperature (T= +21 °C ± 3 °C) for temperature range (Ta), (Tb) and (Tc) and at maximum long term temperature for temperature range (Tb) and (Tc) [T= +50 °C for temperature range b)].

The anchor shall be installed at normal temperature.

The anchor is then subjected to a tension load according to equation (A.5.3) which is kept constant (variation within ± 5 %). Maintain the load and temperature and measure the displacements until they appear to have stabilised, but at least for three months.

For the tests at the maximum long term temperature [temperature range (Tb) and (Tc)] the test specimens, the loading equipment, the displacement transducers and the installed anchors shall be heated to the maximum long term temperature at least for 24 hours before loading the anchors.

$N_P = 0{,}4 \cdot N_{Ru,m}$ (A.5.3)

$N_{Ru,m}$ = mean ultimate load in the test series according to Table 2.4.3, line 2 of this Guideline.

After completion of the sustained load test the anchor shall be unloaded, the displacement measured and immediately after unloading a confined tension test performed.

### A.5.8 Maximum torque moment

The torque moment shall be measured with a calibrated torque moment transducer. The torque moment shall be increased until failure of the injection anchor.

The maximum torque moment for use category **c** (use in hollow or perforated masonry) shall be carried out in hollow units. The tests shall be carried out at the most unfavourable setting position, which give the lowest failure torque moments.

The suitability tests for use categories **b** (use in solid masonry) shall be carried out in solid masonry and for use categories **d** (use in autoclaved aerated concrete masonry) shall be done in autoclaved aerated concrete.

### A.5.9 Functioning under freeze/thaw conditions

The tests are carried out for injection anchors with a service condition in wet substrate only. The tests are performed in freeze-thaw resistant member. The tests may also be carried out in freeze-thaw resistant concrete C50/60; in this case the corresponding reference tests are required in concrete under normal condition as well.

Cover the top surface of the test member with tap water to a depth of 12 mm, other exposed surfaces shall be sealed to prevent evaporation of water.

Load anchor to $N_p$ according to Equation (A.5.3).

Carry out 50 freeze/thaw cycles as follows:

- Raise the temperature of the chamber to +20 ± 2 °C within 1 hour, maintain the chamber temperature at +20 ± 2 °C for 7 hours.
- Lower the temperature of the chamber to -20 ± 2 °C within 2 hours, maintain the chamber temperature at -20 ± 2 °C for 14 hours (total of 16 hours).

If the test is interrupted, the samples shall always be stored at a temperature of -20 ± 2 °C between the cycles.

The displacements shall be measured during the temperature cycles.

After completion of 50 cycles, carry out a confined tension test at normal ambient temperature.

### A.5.10 Durability of the bonding material

With slice tests, the sensitivity of installed anchors to different environmental exposure can be shown.

The slice tests shall be carried out in concrete.

Test specimen:

The concrete compressive strength class shall be C20/25. The diameter or side length of the concrete specimen shall be equal to or exceed 150 mm. The test specimen may be manufactured from cubes or cylinders or may be cut from a larger slab. They can be cast; it is also allowed to diamond core concrete cylinders from slabs.

One anchor (medium diameter) to be installed per cylinder or cube on the central axis in dry concrete, drill bit $d_{cut,m}$, according to the manufacturer's installation instructions. The embedded part shall be made out of stainless steel.

After curing of the adhesive according to the manufacturer's instructions the concrete cylinders or cubes are carefully sawn into 30 mm thick slices with a diamond saw. The top slice shall be discarded.

To gain sufficient information from the slice tests, at least 30 slices are necessary (10 slices for every environmental exposure tests and 10 slices for the comparison tests under normal climate conditions).

Storage of the test specimen under environmental exposure:

The slices with adhesive anchors are subjected to water with high alkalinity and condensed water with sulphurous atmosphere. For comparison tests slices stored under normal climate conditions (dry / +21 °C ± 3 °C / relative humidity 50 ± 5 %) for 2 000 hours are necessary.

High alkalinity:

The slices are stored under standard climate conditions in a container filled with an alkaline fluid (pH = 12,5). All slices shall be completely covered for 2 000 hours. The alkaline fluid is produced by mixing water with KOH (potassium hydroxide) powder or tablets until the pH-value of 12,5 is reached. The alkalinity of pH = 12,5 shall be kept as close as possible to 12,5 during the storage and not fall below a value of 12,5. Therefore the pH-value shall be checked and monitored at regular intervals (at least daily).

Sulphurous atmosphere:

The tests in sulphurous atmosphere shall be performed according to EN ISO 6988:1994 [13]. The slices are put into the test chamber, however in contrast to EN ISO 6988:1994 [13] the theoretical sulphur dioxide concentration shall be 0,67 % at the beginning of a cycle. This theoretical sulphur dioxide concentration corresponds to 2 $dm^3$ of $SO_2$ for a test chamber volume of 300 $dm^3$. At least 80 cycles shall be carried out.

