EAD **330076-01-0604**

www.eota.eu

May 2021

European Assessment Document for

Metal injection anchors for use in masonry

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

Post-installed metal injection anchors are placed into pre-drilled holes in masonry and anchored by bonding and mechanical interlock.

Injection anchors consist of a threaded rod, deformed reinforced bar, internal threaded socket, or other shapes (in the following also called inserts) and the mortar, placed into drilled holes perpendicular to the surface (maximum deviation 5°) in masonry and anchored by bonding the metal anchoring element to the sides of the drilled hole by means of mortar and by mechanical interlock (see Figure 1.1.1). Mesh sleeves made of metal or plastic are also covered in this EAD as part of the anchoring system (see Figure 1.1.3).

All the metal anchoring elements directly anchored in the masonry and designed to transmit the applied loads are made either of carbon steel, stainless-steel or malleable cast iron (in the following also called steel).

The EAD applies also for threaded rods supplied by a party other than the manufacturer of the bonding material (commercial rods), if the material properties defined in the ETA are kept.

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

This EAD applies to anchors with a minimum thread size of 6 mm (M6).

The minimum embedment depth of the anchor min h_{ef} is 50 mm. This EAD applies to applications where the minimum thickness of the masonry members in which injection anchors are installed is $h_{min,mas} = h_{ef} + 30$ mm (at least $h_{min,mas} = 80$ mm). The maximum embedment depth is max $h_{ef} = h_{min,mas} - 30$ mm.

The minimum thickness of prefabricated reinforced components of autoclaved aerated concrete is $h_{min,AAC} \geq 2\ h_{ef}$ but at least 100 mm.

This EAD covers anchors with an internal thread with a thread length of at least d + 5 mm.

The product is not covered by a harmonised European standard (hEN).

The product is not fully covered by the following harmonised technical specification: EAD 330076-00-0604[1] [1]. Compared to the previous version of the EAD, the following changes are introduced:

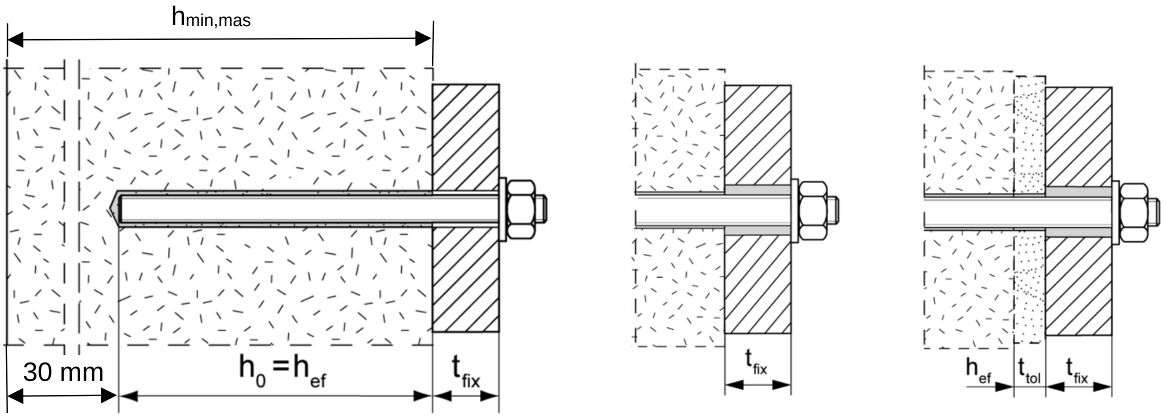
- Extension of the intended use and assessment of the anchor performance for installation under freezing conditions in section 2.2.2.
- Extension of the intended use and assessment of the anchor performance in cracked and non-cracked prefabricated reinforced components of autoclaved aerated concrete according to EN 12602 [6].
- Consideration of EN 1993-1-4 [20] for durability of anchors made of stainless-steel.
- Resistances under fire exposure in section 2.2.13.
- Resistance under seismic actions in section 2.2.9 to 2.2.11.

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

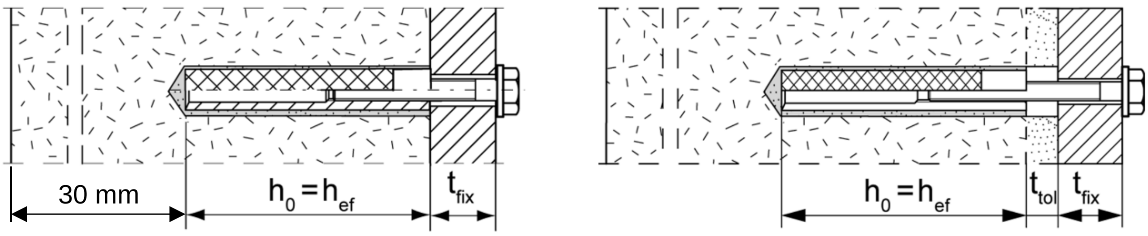
It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

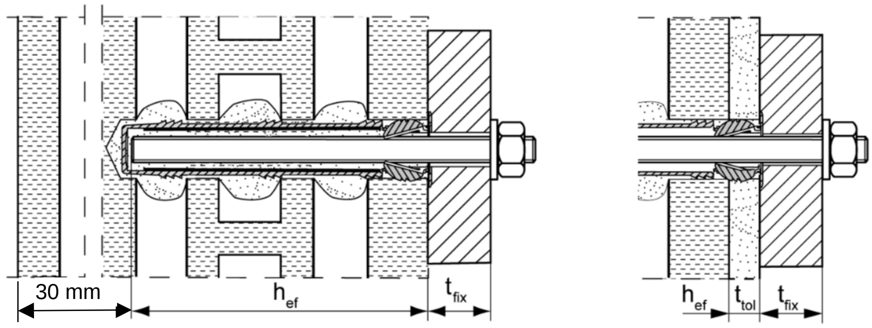
1 All undated references to standards or to EADs in this EAD are to be understood as references to the dated versions listed in chapter 4.



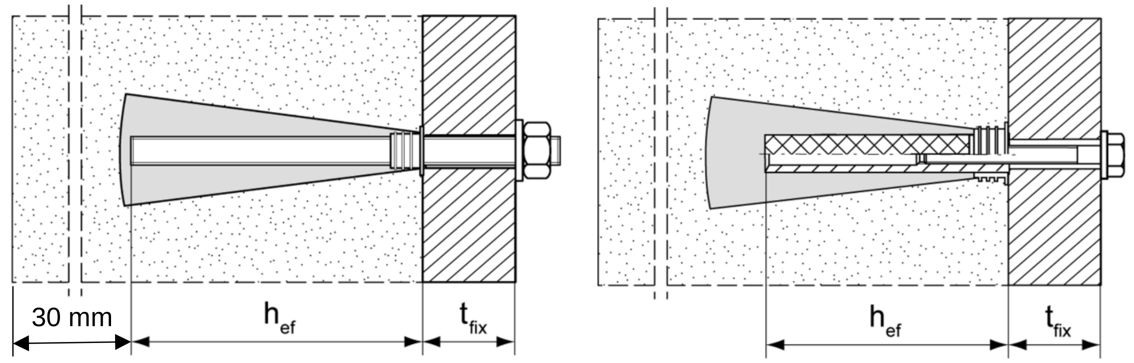
Injection anchor (threaded rod) in solid brick



Injection anchor (internal threaded socket in solid brick)



Injection anchor in hollow brick



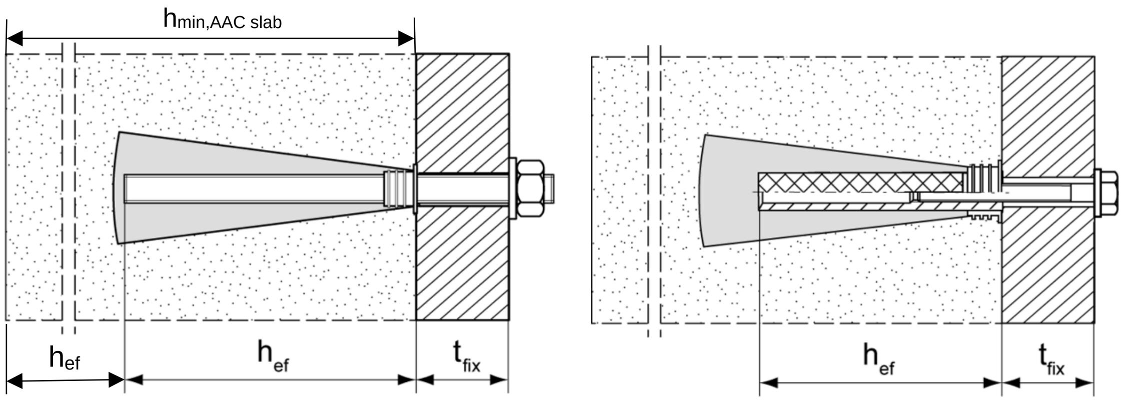
Injection anchor in autoclaved aerated concrete masonry

h_{ef} = effective embedment depth (min h_{ef} = 50 mm, max h_{ef} = $h_{min,mas}$ -30 mm)

$h_{min,mas}$ = minimum thickness of masonry member

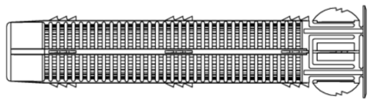
h_0 = depth of drill hole t_{fix} = thickness of fixture t_{tol} = possible tolerance layer

Figure 1.1.1: Examples of injection anchors in different brick types of masonry

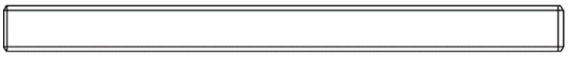


h_{ef} = effective embedment depth (min h_{ef} = 50 mm)
$h_{min,AAC\ slab}$ = minimum thickness of autoclaved aerated concrete slabs
t_{fix} = thickness of fixture

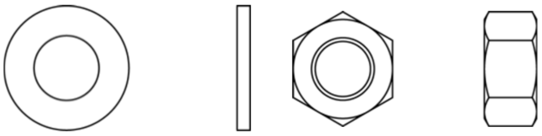
Figure 1.1.2: Examples of injection anchors in autoclaved aerated concrete slabs



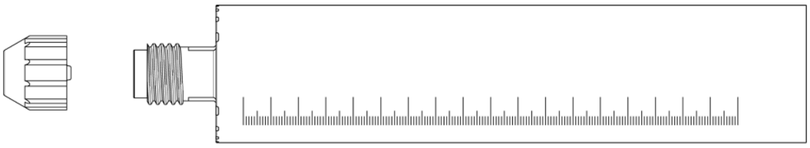
Sieve sleeve



Threaded rod

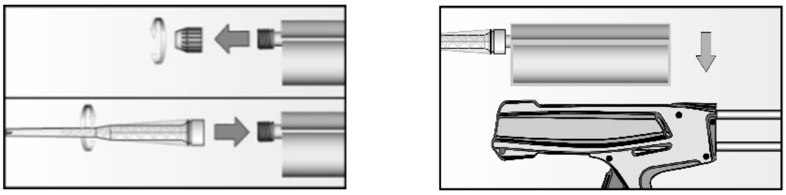


Washer and nut



Injection cartridge

Static mixer with injection adapter and centring sleeve



Preparation for injection

Figure 1.1.3: Examples of components of injection anchors and installation tools

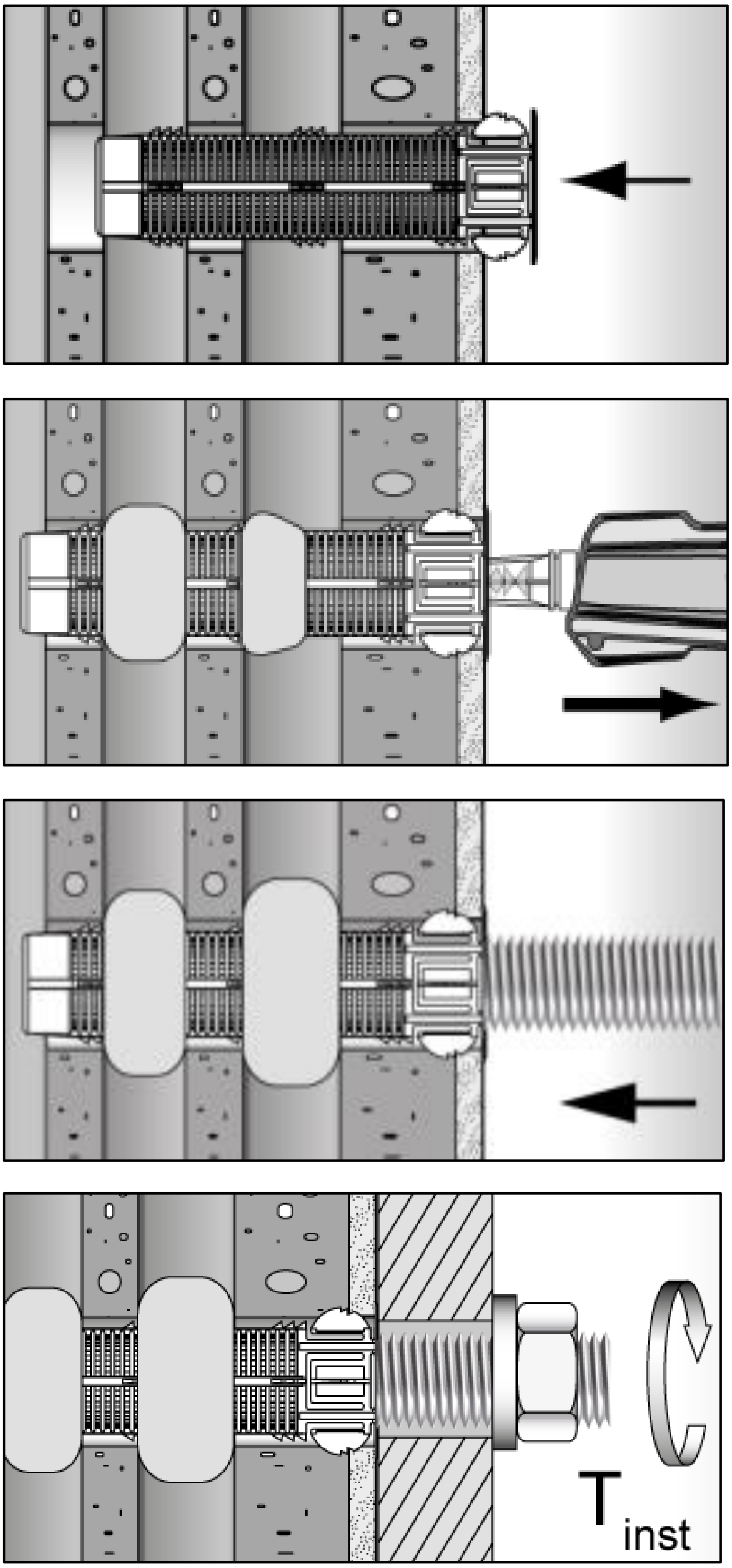


Figure 1.1.4: Example of installation of injection anchors (T_{inst} = installation torque)

1.2 Information on the intended use of the construction product

1.2.1 Intended use

The injection anchors are intended to be used in masonry units of clay, calcium silicate, normal weight concrete and lightweight aggregate concrete (solid and hollow or perforated format blocks), autoclaved aerated concrete (AAC) or other similar materials. The injection anchor may also be used in joints of masonry.

As far as the specification of the different masonry units is concerned, EN 771-1 to 5 [2] may be taken as reference. The construction of masonry structures in which the injection anchors are to be applied shall be comparable with the structural rules for masonry, such as EN 1996-1-1 [5], Clause 5 and 10.

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.

The base materials are subdivided into the following groups:

Base material Group **b**: Metal injection anchors for use in **solid masonry** (this group 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)

Base material Group **c**: Metal injection anchors for use in **hollow or perforated masonry**

Base material Group **d**: Metal injection anchors for use in **autoclaved aerated concrete** (AAC) **masonry**

The injection anchors are also intended to be used in cracked and non-cracked prefabricated reinforced components of autoclaved aerated concrete according to EN 12602 [6] (slabs). The width of the components is ≤ 700 mm. Injection anchors are intended to be used in AAC-slabs where the design value of shear stresses in the member caused by the fastening are less or equal to 40% of the design values of resistance of the member in the critical cross section.

Following use conditions in respect of installation and use are differentiated:

Condition **d/d:** **Installation** in **dry** base material **and use** in structures subject to **dry**, internal conditions,

Condition **w/d:** **Installation in** dry or **wet** base material and **use** in structures subject to **dry**, internal conditions,

Condition **w/w:** **Installation** in dry or **wet** base material **and use** in structures subject to dry or **wet** environmental conditions.

This EAD covers a range of temperature during installation and curing of the bonding material in the base material between minimum installation temperature not lower than -40 °C and the maximum installation temperature not higher than +40°C.

If the product is intended for the installation under freezing conditions, these can be further detailed either as standard variation of temperature or rapid variation of temperature after installation. Standard variation temperature is defined as temperature variation which occurs in a period longer than a 12-hour period from a low temperature less than 0 °C to a high temperature of +24 °C or more, while rapid variation temperature is defined as temperature variation within a 12-hour period from a low temperature less than 0 °C to a high temperature of +24 °C or more.