Slice tests:

After the storage time, the thickness of the slices is measured and the metal segments of the bonded anchors are pushed out of the slice, then the slice is placed centrally to the hole of the steel rig plate. If slices are unreinforced, splitting may be prevented by confinement. Care shall be taken to ensure that the loading punch acts centrally on the anchor rod.

The results of at least 10 tests shall be taken for every environmental exposure and for comparison; results with splitting failure shall be ignored.

## A.6 Test report

As a minimum requirement, the report shall include at least the following information:

**General**

- Description and type of injection anchor
- Anchor identification (dimensions, materials, coating, production method)
- Name and address of manufacturer
- Name and address of test laboratory
- Date of tests
- Name of person responsible for the tests
- Type of test (e.g. tension, shear, short-term or repeated load test)
- Number of tests
- Testing equipment: load cells, load cylinder, displacement transducer, software, hardware, data recording
- Test rigs, illustrated by sketches or photographs
- Particulars concerning support of the test rig on the test member

**Test members**

- Base material
- Dimensions of control specimens, and/or cores (if applicable) measured value of compressive strength at the time of testing (individual results and mean value)
- Dimensions of test member, for perforated units also the hole configuration
- Nature and positioning of any reinforcement (for AAC only)
- Direction of concrete pouring (for AAC only)

**Anchor installation**

- Information on the positioning of the injection anchor
- Distances of anchors from edges of test member
- Tools employed for anchor installation, e.g. impact drilling tool, drilling hammer, other equipment, e.g. torque wrench
- Type of drill bit, manufacturer’s mark and measured drill bit dimensions, particularly the effective diameter, $d_{cut}$, of the hard metal insert
- Information on the direction of drilling
- Information on cleaning of the hole
- Depth of drill hole
- Depth of anchorage
- Information on the direction of installation
- Installation time and testing time or other parameters for control of installation
- Type of attachment

**Measured values**

- Parameters of load application (e.g. rate of increase of load or size of load increase steps)
- Displacements measured as a function of the applied load
- Any special observations concerning application of the load
- Failure load
- Failure mode
- Radius (maximum radius, minimum radius) and height of a cone produced in the test (where applicable)
- Particulars of repeated load tests
  - minimum and maximum load
  - frequency of cycles
  - number of cycles
  - displacements as function of the number of cycles
- Particulars of sustained load tests
  - constant load on injection anchor and method of applying it
  - anchor displacement as a function of time
- Particulars of torque test
  - maximum torque moment at failure

The above measurements shall be recorded for each test.

- Particulars of identification tests
  - dimensions of the parts of the injection anchor and the drilling- and installation tools
  - properties (e.g. tensile strength, elastic limit, elongation at rupture)

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# ETAG 029

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**GUIDELINE FOR EUROPEAN TECHNICAL APPROVAL**

**of**

# METAL INJECTION ANCHORS FOR USE IN MASONRY

## Annex B (informative)

## RECOMMENDATIONS FOR TESTS TO BE CARRIED OUT ON CONSTRUCTION WORKS



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# ANNEX B (informative): RECOMMENDATIONS FOR TESTS TO BE CARRIED OUT ON CONSTRUCTION WORKS

## B.1. General

This annex is valid for injection anchors with a European Technical Approval only. The approval can cover injection anchors for use in solid masonry, hollow or perforated masonry and autoclaved aerated concrete masonry.

The characteristic resistances given in the approval for use in solid masonry are valid for the base material and the bricks which have been used in the tests or larger brick sizes and larger compressive strength of the masonry unit. The characteristic resistances given in the approval for use in hollow or perforated masonry are valid only for the bricks and blocks which have been used in the tests regarding base material, size of the units, compressive strength and configuration of the voids.

In the absence of national requirements, the characteristic resistance of the injection anchor may be determined by the following so-called "job site tests", if the injection anchor has an approval with characteristic values for the same type of base material (e.g. clay, calcium silicate, lightweight aggregate or autoclaved aerated concrete) as is present on the construction works. Furthermore, job site tests for use in solid masonry are possible only if the injection anchor has an approval for use in solid masonry and job site tests for use in hollow or perforated masonry are possible only if the injection anchor has an approval for use in hollow or perforated masonry.

This characteristic resistance to be applied to an injection anchor should be determined by means of at least 15 tests carried out on the construction work with a centric tension load acting on the injection anchor. These tests may also performed in a laboratory under equivalent conditions as used on construction work

Execution and evaluation of the tests as well as issue of the test report and determination of the characteristic resistance should be supervised by the person responsible for execution of works on site and be carried out by a competent person.

The number and position of the injection anchors to be tested should be adapted to the relevant special conditions of the construction work in question and, for example, in the case of blind and larger areas, be increased such that reliable information about the characteristic resistance of the injection anchor embedded in the base material in question can be derived. The tests should take account of the unfavourable conditions of practical execution.