This EAD covers service temperature ranges of the base material (anchorage base) during the working life as:

Temperature range **Ta:** - 40 °C to + 40 °C
(maximum short-term temperature + 40 °C and
maximum long-term temperature + 24 °C)

Temperature range **Tb:** - 40 °C to + 80 °C
(maximum short-term temperature + 80 °C and
maximum long-term temperature + 50 °C)

Temperature range **Tc:** possible other or additional temperature range from -40°C to +T1 depending on the product is intended for
(maximum short-term: T1 > + 40 °C and
maximum long-term: 0,6 T1 to 1,0 T1)

The product is intended for base materials and their installation conditions defined as follows:

- masonry material (clay, calcium silicate, normal weight concrete, lightweight aggregate concrete, autoclaved aerated concrete or other similar materials),
- the specific masonry units including size of units, geometry of holes, webs and shells,
- for masonry units according to EN 771-1 to EN 771-5 [2]: mean gross dry density according to EN 772-13 [14] and normalised mean compressive strength of the masonry unit and mean compressive strength according to EN 772-1 [3],
- for AAC slabs according to EN 12602 [6]: mean dry density and characteristic compressive strength,
- for joints unfilled with mortar: joint width,
- for joints filled with mortar according to EN 998-2 [9]: mortar class, joint width,
- consideration of plaster or similar materials,
- setting position (wall side or reveal, distance to joints).

The anchors are intended to be subject to

> static or quasi-static actions in tension, shear or combined tension and shear or bending or seismic actions in tension, shear or combined tension and shear but not to bending.

The anchors are intended to be used in areas with no or very low seismicity or seismicity above "very low" as defined in EN 1998-1, Clause 3.2.1 [11]. This EAD covers applications where the masonry members in which the anchors are embedded are subject to static or quasi-static actions or seismic actions.

The behaviour of anchors in regions of masonry structures, where large deformations and large cracks are expected (e.g., along the diagonals of shear walls) is not covered in the assessment of this EAD the assessment of anchors under seismic actions; anchors shall be placed outside of these regions.

This EAD covers applications where the masonry members from base material groups b and d, in which the anchors are embedded, are subject to seismic actions.

Steel parts with coatings for protection against corrosion during storage before use (zinc coating with a minimum thickness of 5 microns) are intended to be used in structures subject to dry internal conditions.

The intended use regarding other environmental conditions of the anchor made of stainless-steel results from its corrosion resistance class (CRC) according to EN 1993-1-4 [20], Table A.3 in connection with EN 1993-1-4 [20], Table A.2 and A.1.

The metal injection anchor is intended to be used with requirements related to resistance to fire (only for masonry subject to dry internal conditions).

This EAD is intended to provide characteristic resistances and other essential characteristics needed as inputs for design processes (calculations) according to TR 054 [12].

The characteristic resistance for normalised solid bricks and autoclaved aerated concrete are also valid for larger brick sizes and larger compressive strength of the masonry unit.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the metal injection anchor for use in masonry for the intended use of 50 years when installed in the works (provided that the metal injection anchor for use in masonry is subject to appropriate installation (see 1.1)). These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

---

2 The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

1.3 Specific terms used in this EAD

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
AAC	=	autoclaved aerated concrete
MPII	=	Manufacturer's Product Installation Instruction

Anchors

The notations and symbols frequently used in this EAD 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), see also Figure 1.3.1
c_{cr}	=	characteristic edge distance for ensuring the transmission of the characteristic resistance of a single injection anchor
c_{min}	=	minimum edge distance
$c_{min,test}$	=	minimum edge distance in tests
$c_{min,fi}$	=	minimum edge distance for fire resistance
$c_{min,test,fi}$	=	minimum edge distance for fire resistance in tests
d	=	anchor bolt/thread diameter
d_0	=	nominal drill hole diameter
d_{cut}	=	drill bit diameter
$d_{cut,m}$	=	medium of drill bit diameter
d_f	=	diameter of clearance hole of the fixture
d_{nom}	=	outside diameter of anchor
h	=	thickness of masonry member (wall)
h_{min}	=	minimum thickness of masonry member in which the anchor is installed
h_{ef}	=	effective embedment depth
h_{nom}	=	overall anchor embedment depth in the masonry
h_{unit}	=	height of the masonry unit
l_{unit}	=	length of the masonry unit
s	=	spacing of the injection anchor
s_{cr}	=	characteristic spacing for ensuring the transmission of the characteristic resistance of a single injection anchor
$s_{cr,II}$	=	s_{cr} parallel to the horizontal joint, see also Figure 1.3.1
$s_{cr,\perp}$	=	s_{cr} perpendicular to the horizontal joint, see also Figure 1.3.1
s_{min}	=	minimum spacing
$s_{min,test}$	=	minimum spacing in tests
$s_{min,II}$	=	minimum spacing parallel to the horizontal joint, see also Figure 1.3.1
$s_{min,\perp}$	=	minimum spacing perpendicular to the horizontal joint, see also Figure 1.3.1
$s_{min,fi}$	=	minimum spacing for fire resistance
$s_{min,test,fi}$	=	minimum spacing for fire resistance in tests
T	=	torque moment
max T_{inst}	=	maximum torque moment for fixing the attachment
T_u	=	maximum torque moment during failure (ultimate torque)
t	=	thickness of outer web of the brick

Base materials (masonry) and metal parts of anchor

ρ	=	bulk density of masonry unit
f_b	=	normalised mean compressive strength of masonry unit (according to EN 772-1 [3])
$f_{b,test}$	=	normalised mean compressive strength of the test masonry unit (according to EN 772-1 [3]) at the time of testing
f_m	=	nominal compressive strength of masonry mortar (according to EN 998-2 [6]) given in the ETA
$f_{m,test}$	=	mean compressive strength of the masonry mortar (according to EN 1015-11 [30]) at the time of testing
$f_{u,test}$	=	ultimate mean steel strength of tested metal part
f_{uk}	=	characteristic ultimate strength of the metal part

Loads / Forces

F	=	force in general
N	=	normal force (+N = tension force)
V	=	shear force
M	=	moment

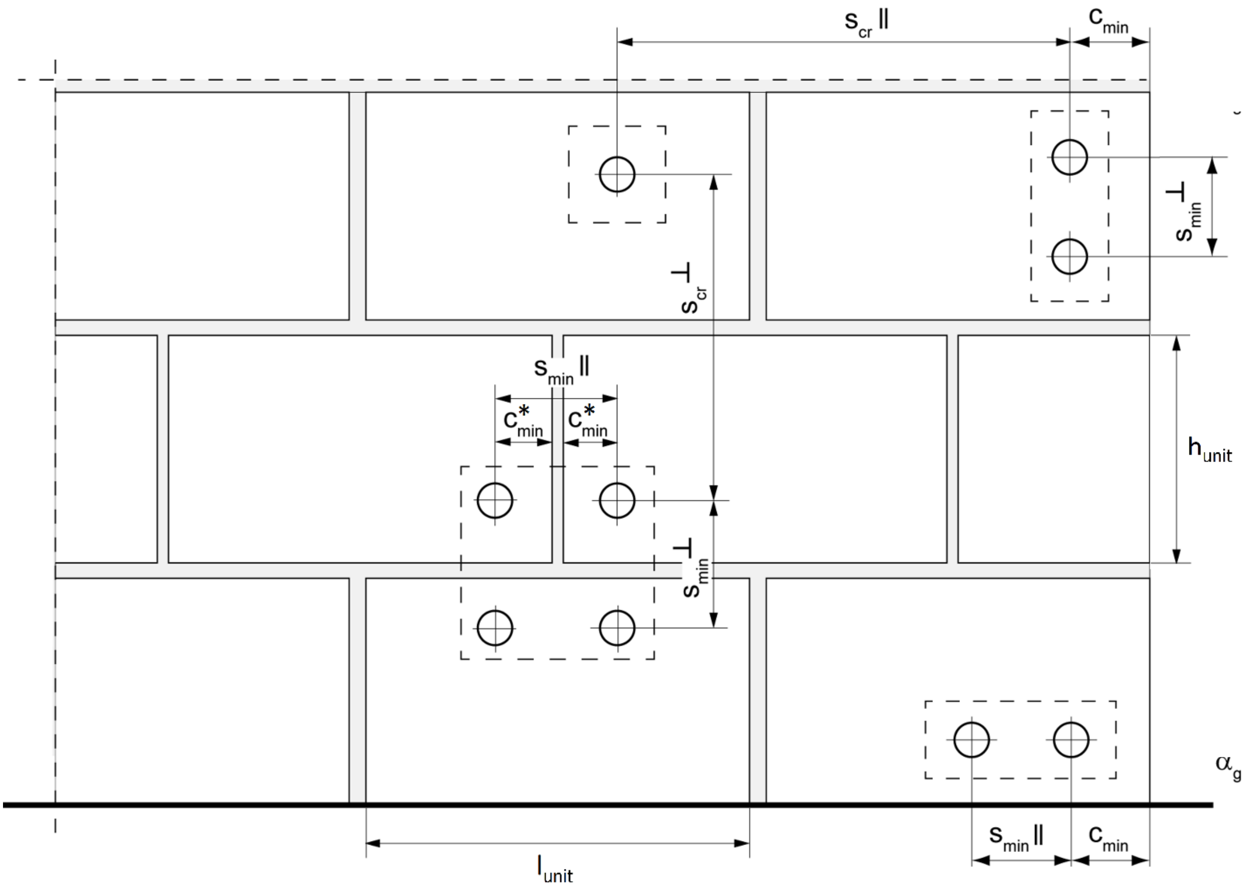
Tests / Assessment

n	=	number of tests of a test series
v	=	coefficient of variation
$\alpha_{N,seis}$	=	seismic tension reduction factor for failure modes pull-out (bond) or brick breakout failure
Δw	=	crack width
Δw_{bot}	=	crack width at bottom side of the test member (i.e., at the averted side from anchor installation)
Δw_{hef}	=	crack width at the level of the embedment depth h_{ef}
Δw_{top}	=	crack width at top side of the test member (i.e., the side in which the anchor is installed)
$\delta(\delta_N, \delta_V)$	=	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.
δ_{N0}	=	displacement of the anchor under short-term tension loading
δ_{V0}	=	displacement of the anchor under short-term shear loading
$\delta_{N,eq}$	=	factor for displacements increase in tension versus static case
$\delta_{V,eq}$	=	factor for displacements increase in shear versus static case
$\delta_{N\infty}$	=	displacement of the anchor under long-term tension loading
$\delta_{V\infty}$	=	displacement of the anchor under long-term shear loading
δ_{appl}	=	displacement amplitude applied in simulated seismic tests
α	=	reduction factor
$\alpha_{V,seis}$	=	seismic shear reduction factor
β	=	reduction factor for all different influences
$N_{Rk,eq}$	=	characteristic values reported in the ETA for pull-out (bond) or brick breakout failure in tension
$N_{Rk,s}$	=	characteristic resistance to steel failure of a single anchor under tension load
$N_{Rk,s,eq}$	=	characteristic values reported in the ETA for steel failure in tension
$N_{Rk,p}$	=	characteristic resistance to pull-out failure of a single anchor under tension load
$N_{Rk,b}$	=	characteristic resistance to brick break-out failure of a single anchor under tension load
$N_{Rk,p,c}$	=	characteristic resistance of pull-out failure of the anchor with edge effects
$N_{Rk,b,c}$	=	characteristic resistance of brick breakout failure of the anchor with edge effects
$V_{Rk,b}$	=	characteristic resistance to local brick failure of a single anchor under shear load
$V_{Rk,b,eq}$	=	characteristic values reported in the ETA for steel failure in shear

$V_{Rk,c,II}$	=	characteristic resistance to brick edge failure of a single anchor under shear load parallel to the edge
$V_{Rk,c,\perp}$	=	characteristic resistance to brick edge failure of a single anchor under shear load perpendicular to the edge
$V_{Rk,s}$	=	characteristic resistance to steel failure of a single anchor under shear load without lever arm
$V_{Rk,s,eq}$	=	characteristic values reported in the ETA for pull-out (bond) or brick breakout failure in shear
$M^0_{Rk,s}$	=	characteristic resistance to steel failure of a single anchor under shear load with lever arm
N^g_{Rk}	=	characteristic resistance to brick breakout failure of an anchor group under tension load
$V^g_{Rk,b}$	=	characteristic resistance to local brick failure of an anchor group to local brick failure under shear load
$V^g_{Rk,c,II}$	=	characteristic resistance to brick edge failure of an anchor group under shear load parallel to the edge
$V^g_{Rk,c,\perp}$	=	characteristic resistance to brick edge failure of an anchor group under shear load perpendicular to the edge
$\alpha_{g,N}$	=	group factor under tension load
$\alpha_{g,V,II}$	=	group factor under shear loading parallel to the edge
$\alpha_{g,V,\perp}$	=	group factor under shear loading perpendicular to the edge
$N_{Rk,s,fi}$	=	Fire resistance to steel failure under tension load
$N_{Rk,p,fi}$	=	Fire resistance to pull-out failure under tension load
$N_{Rk,b,fi}$	=	Fire resistance to brick breakout failure under tension load
$V_{Rk,s,fi}$	=	Fire resistance to steel failure under shear load without lever arm
$M^0_{Rk,s,fi}$	=	Fire resistance to steel failure under shear load with lever arm

Temperature terms

Service temperature:	Range of ambient temperatures of the base material 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:	resulting from intended use of the anchor, within the range of 0,6 times to 1,0 times the maximum short-term temperature (based on the unit °C).
Normal ambient temperature:	base material temperature 21 °C ± 3 °C (for test conditions only)
Installation ambient temperature:	The temperature range of the base material resulting from intended use of the anchor for installation and during curing of the bonding material.
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.



c_{min}	=	minimum edge distance
c_{min}^{*}	=	minimum edge distance, only if vertical joints are not filled with mortar
$s_{cr,II}$	=	characteristic spacing parallel to the horizontal joint
$s_{cr,\perp}$	=	characteristic spacing perpendicular to the horizontal joint
$s_{min,II}$	=	minimum spacing parallel to the horizontal joint
$s_{min,\perp}$	=	minimum spacing perpendicular to the horizontal joint
l_{unit}	=	length of the masonry unit
h_{unit}	=	height of the masonry unit

Figure 1.3.1: Edge distances and spacing

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of the metal injection anchor for use in masonry is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
Characteristic resistance for static and quasi-static loading			
1	Characteristic resistance to steel failure of a single anchor under tension loading	EAD 330499-01-0601 [10], 2.2.1	Level $N_{Rk,s}$ [kN]
2	Characteristic resistance to steel failure of a single anchor under shear loading with and without lever arm	2.2.1	Level $V_{Rk,s}$ [kN], $M^0_{Rk,s}$ [Nm]
3	Characteristic resistance to pull-out failure or brick breakout failure of a single anchor under tension loading	2.2.2	Level $N_{Rk,p}$, $N_{Rk,b}$ [kN], $N_{Rk,p,c}$, $N_{Rk,b,c}$ [kN], β [-]
4	Characteristic resistance to local brick failure or brick edge failure of a single anchor under shear loading	2.2.3	Level $V_{Rk,b}$, $V_{Rk,c,II}$, $V_{Rk,c,\perp}$ [kN],
5	Characteristic resistance to brick breakout failure of an anchor group under tension loading	2.2.4	Level N^g_{Rk} [kN], $\alpha_{g,N}$ [-]
6	Characteristic resistance to local brick failure or brick edge failure of an anchor group under shear loading	2.2.5	Level $V^g_{Rk,b}$, $V^g_{Rk,c,II}$, $V^g_{Rk,c,\perp}$, [kN] $\alpha_{g,V,II}$, $\alpha_{g,V,\perp}$ [-]
7	Edge distances, spacing, member thickness	2.2.6	Level c_{cr}, s_{cr}, c_{min}, $s_{min,II}$, $s_{min,\perp}$, h_{min} [mm]
8	Displacements under tension and shear loading	2.2.7	Level δ_{N0}, $\delta_{N\infty}$, δ_{V0}, $\delta_{V\infty}$ [mm]
9	Maximum installation torque	2.2.8	Level max. T_{inst} [Nm]

No	Essential characteristic	Assessment method	Type of expression of product performance
Characteristic resistance and displacements for seismic loading			
10	Resistance to tension load, displacements	2.2.9	Level $N_{Rk,s,eq}$, $N_{Rk,eq}$ [kN], $\alpha_{N,seis}$ [-], $\delta_{N,eq}$ [mm]
11	Resistance to shear load, displacements	2.2.10	Level $V_{Rk,s,eq}$, $V_{Rk,b,eq}$ [kN], $\alpha_{V,seis}$ [-], $\delta_{V,eq}$ [mm]
12	Factor for annular gap	2.2.11	Level α_{gap} [-]
Basic Works Requirement 2: Safety in case of fire			
13	Reaction to fire	2.2.12	Class
14	Resistance to fire under tension and shear loading with and without lever arm, minimum edge distances and spacing	2.2.13	Level $N_{Rk,s,fi}$ [kN], $N_{Rk,p,fi}$ [kN], $N_{Rk,b,fi}$ [kN], $V_{Rk,s,fi}$ [kN], $M^0_{Rk,s,fi}$ [Nm], $c_{cr,fi}$, $s_{cr,fi}$ [mm]
Basic Works Requirement 3: Hygiene, health and the environment			
15	Content, emission and/or release of dangerous substances	2.2.14	Description

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as "shall be stated in the ETA" or "it has to be given in the ETA" shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

For assessment methods presented in chapter 2.2 details of tests and general aspects of assessment are given in Annexes A, B and C.

Expressions of results of the assessment (see Table 2.1.1, last column and relevant chapters 2.2.x) shall be given in the ETA.

2.2.1 Characteristic resistance to steel failure of a single anchor under shear loading with and without lever arm

Purpose of the assessment

Determination of characteristic resistance to steel failure of a single anchor under shear loading.

Assessment method

The characteristic resistance to steel failure shall be calculated for steel elements with constant strength over the length of the element as given below. The smallest cross section of the anchor in the area of load transfer applies.

$$V_{Rk,s} = 0{,}5 \cdot A_s \cdot f_{uk} \text{ [N]} \quad (2.2.1.1)$$

$$M^0_{Rk,s} = 1{,}2 \cdot W_{el} \cdot f_{uk} \text{ [Nm]} \quad (2.2.1.2)$$

In case of steel failure in the tests A3 according to Table A.1.1, $V_{Rk,s}$ (characteristic resistance of steel failure of the anchor) shall be calculated according to the following Equation:

$$V_{Rk,s} = \min \left(V_{Rk,b} \, (f_{uk} / f_{u,test});\ 0{,}5 \cdot A_s \cdot f_{uk}\right) \quad (2.2.1.3)$$

with:
- $V_{Rk,b}$ = characteristic resistance according to Equation (2.2.3.1)
- A_s = decisive cross section of the anchor
- W_{el} = elastic section modulus calculated from the stressed cross section of the embedded metal part
- f_{uk} = nominal characteristic steel ultimate strength
- $f_{u,test}$ = steel ultimate strength at the time of testing ≥ f_{uk}

Expression of results: $V_{Rk,s}$ [kN], $M^0_{Rk,s}$ [Nm]

2.2.2 Characteristic resistance to pull-out failure or brick breakout failure of a single anchor under tension loading

Purpose of the assessment

Determination of characteristic resistance to pull-out failure or brick breakout failure of a single anchor under tension loading.

Assessment method

1. Performance of tests

Tests shall be performed according to Table A.1.1, test series A2 and A4 and according to Table A.1.2, test series F1 to F9. Test details are given in Annex A:

- Selection of base material according to the intended use (see 1.2.1 and A.1 and A.2)
- Install the anchor according to A.3.
- Use test equipment and test arrangement according to A.4, Example of test rig see Figure A.4.1 and A.4
- Test procedure and test details see Tables A.1.1 and A.2 (last column)

- Prepare test report according to A.6

2. Assessment of functioning in dry or wet base material (test series F1a and F1b according to Table A.1.2)

- Determine α according to Equation (B.4.1)
- Determine reduction factor $\alpha_{2,F1a} = \alpha / 0{,}8$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F1a} = 1{,}0$
- Determine reduction factor $\alpha_{2,F1b} = \alpha / 0{,}8$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F1b} = 1{,}0$

3. Assessment of functioning at increased temperature (test series F2a according to Table A.1.2)

Maximum long-term temperature:

- Determine α according to Equation (B.4.1)
- Determine reduction factor $\alpha_{2,F2,mlt} = \alpha / 1{,}0$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F2,mlt} = 1{,}0$

Maximum short-term temperature:

- Determine α according to Equation (B.4.1), but with reference test series F2a under long-term temperature instead of test series A1
- Determine reduction factor $\alpha_{2,F2,mst} = \alpha / 0{,}8$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F2,mst} = 1{,}0$

4. Assessment of functioning at low installation temperature (test series F2b according to Table A.1.2 or according to EAD 330499-01-0601 [10])

Installation temperature ≥ 0°C:

- Assessment of test series F2b and determination of reduction factor α according to Equation (B.4.1) of this EAD
- Determine reduction factor $\alpha_{2,F2b} = \alpha / 1{,}0$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F2b} = 1{,}0$

Installation temperature < 0°C:

- Assessment and determination of reduction factor α according to EAD 330499-01-0601 [10], 2.2.2.13
- Determine reduction factor $\alpha_{2,F2b} = \alpha / 0{,}9$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F2b} = 1{,}0$
- Determine $\alpha_{V,N} = ß_{cv}$ according to EAD 330499-01-0601 [10], A.2.3.5, Equation (A.13)

5. Assessment of functioning at minimum curing time at normal ambient temperature (test series F2c according to Table A.1.2):

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 the values measured in reference tests with a "long curing time" in the basic tests. The "long curing time" is the maximum curing time normally used in basic 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.

6. Assessment of functioning at repeated loads (test series F3 according to Table A.1.2)

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_p of the test are smaller than the mean value of the displacements at overcoming loss of adhesion in the reference tests.

If the condition is not met, the test series shall be repeated with a reduced tension load max.$N_{p,red}$ until the condition is fulfilled.

- In case of reduced tension load: determine $\alpha_{p,F3} = max.N_{p,red} / max.N_p \leq 1{,}0$

- Determine α according to Equation (B.4.1) for failure loads measured in the pull-out tests subsequent to the repeated loading
- Determine reduction factor $\alpha_{2,F3} = \alpha / 1,0$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F3} = 1,0$

7. Assessment of functioning at sustained loads (test series F4 according to Table A.1.2)

The displacements measured in the tests shall be extrapolated according to Equation (2.2.2.1) (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.

$$s(t) = s_o + a \cdot t^b \qquad (2.2.2.1)$$

with: 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 the condition is not met, the test series shall be repeated with a reduced tension load max. $N_{p,red}$ until the condition is fulfilled.

- In case of reduced tension load: determine $\alpha_{p,F4}$ = max. $N_{p,red}$ / max. $N_p \leq 1,0$

Normal temperature:

- Determine α according to Equation (B.4.1) for failure loads measured in the pull-out tests subsequent to the sustained loading
- Determine reduction factor $\alpha_{2,F4,nt} = \alpha / 0,9$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F4,nt} = 1,0$

Maximum long-term temperature:

- Determine α according to Equation (B.4.1) for failure loads measured in the pull-out tests subsequent to the sustained loading and using reference test series F2a under maximum long-term temperature instead of test series A1
- Determine reduction factor $\alpha_{2,F4,mlt} = \alpha / 0,9$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F4,mlt} = 1,0$

8. Assessment of freeze/thaw conditions (test series F6 according to Table A.1.2)

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

If the condition is not met, the test series shall be repeated with a reduced tension load max. $N_{p,red}$ until the condition is fulfilled.

- In case of reduced tension load: determine $\alpha_{p,F6}$ = max. $N_{p,red}$ / max. $N_p \leq 1,0$
- Determine α according to Equation (B.4.1) for failure loads measured in the pull-out tests subsequent to the freeze/thaw cycles
- Determine reduction factor $\alpha_{2,F6} = \alpha / 0,9$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F6} = 1,0$

9. Sensitivity to sulphurous atmosphere and high alkalinity

The durability of the bonding material shall be tested 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 shall be performed only for applications in use condition w/w 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 reduction factor α_3 = 0,3 is used in Equation (2.2.2.5),
- 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 $N_{Rk,b}$ (clay or calcium silicate) $\leq N_{Rk,b}$ (concrete brick) with $N_{Rk,b}$ (concrete brick) calculated according to Equation (2.2.2.6) and (2.2.2.5) with α_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).

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.

For slice tests the factor α_3 shall be calculated according to following Equation:

$$\alpha_s = \frac{\tau_{um\,(stored,s)}}{\tau_{um,dry}} \quad (2.2.2.2)$$

$$\alpha_a = \frac{\tau_{um\,(stored,a)}}{\tau_{um,dry}} \quad (2.2.2.3)$$

with: $\tau_{um(stored,s)}$ = mean bond strength of the slices stored in sulphurous atmosphere

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

$\tau_{um,dry}$ = 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 following Equation:

$$\tau_u = \frac{N_u}{\pi \cdot d \cdot h_{sl}} \quad (2.2.2.4)$$

with: N_u = measured maximum load

d = diameter of the embedded part

h_{sl} = thickness of slice, measured values

Determine reduction factor $\alpha_3 = \min((\alpha_s / 0{,}9);(\alpha_a / 1{,}0))$
If the calculated factor α_3 is greater than 1,0, then α_3 = 1,0

<u>10. Assessment of increased crack width (test series F8 according to Table A.1.2, only for AAC slabs)</u>

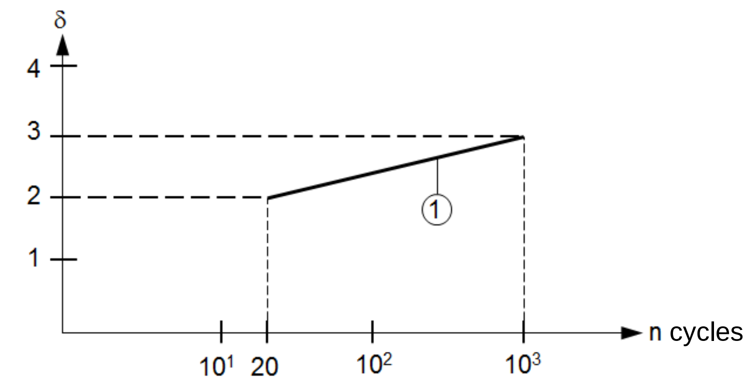
- Determine α according to Equation (B.4.1),
- Determine reduction factor $\alpha_{2,F8} = \alpha / 0{,}8$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F8}$ = 1,0

<u>11. Assessment of crack cycling under load (test series F9 according to Table A.1.2, only for AAC slabs)</u>

In each test the rate of increase of fastener displacements, plotted in a half-logarithmic scale (see Figure 2.2.2.1), shall either decrease or be almost constant: the criteria of the allowable displacement after 20 (δ_{20}) and 1000 (δ_{1000}) cycles of crack opening are graduated as a function of the number of tests as follows:

5 to 9 tests:	δ_{20} ≤ 2 mm and δ_{1000} ≤ 3 mm
10 to 20 tests:	δ_{20} ≤ 2 mm; one tests is allowed to 3 mm
	δ_{1000} ≤ 3 mm; one tests is allowed to 4 mm
> 20 tests:	δ_{20} ≤ 2 mm; 5% of tests are allowed to 3 mm
	δ_{1000} ≤ 3 mm; 5% of tests are allowed to 4 mm

The displacements are considered to be stabilized if the increase of displacements during cycles 750 to 1000 is smaller than the displacement during cycles 500 to 750.



1 maximum allowable displacement

Figure 2.2.2.1 Criteria for results of tests with variable crack width

If in the tests the above given conditions on the displacement behaviour, i.e., rate of increase and allowable displacements, are not fulfilled, the test series shall be repeated with a reduced tension load $N_{p,red}$ until the conditions are fulfilled.

- In case of reduced tension load: determine $\alpha_{p,F9}$ = max. $N_{p,red}$ / max. $N_p \leq 1{,}0$
- Determine α according to Equation (B.4.1) for failure loads measured in the pull-out tests subsequent to the crack cycling
- Determine reduction factor $\alpha_{2,F9} = \alpha / 0{,}9$
  If the calculated factor is greater than 1,0, then $\alpha_{2,F9} = 1{,}0$

12. Determination of characteristic resistance

The reduction factor β considers the different influences affecting the performance of the anchor and shall be calculated as follows:

$$\beta = \min(\min \alpha_1 ; \min \alpha_{2,F1,F3,F4,F6} ; \min \alpha_{2,F8,F9}) \cdot \min \alpha_{2,F2} \cdot \min \alpha_3 \cdot \min \alpha_{V,N} \cdot \min \alpha_p \quad (2.2.2.5)$$

with:

min α_1	=	minimum value α_1 according to Equation (B.5.1) or (B.5.2) Reduction factor from the load/displacement behaviour of all tests
min $\alpha_{2,F2}$	=	minimum value α_2 according to 2.2.2/3 and 2.2.2/4 Reduction factor from the ultimate loads in the functioning tests according to Table A.1.2, test series F2 (temperature)
min $\alpha_{2,F1,F3,F4,F6}$	=	minimum value α_2 according to 2.2.2/2, 2.2.2/6, 2.2.2/7 and 2.2.2/8 Reduction factor from the ultimate loads in the functioning tests according to Table A.1.1, test series F1, F3, F4 and F6
min $\alpha_{2,F8,F9}$	=	only for cracked AAC slabs: minimum value α_2 according to 2.2.2/10 and 2.2.2/11, Reduction factor from the ultimate loads in the functioning tests according to Table A.1.2, test series F8 and F9 (cracks)
min $\alpha_{V,N}$	=	minimum value α_V according to Equations (B.3.1) or (B.3.2) or according to 2.2.2/4 for installation temperature < 0°C Reduction factor from the coefficient of variation of the ultimate loads in the functioning and basic tension tests
min α_3	=	reduction factor according to 2.2.2/9 Reduction factor from the durability behaviour of all tests
min α_p	=	minimum reduction factor according to 2.2.2/6, 2.2.2/7, 2.2.2/8, 2.2.2/11 Reduction factor from reduced loads in functioning tests Table A.1.1, test series F3, F4 and F6 and F9 (F9: only for cracked AAC slabs)

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

$$N_{Rk,p} = N_{Rk,b} = N_{5\%,A2} \cdot \beta \quad \text{for } c_{cr} = \text{according to 2.2.6} \quad (2.2.2.6)$$

$N_{Rk,p,c} = N_{Rk,b,c} = N_{5\%,A4} \cdot \beta$ for $c_{min} = c_{min,test}$ (2.2.2.7)

with:

- $N_{Rk,p}$ = characteristic resistance of pull-out failure of the anchor
- $N_{Rk,b}$ = characteristic resistance of brick break out failure
- $N_{Rk,p,c}$ = characteristic resistance of pull-out failure of the anchor with edge effects
- $N_{Rk,b,c}$ = characteristic resistance of brick break out failure with edge effects
- $N_{5\%,A2}$ = $F_{5\%}$ according to B.2 evaluated from the results of test series A2 according to Table A.1.1 $\leq N_{5\%,A1}$
- $N_{5\%,A4}$ = $F_{5\%}$ according to B.2 evaluated from the results of test series A4 according to Table A.1.1 $\leq N_{5\%,A1}$
- $N_{5\%,A1}$ = $F_{5\%}$ according to B.2 evaluated from the results of test series A1 according to Table A.1.1
- β = according to Equation (2.2.2.5)

For $N_{Rk,p} = N_{Rk,b} < 1{,}5$ KN the value of the characteristic resistance $N_{Rk,p}$, $N_{Rk,b}$, $N_{Rk,p,c}$, $N_{Rk,b,c}$ shall be rounded down to the following numbers: 0,3 / 0,4 / 0,5 / 0,6 / 0,75 / 0,9 / 1,2 kN.

For $N_{Rk,p} = N_{Rk,b} \geq 1{,}5$ KN the value of the characteristic resistance $N_{Rk,p}$, $N_{Rk,b}$, $N_{Rk,p,c}$, $N_{Rk,b,c}$ shall be rounded down to steps of 0,5 kN (Examples: 1,5 / 2,0 / 2,5 / 3,0).

Expression of results: $N_{Rk,p}$, $N_{Rk,b}$, $N_{Rk,p,c}$, $N_{Rk,b,c}$ [kN]

2.2.3 Characteristic resistance to local brick failure and brick edge failure of a single anchor under shear loading

Purpose of the assessment

Determination of characteristic resistance to local brick failure and brick edge failure of a single anchor under shear loading.

Assessment method

1. Performance of tests

Tests shall be performed according to Table A.1.1, test series A3 and A5. Test details are given in Annex A.

- Selection of base material according to the intended use (see 1.2.1 and A.1 and A.2)
- Install the anchor according to A.3.
- Use test equipment and test arrangement according to A.4, Example of test rig see Figure A.4.3
- Test procedure see A.5.1 and A.5.3
- Prepare test report according to A.6

2. Determination of characteristic resistance

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

$V_{Rk,b} = V_{5\%,A3} \cdot \min \alpha_1 \cdot \min \alpha_{V,V}$ for c_{cr} = according to 2.2.6 (2.2.3.1)

$V_{Rk,c,II} = V_{5\%,A5,II} \cdot \min \alpha_1 \cdot \min \alpha_{V,V}$ for $c_{min} = c_{min,test}$ (2.2.3.2)

$V_{Rk,c,\perp} = V_{5\%,A5,\perp} \cdot \min \alpha_1 \cdot \min \alpha_{V,V}$ for $c_{min} = c_{min,test}$ (2.2.3.3)

with:

- $V_{Rk,b}$ = characteristic resistance of local brick failure independent of the failure mode
- $V_{Rk,c,II}$ = characteristic resistance of brick break out failure with edge influence under shear loading parallel to the edge
- $V_{Rk,c,\perp}$ = characteristic resistance of brick break out failure with edge influence under shear loading perpendicular to the edge
- $V_{5\%,A3}$ = $F_{5\%}$ according to B.2 evaluated from the results of test series A3 according to Table A.1.1

$V_{5\%,A5,II}$	=	$F_{5\%}$ according to B.2 evaluated from the results of test series A5 according to Table A.1.1 with shear loading parallel to the edge
$V_{5\%,A5,\perp}$	=	$F_{5\%}$ according to B.2 evaluated from the results of test series A5 according to Table A.1.1 with shear loading perpendicular to the edge
min α_1	=	minimum value α_1 according to B.5, reduction factor from the load/displacement behaviour of all tests
min $\alpha_{V,V}$	=	minimum value α_V according to Equation (B.3.2) minimum reduction factor from the coefficient of variation of the ultimate loads in the basic shear tests

For $V_{Rk,b}$, $V_{Rk,c}$ < 1,5 KN the value of the characteristic resistance $V_{Rk,b}$, $V_{Rk,c}$ shall be rounded down to the following numbers: 0,3 / 0,4 / 0,5 / 0,6 / 0,75 / 0,9 / 1,2 kN.