## B.2. Assembly

The injection anchor to be tested should be installed (e.g. preparation of drill hole, drilling tool to be used, drill bit, type of drilling hammer or rotation, thickness of fixture) and as far as spacing and edge distances are concerned be distributed in the same way as foreseen for the intended use.

Depending on the drilling tool, hard metal hammer-drill bits or hard metal percussion drill bits according to ISO 5468:2006 [10] should be used.

The cleaning process of the drill hole should follow the manufacturer's installation instruction using the corresponding tools.

## B.3. Execution and evaluation of tests

### B.3.1 General

The characteristic resistance may be determined by pull-out tests according to B.3.2 or proof-load tests according to B.3.3. The characteristic resistance $F_{Rk1}$ or $F_{Rk2}$ has to be equal to or smaller than the characteristic resistance $F_{Rk}$ which is given in the approval for the same category of masonry (bricks or blocks).

The test rig used for the tests should allow a continuous slow increase of load recorded by calibrated measuring equipment.

The load should act perpendicular to the surface of the base material and be transmitted to the injection anchor via a hinge. The reaction forces should be transmitted to the base material such that possible breakout of the masonry is not restricted. This condition is considered as fulfilled if the support reaction forces are transmitted either in adjacent masonry units or at a distance of at least 150 mm from the injection anchors.

In absence of national regulations the partial safety factors for the resistance of the injection anchor may be taken as $\gamma_M = 2,5$ for use in masonry.

### B.3.2 Pull-out tests

#### B.3.2.1 Execution of pull-out tests

The load should be progressively increased so that the ultimate load is achieved after not less than about 1 minute. Recording of load is carried out when the ultimate load is achieved.

#### B.3.2.2 Evaluation of the results of the pull-out tests

If the number of pull-out tests is equal to or more than 15, the characteristic resistance $N_{Rk1}$ is obtained from the measured values of $N_1$ as follows:

$$N_{Rk1} = 0,5 \cdot N_1 \leq N_{Rk,ETA} \qquad \text{(B.3.1.a)}$$

with: $N_1$ = mean value of the five smallest measured values at the ultimate load

$N_{Rk,ETA}$ = characteristic resistance $N_{Rk}$ given in the ETA for the same category of masonry

If the number of pull-out tests is smaller than 15, the characteristic values are to be determined as a 5 % fractile taking into account the $\beta$ factor, given in the ETA for the base material under consideration.

Example with 10 tests:

$$N_{Rk1} = N_{Rm} \cdot (1 - 2,57 \cdot v) \cdot \beta \leq N_{Rk,ETA} \qquad \text{(B.3.1.b)}$$

with: $N_{Rm}$ = mean value of the ultimate load of the 10 tests

$v$ = coefficient of variation of the ultimate load

$\beta$ = factor to consider the different influences of the product, given in the ETA

The minimum number of pull-out tests is 5; with 5 tests the following equation has to be used:

Example with 5 tests:

$$N_{Rk1} = N_{Rm} \cdot (1 - 3,4 \cdot v) \cdot \beta \leq N_{Rk,ETA} \qquad \text{(B.3.1.c)}$$

For shear loads it can be assumed:

if $V_{Rk,ETA} \geq N_{Rk,ETA}$: $V_{Rk1} = N_{Rk1} \leq V_{Rk,c}$ according to C.5.2.2.5 (Annex C)

if $V_{Rk,ETA} < N_{Rk,ETA}$: $V_{Rk1} = N_{Rk1} \cdot (V_{Rk,ETA} / N_{Rk,ETA}) \leq V_{Rk,c}$ according to C.5.2.2.5 (Annex C)

### B.3.3 Proof-load tests

#### B.3.3.1 Execution of proof-load tests

The load should be progressively increased until the proof load $N_p$ is achieved.

$$N_p \geq 0{,}8 \cdot N_{Sd} \cdot \gamma_M \cdot 1/\beta \qquad \text{(B.3.2)}$$

$N_p$ = load $N_p$ for the proof load tests

$N_{Sd}$ = design value of action ($N_{Sk} \cdot \gamma_F$)

$\gamma_M$ = partial safety factors for the resistance ($\gamma_M$ = 2,5)

$\beta$ = factor to consider the different influences of the product; given in the ETA

#### B.3.3.2 Evaluation of the results of proof-load tests

If visible movement or displacement of the injection anchors does not occur in all tests under the proof-load, then an estimate for the characteristic resistance $N_{Rk2}$ may be obtained as follows:

$$N_{Rk2} = 1/0{,}8 \cdot N_p \cdot \beta \leq N_{Rk,ETA} \qquad \text{(B.3.3)}$$

$N_{Rk,ETA}$ = characteristic resistance $F_{Rk}$ given in the ETA for the same category of masonry

$N_p$ = see Equation (B.3.2)

$\beta$ = factor to consider the different influences of the product; given in the ETA

For shear loads it can be assumed:

if $V_{Rk,ETA} \geq N_{Rk,ETA}$: $V_{Rk2} = N_{Rk2} \leq V_{Rk,c}$ according to C.5.2.2.5 (Annex C)

if $V_{Rk,ETA} < N_{Rk,ETA}$: $V_{Rk2} = N_{Rk2} \cdot (V_{Rk,ETA} / N_{Rk,ETA}) \leq V_{Rk,c}$ according to C.5.2.2.5 (Annex C)

### B.4. Test report

The test report should include all information necessary to assess the resistance of the tested injection anchor. It should be given to the person responsible for the design of the fastening. The following information is necessary e.g.:

Name of product

Construction work

Building owner

Date and place of tests

Test rig

Type of structure to be fixed

Masonry (type of brick, strength class, all dimensions of bricks and mortar group if possible);
Visual assessment of masonry (flush joints, joint clearance, regularity);
Thickness of plaster layer or intervening layer (e.g. insulation), if existing

Injection anchors

Cutting diameter of hard metal hammer-drill bits

Type of used drill method (hammer drill, impact drill, core drill)

Cleaning process of the drill hole in detail

Results of tests including indication of value $N_1$ or $N_p$; mode of failure

Tests carried out or supervised by; Signature

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## METAL INJECTION ANCHORS FOR USE IN MASONRY

## Annex C : DESIGN METHODS FOR ANCHORAGES



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TABLE OF CONTENTS

## Introduction

The design method for anchorages is intended to be used for the design of anchorages under due consideration of the safety and design concept within the scope of the European Technical Approvals of injection anchors for use in masonry.

The design method given in Annex C is based on the assumption that the required tests for assessing the admissible service conditions given in this Guideline have been carried out. The use of other design methods will require reconsideration of the necessary tests.

The proof of local transmission of the anchor loads into the masonry units is delivered by using the design methods described in this document. Proof of transmission of anchor loads to the supports of the masonry members shall be done by the engineer of the construction works.

## C.1 Scope

### C.1.1 Type of anchors, anchor groups and number of anchors

The design method applies to the design of injection anchors in masonry units of clay, calcium silicate, normal weight concrete, light weight concrete, autoclaved aerated concrete (AAC) or other similar materials using anchors which fulfil the requirements of this Guideline. The characteristic values are given in the relevant approval.

The design method is valid for single anchors and anchor groups with two or four anchors. In an anchor group only anchors of the same type, size and length shall be used.

### C.1.2 Member

#### C.1.2.1 Solid and hollow or perforated masonry

The masonry member shall be of solid or hollow or perforated masonry units made of clay or calcium silicate, normal weight concrete or light weight concrete.

The detailed information of the corresponding base material is given in the approval, e.g. base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width).

#### C.1.2.2 Autoclaved aerated concrete

The autoclaved aerated concrete member shall be according to EN 771-4:2011 [2] or EN 12 602:2008 [3].

### C.1.3 Type and direction of load

This ETAG applies only to anchors subject to static or quasi-static actions in tension, shear or combined tension and shear or bending. The anchors may be used in areas with very low seismicity according to EN 1998-1:2004 + AC 2009 [15].

## C.2 Terminology and symbols

The explanations of the notations and symbols are given in the general part of the ETAG.

## C.3 Design and safety concept

### C.3.1 General

The design of anchorages shall be in accordance with the general rules given in EN 1990:2002 + A1:2005 / AC:2010 [11]. It shall be shown that the value of the design actions $S_d$ does not exceed the value of the design resistance $R_d$.

$$S_d \leq R_d \qquad \text{(C.3.1)}$$

$S_d$ = value of design action
$R_d$ = value of design resistance

**Actions** to be used in design may be obtained from national regulations or in the absence of them from the relevant parts of EN 1991:2002 + AC 2009 [12].

The partial safety factors for actions may be taken from national regulations or in the absence of them according to EN 1990:2002 + A1:2005 / AC:2010 [11].

The design **resistance** is calculated as follows:

$$R_d = R_k / \gamma_M \qquad \text{(C.3.2)}$$

$R_k$ = characteristic resistance of a single anchor or an anchor group
$\gamma_M$ = partial safety factor for material

### C.3.2 Ultimate limit state

#### C.3.2.1 Design resistance

The design resistance is calculated according to Equation (C.3.2).