For $V_{Rk,b}$, $V_{Rk,c}$ ≥ 1,5 KN the value of the characteristic resistance $V_{Rk,b}$, $V_{Rk,c}$ shall be rounded down to steps of 0,5 kN (Examples: 1,5 / 2,0 / 2,5 / 3,0).

Expression of results: $V_{Rk,b}$, $V_{Rk,c,II}$, $V_{Rk,c,\perp}$ [kN]

2.2.4 Characteristic resistance to brick breakout failure of an anchor group under tension loading

Purpose of the assessment

Determination of characteristic resistance to brick breakout failure of an anchor group under tension loading depending on the edge distance and spacing (for definition of edge distance and spacing see also Figure 1.3.1).

Assessment method

In case of ($s_{min,II} \geq s_{cr} = 3\ h_{ef}$) and ($s_{min,\perp} \geq s_{cr} = 3\ h_{ef}$) and ($c_{min} \geq c_{cr} = 1{,}5\ h_{ef}$) for solid masonry or ($s_{min,II} \geq s_{cr} = l_{unit}$) and ($s_{min,\perp} \geq s_{cr} = h_{unit}$) and ($c_{min} \geq c_{cr} = 1{,}5\ h_{ef}$) for hollow or perforated masonry (see also 2.2.6) no tests are necessary. Under these conditions, group factors and characteristic resistances are given as follows:

$$N_{Rk}^{g} = \alpha_{g,N} \cdot N_{Rk,b} \qquad (2.2.4.1)$$

with $\alpha_{g,N}$ = 2,0 for double anchor groups

$\alpha_{g,N}$ = 4,0 for quadruple anchor groups

$N_{Rk,b}$ = according to Equation (2.2.2.6)

In case of ($s_{min,II} < s_{cr} = 3\ h_{ef}$) or ($s_{min,\perp} < s_{cr} = 3\ h_{ef}$) or ($c_{min} < c_{cr} = 1{,}5\ h_{ef}$) for solid masonry or ($s_{min,II} < s_{cr} = l_{unit}$) and ($s_{min,\perp} < s_{cr} = h_{unit}$) and ($c_{min} < c_{cr} = 1{,}5\ h_{ef}$) for hollow or perforated masonry (see also 2.2.6) the following steps shall be performed.

1. Performance of tests

Tests shall be performed according to Table A.1.1, test series A6. Test details are given in Annex A. The tested configuration will be given in the ETA.

- Selection of base material according to the intended use (see 1.2.1 and A.1 and A.2)
- Install the anchor according to A.3.
- Use test equipment and test arrangement according to A.4, Example of test rig see Figure A.4.1
- Test procedure see A.5.1 and A.5.2
- Prepare test report according to A.6

2. Determination of characteristic resistance of an anchor group

According to the tested configuration the characteristic resistances of an anchor group under tension loading for minimum edge distances c_{min} and minimum spacing s_{min} (see 2.2.6) shall be calculated as follows.

$$N_{Rk}^{g} = N_{5\%,A6} \cdot \beta \qquad (2.2.4.2)$$

for $c_{min} = c_{min,test}$ and $s_{min,II} = s_{min,II,test}$ and/or $s_{min,\perp} = s_{min,\perp,test}$

with: N_{Rk}^{g} = characteristic resistance of the anchor group under tension loading

$N_{5\%,A6}$ = $F_{5\%}$ according to B.2
evaluated from the results of test series A6 according to Table A.1.1

β according to Equation (2.2.2.5)

If the characteristic resistance of a double anchor group exceeds twice $N_{Rk,b,c}$ (according to Equation (2.2.2.7)), then N_{Rk}^g = 2 $N_{Rk,b,c}$. If the characteristic resistance of a quadruple anchor group exceeds four times $N_{Rk,b}$ (according to Equation (2.2.2.7)), then N_{Rk}^g = 4 $N_{Rk,b,c}$.

The value of the characteristic resistance N_{Rk}^g shall be rounded down to the numbers given in 2.2.2.

3. Determination of group factors

The characteristic resistance of the tested anchor group may be transferred to anchor groups of anchors with smaller sizes and smaller characteristic resistance of the single anchor with the same edge distances and spacings in the same base material by using group factors.

Depending on the tested configuration the group factor shall be calculated as follows:

Quadruple anchor group $c_{min} = c_{min,test}$, $s_{min,II} = s_{min,II,test}$, $s_{min,\perp} = s_{min,\perp,test}$

$$\alpha_{g,N} = \min\left((N_{um,A6} / N_{um,A4}) \; ; \; (N_{5\%,A6} / N_{5\%,A4})\right) \tag{2.2.4.3}$$

Double anchor group with $c_{min} = c_{min,test}$, $s_{min,II} = s_{min,II,test}$

$$\alpha_{g,N,II} = \min\left((N_{um,A6} / N_{um,A4}) \; ; \; (N_{5\%,A6} / N_{5\%,A4})\right) \tag{2.2.4.4}$$

Double anchor group with $c_{min} = c_{min,test}$, $s_{min,\perp} = s_{min,\perp,test}$

$$\alpha_{g,N,\perp} = \min\left((N_{um,A6} / N_{um,A4}) \; ; \; (N_{5\%,A6} / N_{5\%,A4})\right) \tag{2.2.4.5}$$

with: $N_{um,A6}$ = mean failure load in test series A6 according to Table A.1.1

$N_{um,A4}$ = mean failure load in the reference test series A4 according to Table A.1.1

$N_{5\%,A6}$ = $F_{5\%}$ according to B.1, evaluated from test series A6 according to Table A.1.1

$N_{5\%,A4}$ = $F_{5\%}$ according to B.1, evaluated from reference test series A4 according to Table A.1.1

$\alpha_{g,N,II}$ = group factor for double anchor groups parallel to the horizontal joint

$\alpha_{g,N,\perp}$ = group factor for double anchor groups perpendicular to the horizontal joint

The group factor shall be rounded to 0,05.

If the group factor of a double anchor group exceeds 2,0, then α_g = 2,0.

If the group factor of a quadruple anchor group exceeds 4,0, then α_g = 4,0.

4. Determination of characteristic resistance of an anchor group by using group factors

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

$$N_{Rk}^g = \alpha_{g,N} \cdot N_{Rk,b,c} \tag{2.2.4.6}$$

with: N_{Rk}^g = characteristic resistance of the anchor group under tension loading

$N_{Rk,b,c}$ = according to Equation (2.2.2.7)

$\alpha_{g,N}$ = according to Equation (2.2.4.3) to (2.2.4.5)

The value of the characteristic resistance N_{Rk}^g shall be rounded down to the numbers given in 2.2.2.

Expression of results: N_{Rk}^g [kN], $\alpha_{g,N}$ [-] depending on the tested configuration

2.2.5 Characteristic resistance to local brick failure or brick edge failure of an anchor group under shear loading

<u>Purpose of the assessment</u>

Determination of characteristic resistance to brick breakout failure of an anchor group under shear loading depending on the edge distance and spacing (for definition of edge distance and spacing see also Figure 1.3.1).

<u>Assessment method</u>

In case of ($s_{min,II} \geq s_{cr} = 3\ h_{ef}$) and ($s_{min,\perp} \geq s_{cr} = 3\ h_{ef}$) and ($c_{min} \geq c_{cr} = 1{,}5\ h_{ef}$) for solid masonry or ($s_{min,II} \geq s_{cr} = l_{unit}$) and ($s_{min,\perp} \geq s_{cr} = h_{unit}$) and ($c_{min} \geq c_{cr} = 1{,}5\ h_{ef}$) for hollow or perforated masonry (see also 2.2.6) no tests are necessary. Under these conditions group factors and characteristic resistances are given as follows:

$$V_{Rk,b}^{g} = \alpha_{g,V} \cdot V_{Rk,b} \qquad (2.2.5.1)$$

with: $V_{Rk,b}$ = according to Equation (2.2.3.1)

$\alpha_{g,V}$ = 2,0 for double anchor groups

$\alpha_{g,V}$ = 4,0 for quadruple anchor groups

In case of ($s_{min,II} < s_{cr} = 3\ h_{ef}$) or ($s_{min,\perp} < s_{cr} = 3\ h_{ef}$) or ($c_{min} < c_{cr} = 1{,}5\ h_{ef}$) for solid masonry or ($s_{min,II} < s_{cr} = l_{unit}$) and ($s_{min,\perp} < s_{cr} = h_{unit}$) and ($c_{min} < c_{cr} = 1{,}5\ h_{ef}$) for hollow or perforated masonry (see also 2.2.6) the following steps shall be performed .

<u>1. Performance of tests</u>

Tests shall be performed according to Table A.1.1, test series A7. Test details are given in Annex A. The tested configuration will be given in the ETA.

- Selection of base material according to the intended use (see 1.2.1 and A.1 and A.2)
- Install the anchor according to A.3.
- Use test equipment and test arrangement according to A.4, Example of test rig see Figure A.4.3
- Test procedure see A.5.1 and A.5.3
- Prepare test report according to A.6

<u>2. Determination of characteristic resistance of an anchor group</u>

According to the tested configuration the characteristic resistances of an anchor group under shear loading for minimum edge distances c_{min} and minimum spacing s_{min} (see 2.2.6) shall be calculated as follows.

$$V_{Rk,c,II}^{g} = V_{5\%,A7,II} \cdot \min \alpha_1 \cdot \min \alpha_{V,V} \qquad (2.2.5.2)$$

$$V_{Rk,c,\perp}^{g} = V_{5\%,A7,\perp} \cdot \min \alpha_1 \cdot \min \alpha_{V,V} \qquad (2.2.5.3)$$

for $c_{min} = c_{min,test}$ and $s_{min,II} = s_{min,II,test}$ and/or $s_{min,\perp} = s_{min,\perp,test}$

with: $V_{Rk,c,II}^{g}$ = characteristic resistance of the screw group under shear loading parallel to the edge

$V_{Rk,c,\perp}^{g}$ = characteristic resistance of the screw group under shear loading perpendicular to the edge

$V_{5\%,A7,II}$ = $F_{5\%}$ according to B.1
evaluated from the results of test series A7,II according to Table A.1.1

$V_{5\%,A7,\perp}$ = $F_{5\%}$ according to B.1
evaluated from the results of test series A7,⊥ according to Table A.1.1

min α_1, min $\alpha_{V,V}$ see 2.2.3

If the characteristic resistance of a double screw group exceeds twice $V_{Rk,c,II}$ (according to Equation (2.2.3.2)), then $V_{Rk,c,II}^{g} = 2\ V_{Rk,c,II}$. If the characteristic resistance of a quadruple screw group exceeds four times $V_{Rk,c,II}$ (according to Equation (2.2.3.2), then $V_{Rk,c,II}^{g} = 4\ V_{Rk,c,II}$.

If the characteristic resistance of a double screw group exceeds twice $V_{Rk,c,\perp}$ (according to Equation (2.2.3.3)), then $V_{Rk,c,\perp}^{g} = 2\ V_{Rk,c,\perp}$. If the characteristic resistance of a quadruple screw group exceeds four times $V_{Rk,c,\perp}$ (according to Equation (2.2.3.3)), then $V_{Rk,c,\perp}^{g} = 4\ V_{Rk,c,\perp}$.

The value of the characteristic resistances $V^g_{Rk,c,II}$ and $V^g_{Rk,c,\perp}$ shall be rounded down to the numbers given in 2.2.3.

<u>3. Determination of group factors</u>

The characteristic resistance of the tested anchor group may be transferred to anchor groups of anchors with smaller sizes and smaller characteristic resistance of the single anchor with the same edge distances and spacings in the same base material by using group factors.

Depending on the tested configuration the group factor shall be calculated as follows:

Quadruple anchor group $c_{min} = c_{min,test}$, $s_{min,II} = s_{min,II,test}$, $s_{min,\perp} = s_{min,\perp,test}$

Shear loading parallel to the edge

$$\alpha_{g,V,II} = \min \left((V_{um,A7,II}/V_{um,A5,II}) ; (V_{5\%,A7,II}/V_{5\%,A5,II}) \right) \qquad (2.2.5.4)$$

Shear loading perpendicular to the edge:

$$\alpha_{g,V,\perp} = \min \left((V_{um,A7,\perp} / V_{um,A5;\perp}) ; (V_{5\%,A7,\perp} / V_{5\%,A5,\perp}) \right) \qquad (2.2.5.5)$$

Double anchor group with $c_{min} = c_{min,test}$, $s_{min,II} = s_{min,II,test}$

Shear loading parallel to the edge

$$\alpha_{g,V,II} = \min \left((V_{um,A7,II} / V_{um,A5,II}) ; (V_{5\%,A7,II} / V_{5\%,A5,II}) \right) \qquad (2.2.5.6)$$

Shear loading perpendicular to the edge

$$\alpha_{g,V,\perp} = \min \left((V_{um,A7,\perp} / V_{um,A5;\perp}) ; (V_{5\%,A7,\perp} / V_{5\%,A5,\perp}) \right) \qquad (2.2.5.7)$$

Double anchor group with $c_{min} = c_{min,test}$, $s_{min,\perp} = s_{min,\perp,test}$

Shear loading parallel to the edge

$$\alpha_{g,V,\perp} = \min \left((V_{um,A7,II} / V_{um,A5,II}) ; (V_{5\%,A7,II} / V_{5\%,A5,II}) \right) \qquad (2.2.5.8)$$

Shear loading perpendicular to the edge

$$\alpha_{g,V,II} = \min \left((V_{um,A7,\perp} / V_{um,A5;\perp}) ; (V_{5\%,A7,\perp} / V_{5\%,A5,\perp}) \right) \qquad (2.2.5.9)$$

with:

$V_{um,A7,II}$	=	mean failure load in test series A7,II according to Table A.1.1
$V_{um,A7,\perp}$	=	mean failure load in test series A7,⊥ according to Table A.1.1
$V_{um,A5,II}$	=	mean failure load in the reference test series A5,II according to Table A.1.1
$V_{um,A5,\perp}$	=	mean failure load in the reference test series A5,⊥ according to Table A.1.1
$V_{5\%,A7,II}$	=	$F_{5\%}$ according to B.1, evaluated from test series A7,II according to Table A.1.1
$V_{5\%,A7,\perp}$	=	$F_{5\%}$ according to B.1, evaluated from test series A7,⊥ according to Table A.1.1
$V_{5\%,A5,II}$	=	$F_{5\%}$ according to B.1, evaluated from reference test series A5,II according to Table A.1.1
$V_{5\%,A5,\perp}$	=	$F_{5\%}$ according to B.1, evaluated from reference test series A5,⊥ according to Table A.1.1
$\alpha_{g,V,II}$	=	group factor for double anchor groups parallel to the horizontal joint
$\alpha_{g,V,\perp}$	=	group factor for double anchor groups perpendicular to the horizontal joint

The group factor shall be rounded to 0,05.

If the group factor of a double anchor group exceeds 2,0, then $\alpha_g = 2,0$.

If the group factor of a quadruple anchor group exceeds 4,0, then $\alpha_g = 4,0$.

<u>4. Determination of characteristic resistance of an anchor group by using group factors</u>

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

$$V^g_{Rk,c,II} = \alpha_{g,V,II} \cdot V_{Rk,c,II} \qquad (2.2.5.10)$$

$$V^g_{Rk,c,\perp} = \alpha_{g,V,\perp} \cdot V_{Rk,c,\perp} \qquad (2.2.5.11)$$

with: $V^g_{Rk,c,II}$ = characteristic resistance of the anchor group under shear loading parallel to the edge

$V^g_{Rk,c,\perp}$ = characteristic resistance of the anchor group under shear loading perpendicular to the edge

$V_{Rk,c,II}$ = according to Equation (2.2.3.2)

$V_{Rk,c,\perp}$ = according to Equation (2.2.3.3)

$\alpha_{g,V,II}$ = according to Equation (2.2.5.4) to (2.2.5.8) depending on the tested configuration

$\alpha_{g,V,\perp}$ = according to Equation (2.2.5.5) to (2.2.5.9) depending on the tested configuration

The value of the characteristic resistances $V^g_{Rk,c,II}$ and $V^g_{Rk,c,\perp}$ shall be rounded down to the numbers given in 2.2.3.

Expression of results: $V^g_{Rk,b}$, $V^g_{Rk,c,II}$, $V^g_{Rk,c,\perp}$ [kN] and $\alpha_{g,V,II}$, $\alpha_{g,V,\perp}$ [-] depending on the tested configuration

2.2.6 Edge distance, spacing, member thickness

Purpose of the assessment

Determination of edge distances, spacing and member thickness for which the characteristic resistances according to 2.2.2 to 2.2.5 are given (for definition of edge distances and spacing see also Figure 1.3.1).