#### C.3.2.2 Partial safety factors for resistances

In the absence of national regulations the following partial safety factors may be used:

##### C.3.2.2.1 Failure (rupture) of the metal part

Tension loading:

$$\gamma_{Ms} = \frac{1{,}2}{f_{yk} / f_{uk}} \geq 1{,}4 \qquad \text{(C.3.3a)}$$

Shear loading of the anchor with and without lever arm:

$$\gamma_{Ms} = \frac{1{,}0}{f_{yk} / f_{uk}} \geq 1{,}25 \qquad f_{uk} \leq 800 \text{ N/mm}^2 \text{ and } f_{yk}/f_{uk} \leq 0{,}8 \qquad \text{(C.3.3b)}$$

$$\gamma_{Ms} = 1{,}5 \qquad f_{uk} > 800 \text{ N/mm}^2 \text{ or } f_{yk}/f_{uk} > 0{,}8$$

##### C.3.2.2.2 Failure of the injection anchor

a) For use in masonry
$\gamma_{Mm} = 2{,}5$

b) For use in autoclaved aerated concrete
$\gamma_{MAAC} = 2{,}0$

### C.3.3 Serviceability limit state

In the serviceability limit state it shall be shown that the displacements occurring under the characteristic actions (see C.6) are not larger than the permissible displacements. The permissible displacements depend on the application in question and shall be evaluated by the designer.

In this check the partial safety factors on actions and on resistances may be assumed to be equal 1,0.

## C.4 Static analysis

### C.4.1 Loads acting on anchors

Distribution of loads acting on anchors shall be calculated according to the theory of elasticity.

For steel failure under tension and shear and for pull-out failure under tension the load acting on the highest loaded anchor shall be determined.

In case of brick edge failure the shear load is assumed to act on the anchor(s) closest to the edge.

### C.4.2 Shear loads with or without lever arm

Shear loads acting on an anchor may be assumed to act without lever arm if all of the following conditions are fulfilled:

1. The fixture shall be made of metal and in the area of the anchorage be fixed directly to the base material without an intermediate layer or with a levelling layer of mortar with a compressive strength $\geq 30$ N/mm$^2$ and a thickness $\leq d/2$.
2. The fixture is in contact with the anchor over a length of at least $0{,}5 \cdot t_{fix}$.
3. The diameter $d_f$ of the hole in the fixture is not greater than the values $d_f$ given in Table C.4.1.

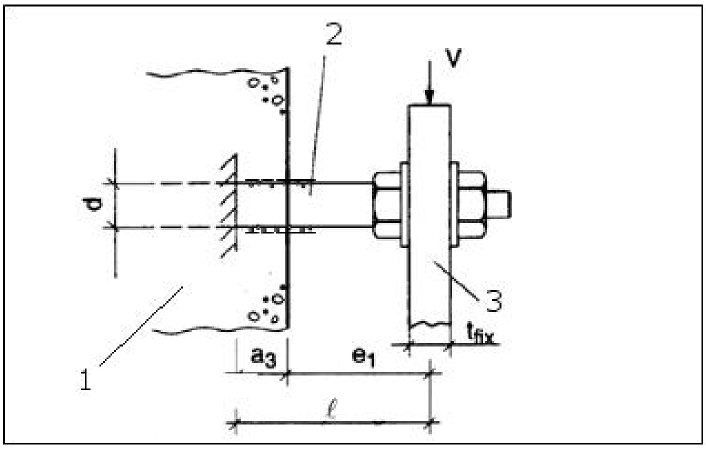
If these conditions are not fulfilled the lever arm is calculated according to Equation (C.4.1) (see Figure C.4.1).

$$l = a_3 + e_1 \qquad \text{(C.4.1)}$$

$e_1$ = distance between shear load and surface of the member
$a_3$ = $0{,}5 \cdot d$
d = diameter of the anchor bolt

**Table C.4.1 – Diameter of clearance hole in the fixture**

| Outside anchor bolt or thread diameter d or $d_{nom}$ (mm) | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of clearance hole in the fixture $d_f$ (mm) | 7 | 9 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 33 |




1 masonry
2 anchor bolt
3 fixture

**Figure C.4.1 – Definition of lever arm**

## C.5 Ultimate limit state

### C.5.1 General

For the design of anchorages in the ultimate limit state, there are two different design methods available. The general design method A is described in C.5.2 and a simplified design method B is given in C.5.3.

Spacing, edge distance as well as thickness of member shall not remain under the given minimum values in the approval.

### C.5.2 Design method A for use in masonry

In design method A it shall be shown that Equation (C.3.1) is observed for all loading directions (tension, shear) as well as all failure modes (steel failure, pull-out failure and brick failure).

In case of a combined tension and shear loading (oblique loading) the condition of interaction according to C.5.2.3 shall be observed.

#### C.5.2.1 Resistance to tension loads

##### C.5.2.1.1 Required proofs

| | | |
|---|---|---|
| Failure of the metal part | $N_{Sd}^{h} \leq N_{Rk,s} / \gamma_{Ms}$ | C.5.2.1.2 |
| Pull-out failure of the anchor | $N_{Sd}^{h} \leq N_{Rk,p} / \gamma_{Mm}$ | C.5.2.1.3 |
| Brick breakout failure | $N_{Sd} \leq N_{Rk,b} / \gamma_{Mm}$<br>$N_{Sd}^{g} \leq N_{Rk}^{g} / \gamma_{Mm}$ | C.5.2.1.4 |
| Pull out of one brick | $N_{Sd} \leq N_{Rk,pb} / \gamma_{Mm}$ | C.5.2.1.5 |
| Influence of joints | $N_{Sd} \leq \alpha_j N_{Rk,p} / \gamma_{Mm}$<br>$N_{Sd} \leq \alpha_j N_{Rk,b} / \gamma_{Mm}$ | C.5.2.1.6 |

For anchorages in AAC the partial safety factor $\gamma_{MAAC}$ is to be used instead of $\gamma_{Mm}$.

##### C.5.2.1.2 Failure of the metal part

The characteristic resistance of an anchor in case of failure of the metal part, $N_{Rk,s}$, is given in the relevant approval.

The value of $N_{Rk,s}$ is obtained from Equation (C.5.1)

$$N_{Rk,s} = A_s \cdot f_{uk} \quad [N] \qquad \text{(C.5.1)}$$

##### C.5.2.1.3 Pull-out failure of the anchor

The characteristic resistance in case of failure by pull-out of the anchor, $N_{Rk,p}$, shall be taken from the relevant approval.

#### C.5.2.1.4 Brick breakout failure

The characteristic resistance of one anchor in case of brick breakout failure $N_{Rk,b}$ and the corresponding values for spacing and edge distance $s_{cr,II}$, $s_{cr,\perp}$ and $c_{cr}$ or $c_{min}$ are given in the relevant approval.

The characteristic resistance of a group of two or four injection anchors $N_{Rk}^{g}$ and the corresponding values for spacing and edge distance $s_{min,II}$, $s_{min,\perp}$ and $c_{min}$ are given in the relevant approval. On the safe side the characteristic resistance of a group with spacing smaller than $s_{cr,II}$ and $s_{cr,\perp}$ can be assumed to be at least the characteristic resistance of a corresponding single anchor.

#### C.5.2.1.5 Pull out of one brick

The characteristic resistance of an anchor or a group of anchors in case of pull out of one brick, $N_{Rk,pb}$, is calculated as follows:

Vertical joints are designed <u>not</u> to be filled with mortar

$$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} \ (0{,}5 \cdot f_{vko} + 0{,}4 \cdot \sigma_d) \qquad \text{(C.5.2)}$$

Vertical joints are designed to be filled with mortar

$$N_{Rk,pb} = 2 \cdot l_{brick} \cdot b_{brick} \ (0{,}5 \cdot f_{vko} + 0{,}4 \cdot \sigma_d) + b_{brick} \cdot h_{brick} \cdot f_{vko} \qquad \text{(C.5.3)}$$

with:
$N_{Rk,pb}$ = characteristic resistance for pull out of one brick
$l_{brick}$ = length of the brick
$b_{brick}$ = breadth of the brick
$h_{brick}$ = height of the brick
$\sigma_d$ = design compressive stress perpendicular to the shear
$f_{vko}$ = initial shear strength according to EN 1996-1-1, Table 3.4

| **Brick type** | **Mortar strength** | **$f_{vko}$ [N/mm²]** |
|---|---|---|
| Clay brick | M2,5 to M9 | 0,2 |
| | M10 to M20 | 0,3 |
| All other types | M2,5 to M9 | 0,15 |
| | M10 to M20 | 0,2 |

#### C.5.2.1.6 Influence of joints

If the joints of the masonry <u>are not visible</u> the characteristic resistances $N_{Rk,p}$ and $N_{Rk,b}$ have to be reduced by the factor $\alpha_j = 0{,}75$.

If the joints of the masonry <u>are visible</u> (e.g. unplastered wall), the following has to be taken into account:

- The characteristic resistance $N_{Rk,p}$ and $N_{Rk,b}$ may be used only if the wall is designed such that the joints are to be <u>filled with mortar</u>.

- If the wall is designed such that the joints are <u>not to be filled with mortar</u> then the characteristic resistance $N_{Rk,p}$ and $N_{Rk,b}$ may be used only if the minimum edge distance $c_{min}$ to the vertical joints is observed. If this minimum edge distance $c_{min}$ cannot be observed then the characteristic resistance $N_{Rk,p}$ and $N_{Rk,b}$ has to be reduced by the factor $\alpha_j = 0{,}75$.