Assessment method

Characteristic edge distances for single anchors are:

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

Characteristic spacing for single anchors are:

- For tests in solid units in walls: s_{cr} = 3,0 h_{ef}
- For tests in solid units in single bricks with l_{unit} < 3,0 h_{ef} or h_{unit} < 3,0 h_{ef}:
  $s_{cr,II}$ = l_{unit} (s_{cr} II horizontal joint),
  $s_{cr,\perp}$ = h_{unit} (s_{cr} $\perp$ horizontal joint)
- For tests in hollow or perforated units: $s_{cr,II}$ = l_{unit} (s_{cr} II horizontal joint),
  $s_{cr,\perp}$ = h_{unit} (s_{cr} $\perp$ horizontal joint)

The minimum edge distance c_{min} and minimum spacing $s_{min,II}$ and $s_{min,\perp}$ are based on the manufacturer's instructions (see also A.1). These values shall be assessed by test series A4 to A7 according to Table A.1.1 in connection with the relevant characteristic resistances according to 2.2.2, 2.2.3, 2.2.4 and 2.2.5.

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

- Anchorages in solid masonry and AAC: s_{min} ≥ max (50 mm; 3 d_0)
- Anchorages in hollow or perforated masonry: s_{min} ≥ max (75 mm; 5 d_0)

In absence of manufacturer's instructions c_{min} = c_{cr} and s_{min} = s_{cr}.

Member thickness h_{min} is specified by the manufacturer. In absence of manufacturer's specification h_{min} = 80 mm.

Edge distances c_{min} and c_{cr} for $V_{Rk,c,\perp}$ are also valid for joints which are not to be filled with mortar.

The distance to the edges of the AAC slabs are ≥ 150 mm.

The spacing between fixing points in AAC slabs are ≥ 600 mm. Fixing points are single anchors, or anchor groups of 2 or 4 anchors.

Expression of results: c_{cr}, s_{cr}, c_{min}, $s_{min,II}$, $s_{min,\perp}$, h_{min} [mm]

2.2.7 Displacements under tension and shear loading

Purpose of the assessment

Determination of displacements of the anchor under tension and shear loading.

Assessment method

As a minimum, the displacements under short-term and long-term tension and shear loading shall be given in the ETA for a tension or shear load F which corresponds to the value according to following Equation:

$$F = \frac{F_{Rk}}{\gamma_F \cdot \gamma_M} \qquad (2.2.7.1)$$

with:

F_{Rk} = characteristic resistance $N_{Rk,b}$ or $V_{Rk,b}$ according to 2.2.2 or 2.2.3
γ_F = 1,4
γ_M = 2,0 for use in autoclaved aerated concrete
= 2,5 for use in all other kinds of masonry

The displacements under short-term tension loading (δ_{N0}) shall be evaluated from the tests with single anchors without edge or spacing effects according to Table A.1.1, test series A2. The displacements under short-term tension loading shall be calculated as 95 %-fractile of the measured displacements at the load F for a confidence level of 90 %.

The long-term tension loading displacements $\delta_{N\infty}$ shall be equal to 2,0 times the value δ_{N0}.

For anchors to be used in AAC slabs the long-term displacements under tension loading, $\delta_{N\infty}$, shall be calculated from the results of crack cycling tests (Table A.1.2, test series F9) according to the following Equation:

$$\delta_{N\infty} = \delta_{m1} / 1,5 \qquad (2.2.7.2)$$

with $\delta_{N\infty}$ = long term tension displacement
δ_{m1} = mean value of anchor displacement δ_1 after 10^3 crack movements measured in test series F9 (see A.5.11)

The displacements under short-term shear loading (δ_{V0}) shall be evaluated from the displacements of corresponding shear tests with single anchors without edge or spacing effects according to Table A.1.1, test series A3 (measurement of displacements - see A.5.3).

The displacements under short-term shear loading shall be calculated as 95 %-fractile of the measured displacements at the load F for a confidence level of 90 %.

The long-term shear loading displacements $\delta_{V\infty}$ shall be be assumed to be equal to 1,5 times the value δ_{V0}.

Under shear loading, the displacements might increase due to a gap between fixture and anchor. Therefore, in the ETA shall be stated clearly if this gap is taken into account in the assessment.

Expression of results: δ_{N0}, $\delta_{N\infty}$, δ_{V0}, $\delta_{V\infty}$ [mm]

2.2.8 Maximum installation torque

Purpose of the assessment

The tests are performed to check if failure occurs during setting (turn-through of the injection anchor), which would then reduce the performance of the injection anchor.

Assessment method

Assessment of maximum torque moment (test series F5 according to Table A.1.2):

The ultimate torque (T_u) and the 5%-fractile of the ultimate torque ($T_{u5\%}$) of the test series F5 shall be determined.

The ratio of the maximum torque T_u during failure to the maximum torque max. T_{inst} specified by the manufacturer shall be determined for every test of the test series. 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.

If no installation torque is specified by the manufacturer, max. T_{inst} shall be determined in all masonry units and joints according to the specific intended use of the anchor, where max. T_{inst} is the maximum torque required to completely set the anchor in tests F5 according to Table A.1.2.

Expression of results: max. T_{inst} [Nm]

2.2.9 Characteristic value of tension resistance under seismic actions (Series M1-R, M1)

Purpose of the assessment

These tests are intended to evaluate the performance of anchors for use in seismic design under simulated seismic tension loading without edge effects, including the effects of cracks.

Assessment method

1. Performance of tests

Test series M1-R and M1 shall be performed with the same embedment depths and test set-up, and in this context this applies especially to the measurement of displacement. The general test conditions are given in section C.3.2. Explanations on anchor types to be tested are given in section C.3.3. Specific test conditions are given in section C.3.4.2 for reference test series M1-R and in section C.3.4.4 for tests under pulsating tension loading (test series M1).

2. Assessment of reference tension tests (test series M1-R)

The following conditions apply:

1. Load-displacement behaviour

   For each anchor tested in test series M1-R, in the load-displacement curve a load plateau with a corresponding slip greater than 10% of the displacement at ultimate load, or a temporary drop in load (first peak load) of more than 5% of the ultimate load up to a load of 50 % of the ultimate load in that single test are not acceptable.

   If these conditions are not fulfilled, the seismic tension resistance shall be reduced considering the load at which a plateau or the first peak occurred as $N_{u,adh}$. A factor α_1 according to B.5 (Equation (B.5.1) or (B.5.2)) shall be calculated for series M1-R and considered in the determination of the factor $\beta_{N,seis}$ (according to 2.2.9/4).

2. Ultimate load:

   The basic reduction for seismic tension loading shall be determined as the ratio of the ultimate load in the seismic reference test series M1-R and the corresponding static test series according to Table A.1.1, test series A2 (uncracked base material) performed in the same type of wall (concerning brick layout, brick type and masonry mortar).

$$\alpha_{M1.R}=\frac{N_{u,m,M1.R}}{N_{u,m,static}} \qquad (2.2.9.1)$$

   with
   $N_{u,m,M1.R}$ = [N] mean ultimate tension load from seismic reference test series M1-R;
   $N_{u,m,static}$ = [N] mean ultimate tension load from static test series according to Table A.1.1, test series A2 (uncracked base material)

3. Scatter of ultimate loads:

$$cv\left(N_{u,M1.R}\right)\leq 30\% \qquad (2.2.9.2)$$

   If this condition is fulfilled $\beta_{cv,M1.R}$ = 1,0. If this condition is not fulfilled the factor $\beta_{cv,M1.R}$ shall be calculated according to Equation (2.2.9.3).

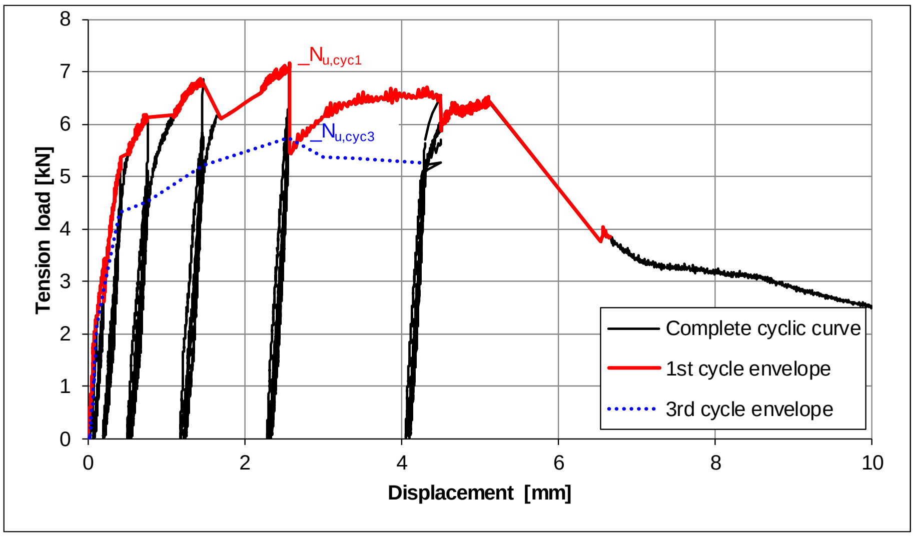
$$\beta_{cv,M1.R}=\frac{1}{1+\left(cv\left(N_{u,M1.R}\right)-30\right)\cdot 0,03} \qquad (2.2.9.3)$$

   where $cv(N_{u,M1.R})$ is the coefficient of variation of the ultimate loads in test series M1.R.

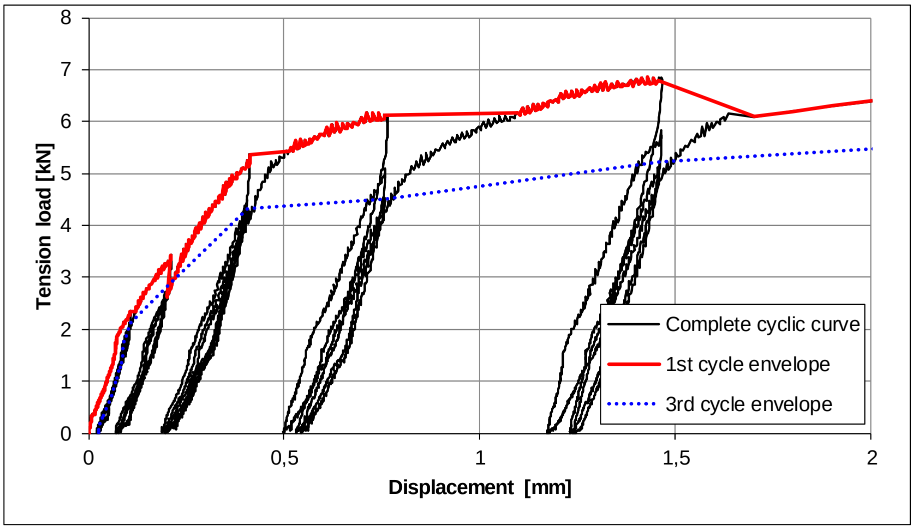
3. Assessment of tests under pulsating tension load (test series M1)

The following conditions apply:

1. For the determination of the ultimate loads, two load-displacement envelope curves shall be constructed respectively as follows (see Figure 2.2.9.1):
   a. For the 1st cycle envelope curve, the segments of the load- displacement curve of the first cycle of each displacement step shall be connected (see red curve in Figure 2.2.9.1).
   b. The 3rd cycles envelope curve shall be constructed by connecting the maximum loads and corresponding displacement datapoints of the load-displacement curves of the third cycle of each displacement step (see blue curve in Figure 2.2.9.1).



a) Complete curves



b) Detail up to 2 mm displacement

Figure 2.2.9.1: Example envelope curves for 1st and 3rd cycles of tension test series M1

2. Cyclic load reductions (all three conditions apply):

   a) Ultimate load:

   The overall ultimate tension load for each test shall be determined from the envelope curves of the 1st displacement cycles.

$$N_{u,m,M1} \geq 0{,}9 \cdot N_{u,m,,M1.R} \qquad (2.2.9.4)$$

with

$$N_{u,m,M1} = \frac{1}{n} \sum_{i=1}^{n} N_{u,cyc1,i} \qquad (2.2.9.5)$$

$N_{u,m,M1.R}$ = [N] mean ultimate tension load from test series M1.R;
$N_{u,m,M1}$ = [N] mean ultimate tension load of 1st cycle envelope of series M1 (compare value of a single test $N_{u,cyc1}$ in Figure 2.2.9.1a)

If this condition is fulfilled, $\alpha_{N,1}$ = 1,0. If this condition is not fulfilled, the factor $\alpha_{N,1}$ shall be determined according to Equation (2.2.9.6).

$$\alpha_{N,1}=\frac{N_{u,m,M1}}{0{,}9\cdot N_{u,m,M1.R}} \qquad (2.2.9.6)$$

If different material batches (metal element; masonry mortar strength; brick strength) are used, the mean ultimate tension resistances from test series M1.R in Equations (2.2.9.4) and (2.2.9.6) shall be normalized according to section C.3.5, where applicable, to the strength in test series M1.

b) Scatter of ultimate loads:

$$cv\left(N_{u,M1}\right) \leq 30\% \qquad (2.2.9.7)$$

If this condition is fulfilled, $\beta_{cv,M1}$ = 1,0. If this condition is not fulfilled, $\beta_{cv,M1}$ shall be determined according to Equation (2.2.9.8).

$$\beta_{cv,M1}=\frac{1}{1+\left(cv(N_{u,M1})\text{-}30\right)\cdot 0{,}03} \qquad (2.2.9.8)$$

where $cv(N_{u,M1})$ is the coefficient of variation of the ultimate tension loads (of 1st cycle envelope) in test series M1.

c) Strength degradation in envelope curves from 1st to 3rd cycle

The in-cycle tension strength degradation shall be determined as the mean of the ratios of the ultimate loads derived in the 3rd and 1st cycle envelopes for each test as given by Equation (2.2.9.9) and Equation (2.2.9.10).

$$\alpha_{N,2}=\frac{1}{n}\sum_{i=1}^{n}\alpha_{N,2,i} \qquad (2.2.9.9)$$

with

$$\alpha_{N,2,i}=\frac{N_{u,cyc3,i}}{N_{u,cyc1,i}}\leq 1 \qquad (2.2.9.10)$$

$N_{u,cyc3,i}$	=	[N]	ultimate tension load of 3rd cycle envelope of test i of series M1 (see Figure 2.2.9.1a)
$N_{u,cyc1,i}$	=	[N]	ultimate tension load of 1st cycle envelope of test i of series M1 M1 (see Figure 2.2.9.1a)
n	=		number of tests per series

The reduction factor α_{M1} resulting from the pulsating tension test series M1shall be determined according to Equation (2.2.9.11).

$$\alpha_{M1}=\alpha_{N,1}\cdot\alpha_{N,2} \qquad (2.2.9.11)$$

4. <u>Determination of decisive reduction factor for seismic tension loading</u>

The reduction factors $\alpha_{N,M,seis}$ and $\beta_{cv,N,seis}$ shall be determined according to Equations (2.2.9.12) and (2.2.9.13), respectively.

$$\alpha_{N,M,seis} = \alpha_{M1.R}\cdot\alpha_{M1} \qquad (2.2.9.12)$$

where

$\alpha_{M1.R}$ = reduction factor α according to 2.2.9/2
α_{M1} = reduction factor α according to 2.2.9/3

$$\beta_{cv,N,\,seis} = \min\left(\beta_{cv,M1.R};\ \beta_{cv,M1};\ \min\alpha_{V,N}\right) \qquad (2.2.9.13)$$

where

$\beta_{cv,M1.R}$ = reduction factor β_{cv} accounting for large scatter according to 2.2.9/2
$\beta_{cv,M1}$ = reduction factor β_{cv} accounting for large scatter according to 2.2.9/3
min $\alpha_{V,N}$ = minimum value α_V obtained from static qualification evaluated according to Equations (B.3.1) or (B.3.2) (reduction factor from the coefficient of variation of the ultimate loads in the functioning and basic service condition tension tests)

The reduction factor $\beta_{N,seis,s}$ considers the different influences affecting the performance of the anchor for failure mode steel failure and shall be calculated as follows:

$$\beta_{N,seis,s} = \min \alpha_1 \cdot \beta_{cv,N,seis} \quad (2.2.9.14)$$

The reduction factor $\beta_{N,seis}$ considers the different influences affecting the performance of the anchor for failure modes pull-out (bond) or brick breakout failureand shall be calculated as follows:

$$\beta_{N,seis} = \min(\min \alpha_1; \min \alpha_{2,F1,F3,F4,F6}) \cdot \min \alpha_{2,F2} \cdot \min \alpha_3 \cdot \beta_{cv,N,seis} \quad (2.2.9.15)$$

where

$\min \alpha_1$	=	minimum value α_1 according Equation (B.5.1) or (B.5.2), including series M1-R (according to 2.2.9/2) Reduction factor from the load/displacement behaviour of all tension tests.
$\min \alpha_{2,F2}$	=	minimum value α_2 according to 2.2.2/3 and 2.2.2/4 Reduction factor from the ultimate loads in the functioning tests according to Table A.1.2, test series F2 (temperature)
$\min \alpha_{2,F1,F3,F4,F6}$	=	minimum value α_2 according to 2.2.2/2, 2.2.2/6, 2.2.2/7 and 2.2.2/8 Reduction factor from the ultimate loads in the functioning tests according to Table A.1.1, test series F1, F3, F4 and F6
$\min \alpha_3$	=	reduction factor according to 2.2.2/9 Reduction factor from the durability behaviour of all tests
$\beta_{cv,N,M,seis}$	=	reduction factor accounting for large scatter according to Equation (2.2.9.13)

The decisive reduction factor $\alpha_{N,seis,s}$ for seismic tension loading for steel failure shall be determined according to Equation (2.2.9.16). The decisive reduction factor $\alpha_{N,seis}$ for seismic tension loading for failure modes pull-out (bond) or brick breakout failure shall be determined according to Equation (2.2.9.17) and shall be given in the ETA for use in the evaluation of on-site test results. They shall be used to determine the characteristic resistances under seismic tension loading according to section 2.2.9/5.

$$\alpha_{N,seis,s} = \alpha_{N,M,seis} \cdot \beta_{N,seis,s} \quad (2.2.9.16)$$

$$\alpha_{N,seis} = \alpha_{N,M,seis} \cdot \beta_{N,seis} \quad (2.2.9.17)$$

5. Determination of characteristic tension resistance for seismic design

The characteristic values reported in the ETA shall be calculated as follows. The values of the characteristic resistance, $N_{Rk,s,eq}$ and $N_{Rk,eq}$, shall be rounded to 3 digits in [kN].

The tension failure modes considered in the evaluation are steel, pull-out (bond) or brick breakout failure. The characteristic seismic tension resistances for these failure modes for single anchors without spacing or edge effects, i.e., $N_{Rk,s,eq}$ and $N_{Rk,eq}$, , to be reported in the ETA shall be determined as follows:

$$N_{Rk,s,eq} = \alpha_{N,seis,s} \cdot N_{Rk,s} \quad [N] \quad \text{for steel tension failure} \quad (2.2.9.18)$$

$$N_{Rk,eq} = \alpha_{N,seis} \cdot N_{Rk0} \quad [N] \quad \text{for pull-out (bond) or brick breakout failure} \quad (2.2.9.19)$$

where

$N_{Rk,s}$	=	[N]	characteristic steel tension resistance as reported in the ETA for static loading;
$N_{Rk,0}$	=	[N]	characteristic resistance for static loading evaluated from tests according to Table A.1.1, test series A2
$\alpha_{N,seis,s}$	=	[-]	seismic tension reduction factor for steel failure as determined by Equation (2.2.9.16)
$\alpha_{N,seis}$	=	[-]	seismic tension reduction factor for pull-out (bond) or brick breakout failure as determined by Equation (2.2.9.17)

The characteristic resistances obtained according to Equations (2.2.9.18) and (2.2.9.19) are applicable to anchors with the tested embedment depth.

If two or more embedment depths for the same anchor diameter have been tested the reduction factors $\alpha_{N,seis,s}$ and $\alpha_{N,seis}$ for an untested intermediate embedment depth shall be taken as the minimum of the two adjacent embedment depths tested. The minimum value of $\alpha_{N,seis,s}$ and $\alpha_{N,seis}$ shall be applied in Equations (2.2.9.18) and (2.2.9.19), respectively.

6. Displacement behaviour under seismic tension action

In case of seismic tension actions, the displacements increase versus static case, because of seismic influences. In the ETA a displacement factor $\delta_{N,eq}$ shall be given as follows.

$$\delta_{N,eq} = 1/k_{tan} \text{ [mm/kN]} \quad (2.2.9.20)$$

where
k_{tan} = [kN/mm] mean stiffness of series M1-R according Equation C.3.4.3.1

Expression of results: $N_{Rk,s,eq}$, $N_{Rk,eq}$ [kN], $\alpha_{N,seis}$ [-], $\delta_{N,eq}$ [mm]

2.2.10 Characteristic value of shear resistance under seismic actions (Series M2-R, M2)

Purpose of the assessment

These tests are intended to evaluate the performance of anchors for use in seismic design under simulated seismic shear loading without edge effects, including the effects of cracks.

Assessment method

1. Performance of tests

Test series M2-R and M2 shall be performed with the same embedment depths and test set-up, and in this context this especially applies to the measurement of displacement. The general test conditions are given in section C.3.2. Explanations for anchor types to be tested are given in section C.3.3. Specific test conditions are given in section C.3.4.2 for reference test series M2-R and in section C.3.4.5 for tests under alternating shear load (test series M2).

2. Assessment of reference shear tests (test series M2-R)

The following conditions apply:

1. Load-displacement behaviour for shear loading
   If in the tests under shear loading (M2-R) ultimate loads at displacements higher than 20 mm occur, the maximum load observed up to a displacement of 20 mm shall be evaluated (compare Section B.2).
2. Ultimate load:

   The basic reduction for seismic shear loading shall be determined as the ratio of the ultimate load in the seismic reference test series M2-R and the corresponding static test series according to Table A.1.1, Test A3 (uncracked base material) performed in the same type of wall (concerning brick layout, brick type and masonry mortar). The factor $\alpha_{M2.R}$ shall be determined according to Equation (2.21).

   $$\alpha_{M2.R} = \frac{V_{u,m,M2.R}}{V_{u,m,static}} \quad (2.21)$$

   with
   $V_{u,m,M2.R}$ = [N] mean ultimate shear load from seismic reference test series M2-R
   $V_{u,m,static}$ = [N] mean ultimate shear load from static test series according to Table A.1.1, test series A3 (uncracked base material)
3. Scatter of ultimate loads:

   $$cv(V_{u,M2.R}) \leq 20\% \quad (2.22)$$

   If this condition is fulfilled, $\beta_{cv,M2.R}$ = 1,0. If this condition is not fulfilled, the factor $\beta_{cv,M2.R}$ shall be determined according to Equation (2.23).

   $$\beta_{cvM.2.R} = \frac{1}{1+\left(cv(V_{u,M2.R})-20\right)\cdot 0{,}03} \quad (2.23)$$

   where $cv(V_{u,M2.R})$ is the coefficient of variation of the ultimate loads in test series M2.R.

2. Assessment of tests under alternating shear load (test series M2)

The following conditions apply:

1. Load-displacement behaviour for shear loading:
   If in the tests under shear loading (M2) ultimate loads at displacements higher than 20 mm occur, the maximum load observed up to a displacement of 20 mm shall be evaluated (compare to Section B.2).
2. For the determination of the ultimate loads, two load-displacement envelope curves shall be constructed respectively as follows (see Figure 2.2.10.1):
   a. For the 1st cycle envelope curve, the segments of the load- displacement curve of the first cycle of each displacement step shall be connected (see red and orange curves in Figure 2.2.10.1).
   b. The 3rd cycles envelope curve shall be constructed by connecting the maximum loads and corresponding displacement datapoints of the load-displacement curves of the third cycle of each displacement step (see blue curves in Figure 2.2.10.1).

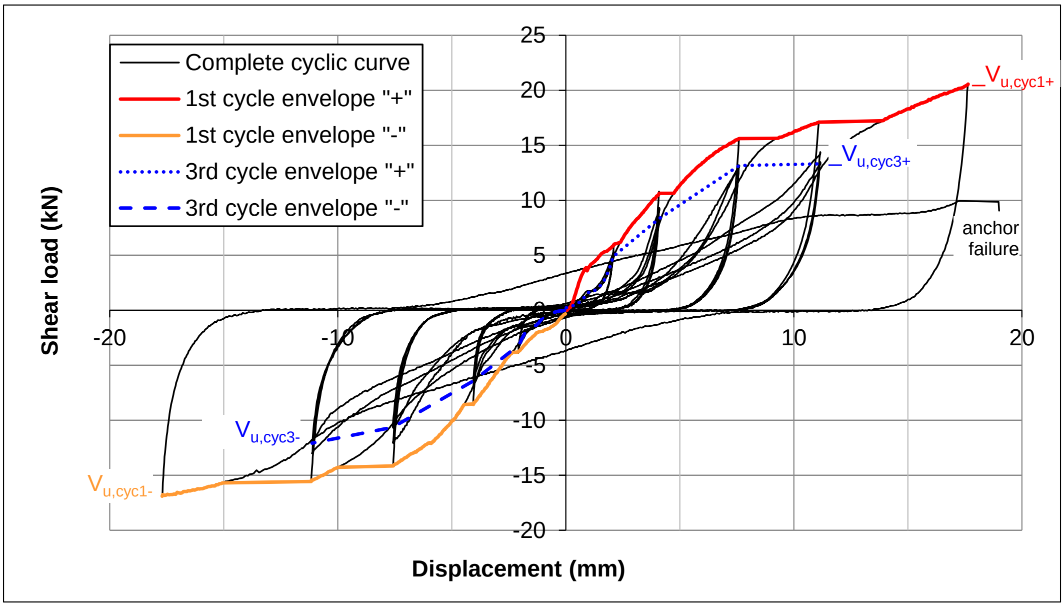


Figure 2.2.10.1: Example envelope curves for 1st and 3rd cycles of shear test series M2

3. Cyclic load reductions (all four conditions apply):

   a) Ultimate load:

   The overall ultimate shear load for each test shall be determined from the envelope curves of the 1st displacement cycles as absolute value.

$$V_{u,m,max,M2} \geq 0{,}95 \cdot V_{u,m,M2.R} \tag{2.24}$$

with

$$V_{u,m,max,M2} = \frac{1}{n}\sum_{i=1}^{n} V_{u,m,max,M2,i} \tag{2.25}$$

[N] mean ultimate shear load of series M2-R

$$V_{u,m,max;M2,i} = \max\left(V_{u,cyc1+,i}; \left|V_{u,cyc1-,i}\right|\right) \tag{2.26}$$

[N] Absolute maximum ultimate shear load of test i of series M2-R

with $V_{u,cyc1+}$ and $V_{u,cyc1-}$ representing the extreme values of the 1st cycle envelope curve in both directions as given in Figure 2.2.10.1.

If this condition is fulfilled, $\alpha_{V,1}$ = 1,0. If this condition is not fulfilled, the factor $\alpha_{V,1}$ shall be determined according to Equation (2.27).

$$\alpha_{V,1} = \frac{V_{u,m,max,M2}}{0{,}95 \cdot V_{u,m,M2.R}} \tag{2.27}$$

If different material batches (metal element; masonry mortar strength; brick strength) are used, the mean ultimate shear resistances from test series M2-R in Equations (2.24) and (2.27) shall be normalized according to section C.3.5, where applicable, to the strength in test series.

b) Scatter of ultimate loads:

$$cv\left(V_{u,max,M2}\right) \leq 20\% \quad (2.28)$$

If this condition is fulfilled, $\beta_{cv,M2}$ = 1,0. If this condition is not fulfilled, $\beta_{cv,M2}$ shall be determined according to Equation (2.29).

$$\beta_{cv,M2} = \frac{1}{1+\left(cv(V_{u,max,M2})-20\right)\cdot 0,03} \quad (2.29)$$

where $cv(V_{u,max,M2})$ is the coefficient of variation of the maximum values of 1st cycle envelopes (ultimate loads) of test series M2.

c) Strength degradation in envelope curves from 1st to 3rd cycle

The in-cycle shear strength degradation shall be determined as the mean of the ratios of the ultimate averaged loads derived in the 3rd and 1st cycle envelopes for each test as given by Equation (2.2.10.10) to Equation (2.2.10.13).

$$\alpha_{V,2} = \frac{1}{n}\sum_{i=1}^{n} \alpha_{V,2,i} \quad (2.2.10.10)$$

with

$$\alpha_{V,2,i} = \frac{V_{u,cyc3,i}}{V_{u,cyc1,i}} \leq 1 \quad (2.2.10.11)$$

$$V_{u,cyc1,i} = \frac{V_{u,cyc1+,i}+\left|V_{u,cyc1-,i}\right|}{2}$$ [N] mean ultimate shear load of 3rd cycle envelope of test i of series M2 (2.30.10.12)

$$V_{u,cyc3,i} = \frac{V_{u,cyc3+,i}+\left|V_{u,cyc3-,i}\right|}{2}$$ [N] mean ultimate shear load of 1st cycle envelope of test i of series M2 (2.2.10.13)

with $V_{u,cyc1+}$, $V_{u,cyc1-}$, $V_{u,cyc3+}$ and $V_{u,cyc3-}$ representing the extreme values of the 1st and 3rd cycle envelope curves in both directions as given in Figure 2.2.10.1;

n = number of tests per series

d) Asymmetry of response in both loading directions

The asymmetry of the response in both loading directions shall be determined as the mean of the ratios of the ultimate loads (average of absolute values of both directions) and the maximum ultimate loads (from both directions) derived in the 1st cycle envelopes as given by Equation (2.2.10.14).

$$\alpha_{V,3} = \frac{1}{n}\sum_{i=1}^{n} \alpha_{V,3,i} \quad (2.2.10.14)$$

with

$$\alpha_{V,3,i} = \frac{V_{u,cyc1,i}}{V_{u,max,M2,i}} \leq 1 \quad (2.231)$$

$V_{u,max,M2,i}$ and $V_{u,cyc1,i}$ as defined in Equations (2.26) and (2.30.10.12), respectively.

The reduction factor α_{M2} resulting from the alternating shear load test series M2 shall be determined according to Equation.

$$\alpha_{M2} = \alpha_{V,1}\cdot\alpha_{V,2}\cdot\alpha_{V,3} \quad (2.2.10.16)$$

3. Determination of decisive reduction factors for seismic shear loading

The reduction factors $\alpha_{V,M}$ and $\beta_{V,seis}$ shall be determined according to Equations (2.2.10.17) and (2.2.10.18), respectively.

$$\alpha_{V,M,seis} = \alpha_{M2.R} \cdot \alpha_{M2} \tag{2.2.10.17}$$

where

$\alpha_{M2.R}$ = reduction factor α according to 2.2.9/2

α_{M2} = reduction factor α according to 2.2.9/3

$$\beta_{V,seis} = \min\left(\beta_{cv,M2.R};\ \beta_{cv,M2};\ \min \alpha_{V,V}\right) \tag{2.2.10.18}$$

where

$\beta_{cv,M2.R}$ = reduction factor β_{cv} accounting for large scatter according to 2.2.9/2

$\beta_{cv,M2}$ = reduction factor β_{cv} accounting for large scatter according to 2.2.9/3

min $\alpha_{V,V}$ = minimum value $\alpha_{V,V}$ according to Equation (B.3.2) (reduction factor from the coefficient of variation of the ultimate loads in the basic service condition shear tests)

The decisive reduction factor for seismic shear loading shall be determined according to Equation (2.2.10.19) and shall be given in the ETA. It shall be used to determine the characteristic resistances under seismic shear loading according to section 2.2.10/4.

$$\alpha_{V,seis} = \alpha_{V,M,seis} \cdot \beta_{V,seis} \tag{2.2.10.19}$$

4. Determination of characteristic shear resistance for seismic design

The characteristic values reported in the ETA shall be calculated as follows. The values of the characteristic resistance, $V_{Rk,s,eq}$ and $V_{Rk,b,eq}$, shall be rounded to 3 digits in [kN].

The shear failure modes considered in the evaluation are steel and local brick failure. The characteristic resistance for steel shear failure and local brick failure under seismic loading, $V_{Rk,s,seis}$ and $V_{Rk,b,seis}$ to be reported in the ETA shall be determined as follows:

$$V_{Rk,s,eq} = \alpha_{V,seis} \cdot V_{Rk,s} \quad [N] \quad \text{for steel shear failure} \tag{2.2.10.20}$$

$$V_{Rk,b,eq} = \alpha_{V,seis} \cdot V_{Rk,b} \quad [N] \quad \text{for local brick failure} \tag{2.2.10.21}$$

where

$V_{Rk,s}$ = [N] characteristic resistance for steel failure given in the ETA for static loading;

$V_{Rk,b}$ = [N] characteristic resistance for local brick failure characteristic evaluated for static loading according from tests according to Table A.1.1, test series A3

$\alpha_{V,seis}$ = [-] seismic shear reduction factor as determined by Equation (2.2.10.19).

The reduction factor according to Equation (2.2.10.19) is valid for anchors with the tested embedment depth and diameter.

The characteristic resistances obtained according to Equations (2.2.10.20) and (2.2.10.21) are applicable to anchors with the tested embedment depth and diameter.

If two or more embedment depths for the same anchor diameter have been tested, for intermediate and not tested embedment depth the corresponding reduction factor $\alpha_{V,seis}$ shall be selected as the minimum of the respective calculated reduction factor determined according to section 2.2.10/3 for the two adjacent tested embedment depths.

For intermediate anchor diameters, which are not tested (i.e., other sizes than small, medium and large as defined in section C.3.1), the corresponding reduction factor $\alpha_{V,seis}$ shall be selected as the minimum of the respective calculated reduction factors determined according to section 2.2.10/3 for the two adjacent tested diameters.

The reduction factor for an intermediate, not tested embedment depth or diameter $\alpha_{V,seis}$ determined in this way shall be applied in Equations (2.2.10.20) and (2.2.10.21).