#### C.5.2.2 Resistance to shear loads

##### C.5.2.2.1 Required proofs

| | | |
|---|---|---|
| Failure of the metal part, shear load without lever arm | $V_{Sd}^{h} \leq V_{Rk,s} / \gamma_{Ms}$ | C.5.2.2.2 |
| Failure of the metal part, shear load with lever arm | $V_{Sd}^{h} \leq V_{Rk,s} / \gamma_{Ms}$ | C.5.2.2.3 |
| Local brick failure | $V_{Sd} \leq V_{Rk,b} / \gamma_{Mm}$<br>$V_{Sd}^{g} \leq V_{Rk}^{g} / \gamma_{Mm}$ | C.5.2.2.4 |
| Brick edge failure | $V_{Sd} \leq V_{Rk,c} / \gamma_{Mm}$<br>$V_{Sd}^{g} \leq V_{Rk}^{g} / \gamma_{Mm}$ | C.5.2.2.5 |
| Pushing out of one brick | $V_{Sd} \leq V_{Rk,pb} / \gamma_{Mm}$ | C.5.2.2.6 |
| Influence of joints | $V_{Sd} \leq \alpha_j V_{Rk,b} / \gamma_{Mm}$<br>$V_{Sd} \leq \alpha_j V_{Rk,c} / \gamma_{Mm}$ | C.5.2.2.7 |

For anchorages in AAC the partial safety factor $\gamma_{MAAC}$ is to be used instead of $\gamma_{Mm}$.

##### C.5.2.2.2 Failure of the metal part, shear load without lever arm

The characteristic resistance of an anchor in case of failure of the metal part due to shear load without lever arm $V_{Rk,s}$ shall be taken from the relevant approval.

In case of no characteristic resistance is given in the ETA, the following equations may be applied.

$$V_{Rk,s} = 0{,}5 \cdot A_s \cdot f_{uk} \quad [N] \qquad (C.5.4)$$

##### C.5.2.2.3 Failure of the metal part, shear load with lever arm

The characteristic resistance of an anchor in case of failure of the metal part due to shear load with lever arm $V_{Rk,s}$ is given by Equation (C.5.5).

$$V_{Rk,s} = \frac{M_{Rk,s}}{\ell} \quad [N] \qquad (C.5.5)$$

$\ell$ lever arm according to Equation (C.4.1)
$M_{Rk,s}$ to be taken from the relevant approval

##### C.5.2.2.4 Local brick failure

The characteristic resistance of one anchor in case of local brick failure $V_{Rk,b}$ and the corresponding values for spacing and edge distance $s_{cr,II}$, $s_{cr,\perp}$ and $c_{cr}$ or $c_{min}$ are given in the relevant approval.

The characteristic resistance of a group of two or four injection anchors $V_{Rk}^{g}$ and the corresponding values for spacing and edge distance $s_{min,II}$, $s_{min,\perp}$ and $c_{min}$ are given in the relevant approval. On the safe side the characteristic resistance of a group with spacing smaller than $s_{cr,II}$ and $s_{cr,\perp}$ can be assumed to be at least the characteristic resistance of a corresponding single anchor.

#### C.5.2.2.5 Brick edge failure

The characteristic resistance for an anchor in the case of brick edge failure $V_{Rk,c}$ and the corresponding values for spacing and edge distance $s_{min,II}$, $s_{min,\perp}$ and $c_{min}$ are given in the relevant ETA.

In case no characteristic resistance is given in the ETA, the following equations may be applied.

For anchorages in solid masonry and AAC the following determination may be used:

$$V_{Rk,c} = k \cdot \sqrt{d_{nom}} \cdot (h_{nom} / d_{nom})^{0,2} \cdot \sqrt{f_b} \cdot c_1^{1,5} \quad [N] \qquad (C.5.6)$$

with:

- $k$ = 0,25 if load direction is to the free edge
  = 0,45 if load direction is parallel to the free edge
- $c_1$ = edge distance closest to the edge in mm
  $c_1 \geq c_{min}$
  If the load is directed to the free edge and the wall is not designed such that the joints are filled with mortar (so no load transfer to other units in the wall is given) then the following conditions shall be fulfilled:
  $c_1 \leq h / 1,5$
  $c_1 \leq h_{brick} / 3$
- $d_{nom}$ outside diameter of the anchor in mm
- $h_{nom}$ overall anchor embedment depth in mm
- $f_b$ normalized mean compressive strength of masonry unit in $N/mm^2$

For anchorages in hollow or perforated masonry the following values correspond to current experience and no further determination is required:

$V_{Rk,c,II}$ = 2,50 kN if load direction is parallel to the free edge with $c_{min} \geq 100$ mm $\geq 6\ d_0$ and
if load direction is to the free edge with $c_{min} \geq 250$ mm
$V_{Rk,c,\perp}$ = 1,25 kN if load direction is to the free edge with $c_{min} \geq 100$ mm
Intermediate values can be interpolated

The characteristic resistance of a group of two or four injection anchors $V^{g}_{Rk,c}$ and the corresponding values for spacing and edge distance $s_{cr,II}$, $s_{cr,\perp}$ and $c_{cr}$ or $c_{min}$ are given in the relevant approval. On the safe side the characteristic resistance of a group with spacing smaller than $s_{cr,II}$ and $s_{cr,\perp}$ can be assumed to be at least the characteristic resistance of a corresponding single anchor.