5. Displacement behaviour under seismic shear action

In case of seismic shear actions, the displacements increase versus static case, because of seismic influences. In the ETA a displacement factor $\delta_{V,eq}$ shall be given as follows.

$$\delta_{V,eq} = 1/(\alpha_{V,2} \cdot k_{tan}) \text{ [mm/kN]} \quad (2.2.10.22)$$

where

k_{tan} = [kN/mm] mean stiffness of series M2-R according Equation C.3.4.3.1

$\alpha_{V,2}$ = [-] strength degradation from the cyclic shear loading series M2 according to Equation (2.2.10.10)

Expression of results: $V_{Rk,s,eq}$, $V_{Rk,b,eq}$ [kN], $\alpha_{V,seis}$ [-], $\delta_{V,eq}$ [mm]

2.2.11 Factor for annular gap for seismic performance

When an annular gap is present between anchor and fixture, the forces on the anchors are amplified under shear loading due to a hammer effect on the anchor.

This effect is considered in the resistance of the fastening by introducing the reduction factor α_{gap}.

The factor α_{gap} shall be taken as equal to 0,5 for anchors with hole clearance according to TR 054 [12] Table 3.1 or equal to 1,0 if the product specifications and or the Manufacturer's Product Installation Instruction (MPII) require a proper filling of the annular gap and shear tests were carried out accordingly. The TAB shall check proper filling of the annular gap using the procedure given in the MPII for single anchors as well as for groups of anchors.

The value of α_{gap} shall be reported in the ETA as a product performance of the anchor as a function of the installation instructions.

When different performances are reported for installation with or without filling of the annular gap, consequently different values of α_{gap} shall be reported, respectively.

Expression of results: α_{gap} [-]

2.2.12 Reaction to fire

The metal parts of injection anchors and the cementitious mortar are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with Commission Decision 96/603/EC, as amended by Commission Decisions 2000/605/EC and 2003/424/EC, without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by 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. Therefore, the bonding material is considered as a small component which has no influence on the reaction to fire of the product and which does not need to be tested and classified separately.

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.

The plastic material of the sieve sleeve (used for installation) is embedded in masonry and can be considered to satisfy any reaction to fire requirements.

Therefore, the performance of the product is class A1.

2.2.13 Resistance to fire under tension and shear loading with and without lever arm, minimum edge distances and spacing

Purpose of the assessment

Determination of resistance to fire of the anchor under tension and shear loading.

Assessment method

Fire resistance of the injection anchor shall be assessed according to EAD 330232-01-0601 [29], with following amendment: The injection anchor shall not be installed in concrete but it shall be installed at the most unfavourable setting position in the brick which gives the lowest characteristic resistance.

Test duration in at least one test shall be greater than the resulting duration of fire resistance.

Tests in sand-lime bricks and clay bricks can be evaluated together if at least 3 tests are performed in sand-lime bricks and 3 tests are performed in clay bricks , assuming that the loads and failure times are approximately the same.

Steel failure under tension loading:

Fire resistance to steel failure under tension loading shall be tested and assessed according to EAD 330232-01-0601 [29], 2.2.17.

$N_{Rk,s,fi}$ shall be determined according to [29], Equation (2.34).

Pull-out failure:

If in tests pull-out failure occurs, $N_{Rk,p,fi}$ shall be assessed according to EAD 330232-01-0601 [29], 2.2.17 with following amendment:

- σ_s shall be replaced by N_p
- $\sigma_{Rk,s}$ shall be replaced by $N_{Rk,p}$
- $\sigma_{Rk,s,fi}$ shall be replaced by $N_{Rk,p,fi}$

If no pull-out failure occurs: $N_{Rk,p,fi} = N_{Rk,s,fi}$ or $N_{Rk,p,fi} = N_{Rk,b,fi}$ (depending on the failure mode in tests).

Brick breakout failure

If in tests brick breakout failure occurs, $N_{Rk,b,fi}$ shall be assessed according to EAD 330232-01-0601 [29], 2.2.17 with following amendment:

- σ_s shall be replaced by N_p
- $\sigma_{Rk,s}$ shall be replaced by $N_{Rk,b}$
- $\sigma_{Rk,s,fi}$ shall be replaced by $N_{Rk,b,fi}$

If no brick breakout failure occurs: $N_{Rk,b,fi} = N_{Rk,s,fi}$ or $N_{Rk,b,fi} = N_{Rk,p,fi}$ (depending on the failure mode in tests).

Steel failure under shear loading

Fire resistance to steel failure under shear loading shall be tested and assessed according to EAD 330232-01-0601 [29], 2.2.19.

$V_{Rk,s,fi}$ shall be determined according to [29], Equation (2.35).

$M^0_{Rk,s,fi}$ shall be determined according to [29], Equation (2.36).

Test duration in at least one test shall be greater than the resulting maximum duration of fire resistance.

Edge distance and spacing

If in the test no splitting and no brick breakout occurs, following characteristic edge distances and spacing may be assumed for the tested injection anchors and the tested bricks (defined by compression strength and geometry):

$s_{cr,fi} = s_{test,fi}$, $c_{cr,fi} = c_{test,fi}$

In all other cases (also when transferring results to other injection anchor or bricks):

$s_{cr,fi} = 4\ h_{ef}$, $c_{cr,fi} = 2\ h_{ef}$

Expression of results: $N_{Rk,s,fi}$ [kN], $N_{Rk,p,fi}$ [kN], $N_{Rk,b,fi}$ [kN], $V_{Rk,s,fi}$ [kN], $M^0_{Rk,s,fi}$ [Nm], $c_{cr,fi}$ [mm], $s_{cr,fi}$ [mm]

2.2.14 Content, emission and/or release of dangerous substances

The performance of the hardened bonding material related to the emissions and/or release and, where appropriate, the content of dangerous substances will be assessed on the basis of the information provided by the manufacturer[3] after identifying the release scenarios taking into account the intended use of the product and the Member States where the manufacturer intends his product to be made available on the market.

The identified intended release scenarios for this product and intended use with respect to dangerous substances are:

IA2: Product with indirect contact to indoor air (e.g., covered products) but possible impact on indoor air.[4]

S/W1: Product with direct contact to soil, ground- and surface water.[5]

S/W2: Product with indirect contact to soil, ground- and surface water.[5]

2.2.14.1 SVOC and VOC

For the intended use covered by the release scenario IA2 semi-volatile organic compounds (SVOC) and volatile organic compounds (VOC) shall be determined in accordance with EN 16516 [22]. The loading factor to be used for emission testing is 0,007 m^2/m^3.

The preparation of the test specimen shall be performed by use of a concrete member in which the anchor is installed in accordance with the manufacturer's product installation instructions (MPII) or (in absence of such instructions) the usual practice of anchor installation. The anchor with maximum thread size shall be used. The embedment depth shall be at least 4d.

Once the test specimen has been produced, as described above, it shall immediately be placed in the emission test chamber. This time is considered the starting time of the emission test.

The test results shall be reported for the relevant parameters (e.g., chamber size, temperature and relative humidity, air exchange rate, loading factor, size of test specimen, conditioning, production date, arrival date, test period, test result) after 3 and 28 days testing.

The relevant test results shall be expressed in [mg/m^3] and stated in the ETA.

2.2.14.2 Leachable substances

For the intended use covered by the release scenario S/W1 the performance of the bonding material concerning leachable substances shall be assessed. A leaching test with subsequent eluate analysis shall take place, each in duplicate. Leaching tests of the bonding material shall be conducted according to CEN/TS 16637-2 [23]. The leachant shall be pH-neutral demineralised water and the ratio of liquid volume to surface area shall be (80 ± 10) l/m^2.

Cubes of the bonding material with dimensions of 100 mm x 100 mm x 100 mm shall be prepared.

In eluates of "6 hours" and "64 days", the following biological tests shall be conducted:

- Acute toxicity test with Daphnia magna Straus according to EN ISO 6341 [24]
- Toxicity test with algae according to EN ISO 15799 [25]
- Luminescent bacteria test according to EN ISO 11348-1 [26], EN ISO 11348-2 [27] or EN ISO 11348-3 [28]

---

3 The manufacturer may be asked to provide to the TAB the REACH related information which he shall accompany the DoP with (cf. Article 6(5) of Regulation (EU) No 305/2011).

The manufacturer is **not** obliged:
- to provide the chemical constitution and composition of the product (or of constituents of the product) to the TAB, or
- to provide a written declaration to the TAB stating whether the product (or constituents of the product) contain(s) substances which are 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 SGDS.

Any information provided by the manufacturer regarding the chemical composition of the products may not be distributed to EOTA or to TABs.

4 Scenario IA2 is applicable for products which are covered with other products but nevertheless could release dangerous substances to indoor air (e.g., products covered with porous/unsealed coverings incapable of avoiding migration, such as gypsum panels).

5 Scenario S/W1 is applicable for products which are in contact with soil or water in a way that dangerous substances could released directly out of the product. Scenario S/W2 is applicable for products which can be leached by rain (e. g., external claddings) and could release dangerous substances which can have an impact on soil and water.

For each biological test, EC20-values shall be determined for dilution ratios 1:2, 1:4, 1:6, 1:8 and 1:16.

If the parameter TOC is higher than 10 mg/l, the following biological tests shall be conducted with the eluates of "6 hours" and "64 days" eluates:

- Biological degradation according to OECD Test Guideline 301 part A, B or E.

Expression of results:

Determined toxicity in biological tests shall be expressed as EC20-values for each dilution ratio. Maximum determined biological degradability shall be expressed as "…% within …hours/days". The respective test methods for analysis shall be specified.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is Decision 97/177/EC.

The system is 1.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the metal injection anchor for use in masonry in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

Table 3.2.1 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
Factory production control (FPC) **[including testing of samples taken at the factory in accordance with a prescribed test plan]**					
Metal parts					
1	Dimensions (outer diameter, inner diameter, thread length, etc.)	Calliper and/or gauge	(1)	3	(2)
2	Tensile load or tensile strength	EN ISO 6892-1 [7], EN ISO 898-1 [8], EN ISO 3506-1 [4]	(1)	3	(2)
3	Yield strength	EN ISO 6892-1 [7], EN ISO 898-1 [8], EN ISO 3506-1 [4]	(1)	3	(2)
4	Zinc plating (where relevant)	x-ray measurement according to EN ISO 3497 [17], magnetic method according to EN ISO 2178 [18], Phase-sensitive eddy-current method according to EN ISO 21968 [19]	(1)	3	(2)
5	Fracture elongation A_5 (where relevant)	EN ISO 6892-1 [7] EN ISO 898-1 [8]	(1)	3	(2)
Injection mortar					
6	Check of batch number and expiry date	visual check	(1)	1	Each batch
7	Components	check material and the mass of components according to recipe	(1)	1	Each batch
8	Specific gravity / Density	Standardized method proposed by the manufacturer according to control plan	(1)	1	Every shift or 8 hours of production per machine
9	Viscosity	Standardized method proposed by the manufacturer according to control plan	(1)	1	Every shift or 8 hours of production per machine
10	Reactivity (gel time, where relevant: max. reaction temperature, time to max reaction temperature)	Standardized method proposed by the manufacturer according to control plan	(1)	1	Each batch
11	Properties of raw material	(e.g., by infrared analysis)	(1)	1	initial testing and each change of batch

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
12	Performance of the cured bonding material	(e.g., tension test to failure)	(1)	3	Each batch
Sieve sleeve					
13	Dimensions (length, diameter, hole size, hole configuration, etc.)	Measuring or optical	(1)	3	Every shift or 8 hours of production per machine
14	Material	Depending on the material: method proposed by the manufacturer according to control plan	(1)	3	Every shift or 8 hours of production per machine

Notes to Table 3.2.1:

(1) Laid down in control plan

(2) Every manufacturing batch or 100.000 elements or when raw material batch has been changed (The lower control interval is decisive)

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for metal injection anchor for use in masonry are laid down in Table 3.3.1.

Table 3.3.1 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
Initial inspection of the manufacturing plant and of factory production control					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the metal injection anchor.	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	**1**/year

4 REFERENCE DOCUMENTS

[1]	EAD 330076-00-0604: 2016-04	Metal injection anchors for use in masonry
[2]	EN 771-1 to 5:2011+ A1:2015	Specification for masonry units
[3]	EN 772-1:2011 + A1:2015	Methods of test for masonry units - Part 1: Determination of compressive strength
[4]	EN ISO 3506-1:2020	Mechanical properties of corrosion-resistant stainless steel fasteners - Part 1: Bolts, screws and studs with specified property classes - Coarse pitch thread and fine pitch thread
[5]	EN 1996-1-1:2022	Design of masonry structures. Part 1-1: General rules for reinforced and unreinforced masonry structure
[6]	EN 12602:2016	Prefabricated reinforced components of autoclaved aerated concrete
[7]	EN ISO 6892-1:2019	Metallic materials - Tensile testing - Part 1: Method of test at room temperature
[8]	EN ISO 898-1:2013	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread
[9]	EN 998-2:2016	Specification for mortar for masonry – Part 2: Masonry mortar
[10]	EAD 330499-01-0601:2018-12	Bonded fasteners for use in concrete
[11]	EN 1998-1:2004/A1:2013	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings
[12]	EOTA TR 054:2016-04	Design methods for anchorages with metal injection anchors for use in masonry
[13]	EOTA TR 053:2016-04	Recommendations for tests of metal injection anchors for use in masonry to be carried out on construction works
[14]	EN 772-13:2000	Methods of test for masonry units – Part 13: Determination of net and gross dry density of masonry units (except for natural stone)
[15]	EN ISO 6988:1994	Metallic and other non-organic coatings – sulphur dioxide test with general condensation of moisture
[16]	ISO 5468:2017	Rotary and rotary impact masonry drill bits with hardmetal tips – Dimensions
[17]	EN ISO 3497:2000	Metallic coatings - Measurement of coating thickness - X-ray spectrometric methods
[18]	EN ISO 2178:2016	Non-magnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method
[19]	EN ISO 21968:2019	Non-magnetic metallic coatings on metallic and non-metallic basis materials - Measurement of coating thickness - Phase-sensitive eddy-current method
[20]	EN 1993-1-4: 2006 + A1:2015+ A2:2020	Eurocode 3: Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels
[22]	EN 16516:2017+A1:2020	Construction products – Assessment of release of dangerous substances – Determination of emissions into indoor air
[23]	CEN/TS 16637-2:2014	Construction products – Assessment of release of dangerous substances – Part 2: Horizontal dynamic surface leaching test
[24]	EN ISO 6341:2012	Water quality - Determination of the inhibition of the mobility of Daphnia magna Straus (Cladocera, Crustacea) - Acute toxicity test (ISO 6341:2012)
[25]	EN ISO 15799:2019	Soil quality - Guidance on the ecotoxicological characterization of soils and soil materials (ISO 15799:2019)

[26]	EN ISO 11348-1: 2008/A1:2018	Water quality - Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test) - Part 1: Method using freshly prepared bacteria (ISO 11348-1:2007)
[27]	EN ISO 11348-2: 2008/A1:2018	Water quality - Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test) - Part 2: Method using liquid-dried bacteria (ISO 11348-2:2007)
[28]	EN ISO 11348-3: 2008/A1:2018	Water quality - Determination of the inhibitory effect of water samples on the light emission of Vibrio fischeri (Luminescent bacteria test) - Part 3: Method using freeze-dried bacteria (ISO 11348-3:2007)
[29]	EAD 330232-01-0601:2019-12	Mechanical fasteners for use in concrete
[30]	EN 1015-11:2019	Methods of test for mortar for masonry - Part 11: Determination of flexural and compressive strength of hardened mortar

Further information and background for assessment methods is given in the following documents:

[31]	Owen, D.	Handbook of Statistical Tables, Addison/Wesley Publishing Company Inc., 1962

ANNEX A TEST PROGRAM AND TEST DETAILS

A.1 Test program

The test program for the assessment consists of

- Basic tension tests and basic shear tests to assess basic values of characteristic resistance (see Table A.1.1) and
- Any other tests (functioning tests) to assess the characteristic resistance regarding various effects for the relevant application range according to the intended use (see Table A.1.2)

If nothing else is stated, all tests shall be performed in all bricks according to the specific intended use of the anchor. If the intended use includes setting positions in joints of masonry, all basic tests shall be also performed in the joints of masonry.

For intended use in low and high strength AAC, test series A1 to A3 according to Table A.1.1 and test series F8 according to Table A.1.2 shall be performed in low and high strength AAC (see A.2.4). All other tests shall be performed in low strength AAC only.

For the characteristic resistance in AAC slabs according to EN 12602 [6] the following conditions apply:

- Tests according to Table A.1.1, test series A1 to A3 shall be performed in non-cracked AAC (Δw = 0 mm) and in cracked AAC (Δw = 0,3 mm),
- Tests according to Table A.1.1, test series A4 to A7 shall be performed in non-cracked AAC (Δw = 0 mm),
- Tests according to Table A.1.2, test series F8 shall be performed in cracked AAC (Δw = 0,5 mm),
- Tests according to Table A.1.2, test series F9 shall be performed with crack cycling (Δw = 0,1 to 0,3 mm),
- Tests according to Table A.1.2, test series F1 to F7 shall be performed in non-cracked AAC (Δw = 0 mm).

All basic tests shall be carried out according to this Annex 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} are based on the manufacturer's instructions. Only if minimum edge distance c_{min} and minimum spacing s_{min} according to the manufacturer's instructions are smaller than the characteristic values c_{cr} and s_{cr} according to 2.2.6, then the performance will be assessed by the corresponding tests according to Table A.1.1. In absence of manufacturer's instructions $c_{min} = c_{cr}$ and $s_{min} = s_{cr}$.