#### C.5.2.2.6 Pushing out of one brick

The characteristic resistance of an anchor or a group of anchors in case of pushing out of one brick on the free edge of a wall, $V_{Rk,pb}$, is calculated as follows:

$$V_{Rk,pb} = (2 \cdot l_{brick} \cdot b_{brick}) \cdot (0,5 \cdot f_{vko} + 0,4 \cdot \sigma_d) \qquad (C.5.7)$$

with:

- $V_{Rk,pb}$ = characteristic resistance for pushing out of one brick
- $l_{brick}$ = length of the brick
- $b_{brick}$ = breadth of the brick
- $\sigma_d$ = design compressive stress perpendicular to the shear
- $f_{vko}$ = initial shear strength according to EN 1996-1-1, Table 3.4

| Brick type | Mortar strength | $f_{vko}$ [$N/mm^2$] |
|---|---|---|
| Clay brick | M2,5 to M9 | 0,2 |
| | M10 to M20 | 0,3 |
| All other types | M2,5 to M9 | 0,15 |
| | M10 to M20 | 0,2 |

#### C.5.2.2.7 Influence of joints

If the joints of the masonry with a designed thickness of 2 mm to 5 mm are not visible the characteristic resistances $V_{Rk,b}$ have to be reduced by the factor $\alpha_j = 0{,}75$. Joints with a designed thickness > 5 mm have to be designed such as a free edge.

If the joints of the masonry are visible (e.g. unplastered wall), the following has to be taken into account:
- The characteristic resistance $V_{Rk,b}$ and $V_{Rk,c}$ may be used only if the wall is designed such that the joints are to be filled with mortar.
- Joints which are not be filled with mortar have to be designed such as a free edge.

### C.5.2.3 Resistance to combined tension and shear loads

For combined tension and shear loads the following equations shall be satisfied:

$$\beta_N \leq 1{,}0 \quad \text{(C.5.8.a)}$$
$$\beta_V \leq 1{,}0 \quad \text{(C.5.8.b)}$$
$$\beta_N + \beta_V \leq 1{,}2 \quad \text{for solid masonry} \quad \text{(C.5.8.c)}$$
$$\beta_N + \beta_V \leq 1{,}0 \quad \text{for perforated or hollow masonry} \quad \text{(C.5.8.d)}$$

With $\beta_N$ ($\beta_V$) = ratio between design action and design resistance for tension (shear) loading. In Equation (C.5.7) the largest value of $\beta_N$ and $\beta_V$ for the different failure modes shall be taken (see C.5.2.1.1 and C.5.2.2.1).

### C.5.3 Design method B for use in masonry

Design method B is based on a simplified approach in which only one value for the design resistance $F_{Rd}$ is given, independent of loading direction and mode of failure. The design resistance $F_{Rd}$ is calculated by the lowest value under consideration of the characteristic resistances and the corresponding partial safety factors. The actual spacing and edge distance shall be equal to or larger than the values of $s_{cr}$ and $c_{cr}$. $F_{Rd}$, $s_{cr}$ and $c_{cr}$ are given in the relevant approval.

In case of shear load with lever arm the characteristic anchor resistance shall be calculated according to Equation (C.5.5). The smallest value of $F_{Rd}$ or $V_{Rk,s} / \gamma_{Ms}$ according to Equation (C.5.5) governs.

The characteristic resistance of an anchor or a group of anchors in case of pull-out or push out of one brick and the influence of joints shall be considered according to C.5.2.1.5, C.5.2.1.6, C.5.2.2.6 and C.5.2.2.7 in every application.

## C.6 Serviceability limit state

### C.6.1 Displacements

The characteristic displacement of the anchor under defined tension and shear loads shall be taken from the approval. It may be assumed that the displacements are a linear function of the applied load. In case of a combined tension and shear load, the displacements for the tension and shear component of the resultant load shall be geometrically added.

In case of shear loads the influence of the hole clearance in the fixture on the expected displacement of the whole anchorage shall be taken into account.

### C.6.2 Shear load with changing sign

If the shear loads acting on the anchor change their sign several times, appropriate measures shall be taken to avoid a fatigue failure of the anchor (e.g. the shear load shall be transferred by friction between the fixture and the base material (e.g. due to a sufficiently high permanent pre-stressing force).

Shear loads with changing sign can occur due to temperature variations in the fastened member (e.g. facade elements). Therefore, either these members are anchored such that no significant shear loads due to the restraint of deformations imposed to the fastened element will occur in the anchor or in shear loading with lever arm the bending stresses in the most stressed anchor $\Delta\sigma = \max\sigma - \min\sigma$ in the serviceability limit state caused by temperature variations shall be limited to 100 N/mm$^2$ for steel.