Table A.1.1: Basic tests for metal injection anchors for use in masonry and AAC slabs

	Purpose of test	Load direc-tion	Distances (3)	Remarks, Tests with	Number of tests (5) (6)			Test details Assess-ment
					s	m	l	
A1	Reference tension tests for functioning tests	N	$c_{test} \geq c_{cr}$ $s_{test} \geq s_{cr}$	single anchors	5	5	5	A.5.2 2.2.2
A2	Characteristic resistance for tension loading not influenced by edge and spacing effects	N	$c_{test} \geq c_{cr}$ $s_{test} \geq s_{cr}$	single anchors	5	5	5	A.5.2 2.2.2
A3	Characteristic resistance for shear loading not influenced by edge and spacing effects	V	$c_{test} \geq c_{cr}$ $s_{test} \geq s_{cr}$	single anchors	5	5	5	A.5.3 2.2.3
A4	Characteristic resistance for tension loading at minimum edge distance (1)	N	$c_{test} = c_{min}$ $s_{test} \geq s_{cr}$	single anchors at the edge of test member	5	5	5	A.5.2 2.2.2
A5,II	Characteristic resistance for shear loading parallel to the edge at minimum edge distance (1) (4)	V_{II}	$c_{test} = c_{min}$ $s_{test} \geq s_{cr}$	single anchors at the edge of test member	5	5	5	A.5.3 2.2.3
A5,⊥	Characteristic resistance for shear loading perpendicular to the edge at minimum edge distance (1)	$V_{\perp}$	$c_{test} = c_{min}$ $s_{test} \geq s_{cr}$	single anchors at the edge of test member	5	5	5	A.5.3 2.2.3
A6	Characteristic resistance for tension loading at minimum spacing (2)	N	$s_{test} = s_{min}$ $c_{test} = c_{min}$	double / quadruple anchor group at the edge of test member	5	5	5	A.5.2 2.2.4
A7,II	Characteristic resistance for shear loading parallel to the edge at minimum spacing (2) (4)	V_{II}	$s_{test} = s_{min}$ $c_{test} = c_{min}$	double / quadruple anchor group at the edge of test member	5	5	5	A.5.3 2.2.5
A7,⊥	Characteristic resistance for shear loading perpendicular to the edge at minimum spacing (2)	$V_{\perp}$	$s_{test} = s_{min}$ $c_{test} = c_{min}$	double / quadruple anchor group at the edge of test member	5	5	5	A.5.3 2.2.5

Notes to Table A.1.1

(1) Tests may be omitted, if minimum edge distances c_{min} is not smaller than the characteristic value c_{cr}.

(2) Tests may be omitted, if minimum spacing s_{min} is not smaller than the characteristic values s_{cr}.

(3) For characteristic edge distances, characteristic spacing and minimum edge distances, minimum spacing see 2.2.6.

(4) Tests may be omitted if $V_{Rk,II} = V_{Rk,\perp}$

(5) If the characteristic resistance of more than 3 sizes are to be assessed, the intermediate sizes need not be tested if the tests of sizes small, medium and large show regularity in failure mode and ultimate load.

(6) Anchor size: s = smallest; m = medium; l = largest

Table A.1.2: Functioning tests for injection anchors to be used in masonry and AAC slabs

	Purpose of test	Base material Group			Ambient base material tempe-rature	Minimum number of tests for anchor size (8)					Crite-ria	Test details, Assess-ment
		b and **c**		**d**								
		Solid clay	Solid calcium silicate	Auto-claved aerated concrete								
	Functioning					s	i	m	i	l	req. α	
F1a	in dry base material	x	x	x	normal	5	-	5	-	5	≥ 0,8	A 5.4a) 2.2.2/2
F1b	in wet base material (3)	x	x	x	normal	5	-	5	-	5	≥ 0,8	A 5.4b) 2.2.2/2
F2a	at increased temperature	x	x	x	+50 °C +80 °C (5)			5 5			≥ 1,0 ≥ 0,8 (6)	A 5.5a) 2.2.2/3
F2b	at low temperature (4)	(1)		x (10)	≥ 0 °C < 0 °C			5			≥ 1,0 ≥ 0,9	A 5.5b) 2.2.2/4 [10] 2.2.2.13
F2c	at minimum curing time	(1)		x	normal			5			≥ 0,9	A 5.5c) 2.2.2/5
F3	under repeated loads	(1)		x	normal	-	-	5	-	-	≥ 1,0	A 5.6 2.2.2/6
F4a	under sustained loads	(1)		x	normal	-	-	5	-	-	≥ 0,9	A 5.7 2.2.2/7
F4b	under sustained loads	(1)		x	+ 50 °C (5)	-	-	5	-	-	≥ 0,9	A 5.7 2.2.2/7
F5	at maximum torque moment	Tests in all types of bricks in which the anchor is intended for			normal	5	5	5	5	5	-	A 5.8 2.2.8
F6	under freeze/thaw condition (7)	(1) (2)			normal	-	-	5	-	-	≥ 0,9	A 5.9 2.2.2/8
F7	Checking durability of the bonding material	C20/25			see 2.2.2/9						≥ 0,9 (sulphur) ≥ 1,0 (alkali)	A 5.10 2.2.2/9
F8	At maximum crack width (Δw = 0,5 mm)	Cracked AAC slabs (9)			normal	5	-	5	-	5	≥ 0,8	A.5.1, A.5.2 2.2.2/10
F9	At crack cycling (Δw = 0,1 to 0,3 mm)	Cracked AAC slabs (9)			normal	5	-	5	-	5	≥ 0,9	A.5.11 2.2.2/11

Notes to Table A.1.2

(1) Tests in solid clay masonry units or solid calcium masonry units, resulting from reference tests according to Table A.1.1, line A1 (the maximum resistance is decisive). If the same injection system (mortar and anchor element) is already assessed regarding the specified functioning in accordance with EAD 330499-01-0601 [10], the results of the relevant functioning tests (reduction factors) can also be used for anchors for use in masonry.

(2) Tests in freeze-thaw resistant base material(s) intended for the anchor (concrete 50/60 can be used as default base material - see also A.5.9 of this EAD).

(3) This test may be omitted for condition **d/d** (dry).

(4) Minimum installation temperature resulting from intended use of the anchor.
(5) For temperature range (Tb), for other temperature ranges see 1.2.1.
(6) Reference values from the tests with maximum long-term temperature +50 °C for temperature range (Tb), for other temperature ranges see 1.2.1.
(7) For use condition **w/w** only.
(8) Anchor size: s = smallest; i = intermediate; m = medium; l = largest

If sieve sleeves are used in solid bricks (or solid parts of bricks), the tests shall be done with sieve sleeve otherwise the tests shall be performed without sieve sleeve.

It is assumed that for each injection anchor size there is only one embedment depth. If the injection anchors are used with two or more embedment depths the tests shall be carried out at each depth.
(9) Only if use in cracked AAC slabs according to EN 12602 [6] is intended.
(10) Tests according to [10] 2.2.2.13 in C20/25.

A.2 Test members

A.2.1 General

All tests shall be carried out in the base material (brick or joint) for which the injection anchor is intended to be used. All tests are carried out with test members with h_{min} according to 2.2.6.

The tests shall be carried out at the most unfavourable setting position in the brick, which gives the lowest resistance of the injection anchor. If also injection anchors in joints are intended to be used, the most unfavourable setting positions in joints shall be considered.

The tests in bricks 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 5 N/mm^2 then the minimum mortar strength shall be given in the ETA. The units for test members of AAC may be glued together.

If tests are performed in joints, the maximum thickness of the joint and the minimum mortar strength corresponds to the intended use of the injection anchor and shall be given in the ETA.

The walls may be lightly pre-stressed (about 0,2 N/mm^2 compressive pre-stressing) in the vertical direction to improve handling and transportation of the wall. The pre-stressing force shall 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).

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

A.2.2 Test member for solid masonry material (Base material Group 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 functioning tests and the reference tests shall be performed with single injection anchors approximately in the centre of the unit under tension loading.

The shear tests according to Table A.1.1, series A3, 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.

A.2.3 Test member for hollow or perforated bricks and hollow blocks (Base material Group c)

The location of the injection anchor with respect to the perforation shall be chosen such that the smallest anchor resistance is expected.

A.2.4 Test member for autoclaved aerated concrete (Base material Group d and slabs)

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

Low strength AAC:

mean dry density: $\rho_m \geq 350$ kg/m³

mean compressive strength: $f_{c,m}$ = 1,8 to 2,8 N/mm²

High strength AAC:

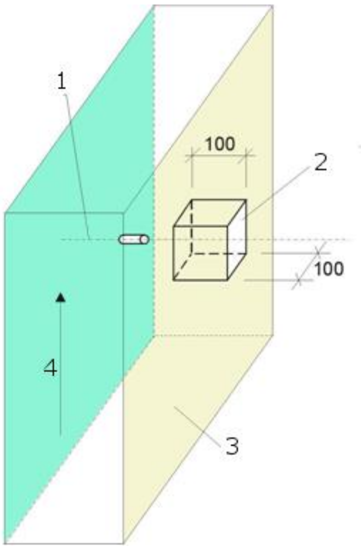
mean dry density: $\rho_m \geq 650$ kg/m³

mean compressive strength: $f_{c,m}$ = 6,5 to 8,0 N/mm²

If these AAC specifications lie outside the parameters allowed in MPII, the lowest or the highest strength respectively, according to MPII shall be used instead.

Samples (cubes/cylinders) shall be taken from the test specimen for determination of the material characteristics (see Figure A.2.4.1). 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 Height of the position of the anchor and the middle of the cube

2 Sample (cube)

3 Test specimen

4 Direction of rise

Dimensions in mm

Figure A.2.4.1 - Taking of samples for autoclaved aerated concrete (AAC)

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 ≤ 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 shall be 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 shall be performed in the direction of metal injection anchor setting (see Figure A.2.4.1).

A.2.5 Test members for tests in cracked AAC

The tests shall be carried out on test members with unidirectional cracks. The crack width shall be approximately constant throughout the member thickness. The thickness of the test member shall be $h \geq 2\ h_{ef}$ but at least 100 mm. To control cracking, so-called ‘crack-formers’ may be built into the member, provided they are not situated near the anchorage zone. An example for a test member is given in Figure A.2.5.1.

In the test with variable crack width the reinforcement ratio (top and bottom reinforcement) shall be

$$\mu = A_s / (b \cdot h) \sim 0{,}01 \qquad \text{(A.2.5.1)}$$

with: μ = reinforcement ratio (top and bottom reinforcement)

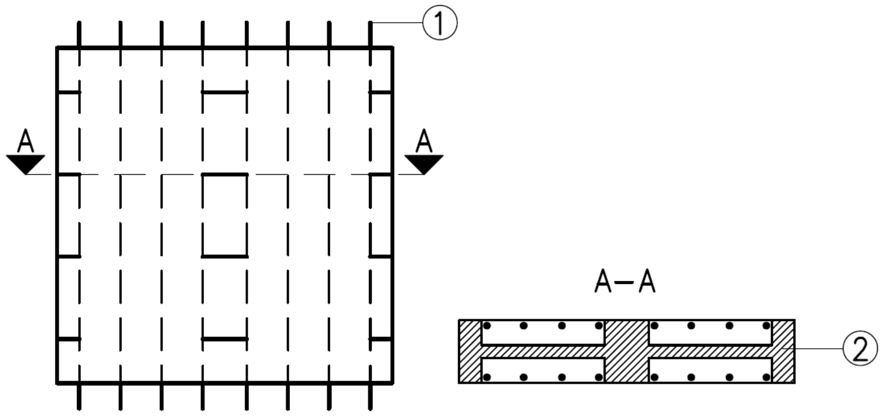
A_s = cross section of the reinforcement

b = width of the test member

h = height of the test member

The spacing of the bars shall be ≤ 250 mm.

For additional information on test member for crack cycling tests see A.5.11.



1 reinforcement

2 crack inducers

Figure A.2.5.1 Example of a test member for anchors tested in cracked AAC

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 functioning tests in dry and wet base material special conditions are specified in A.5.4.

The holes for injection anchors shall be perpendicular (± 5° deviation) to the surface of the member.

If the anchor is intended to be placed in the underside of a slab made of bricks, in the tests the anchor shall be installed upwards in a vertical direction.

In the tests, the drilling tools and the type of drilling specified by the manufacturer shall be used.

If the intended use covers more than one drilling technique, then tests where drilling has an influence shall be carried out for all drilling techniques.

If hard metal hammer-drill bits are used, these bits shall meet the conditions of the standards (e.g., ISO 5468 [16]) 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 (functioning tests and basic tests) the cylindrical hole shall be 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 bit diameter d_0 (mm)	6	8	10	12	14	16	18	20	22	24	30
Tolerances related to nominal drill bit diameter (mm)	+0,4 +0,15	+ 0,45 + 0,2		+ 0,5 + 0,2				+ 0,55 + 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

When testing in cracked AAC, anchors are placed in the middle of hairline cracks. It shall be verified that the anchor is placed over the entire anchoring zone in the crack by suitable methods (e.g., borescope).

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). In unconfined tests an unrestricted formation of the rupture cone of the base material shall be obtained. 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.5.3 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.

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

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 shall be measured. For this reason, a calibrated torque moment transducer with a measuring error < 3 % throughout the whole measuring range shall be used.

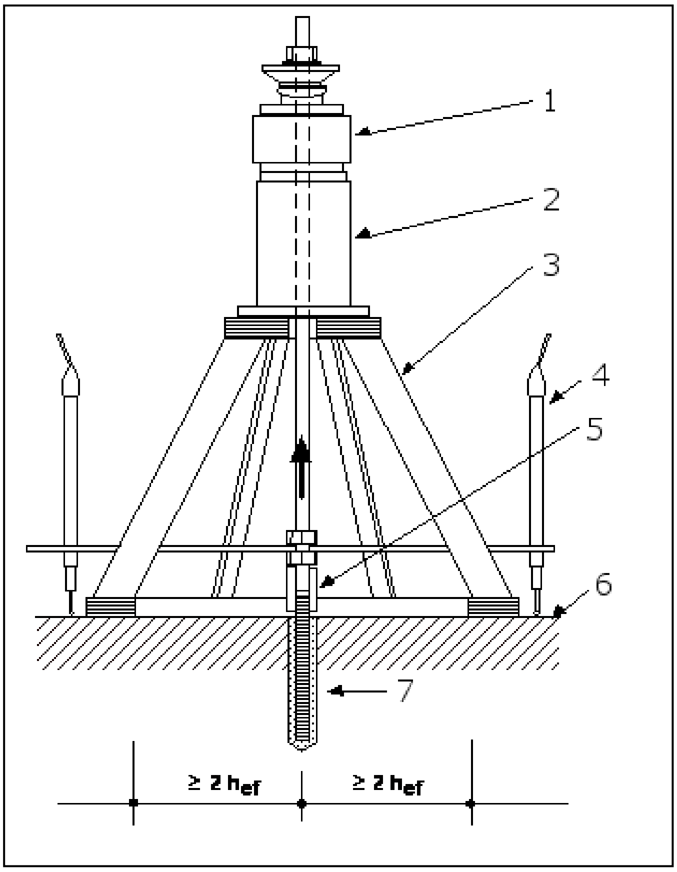
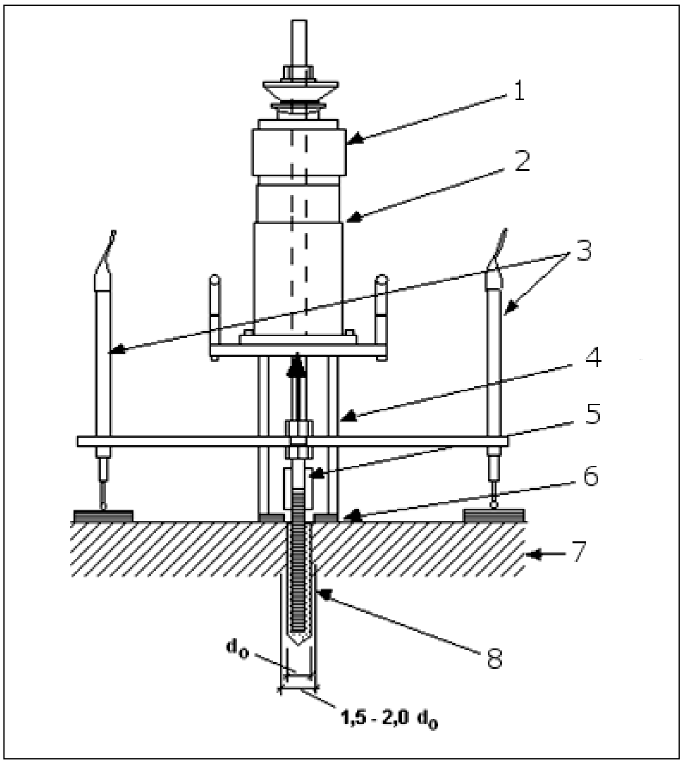


Figure A.4.1 - Example of a tension test rig for unconfined tests



1 Load cell

2 Load cylinder

3 Displacement transducer

4 Support

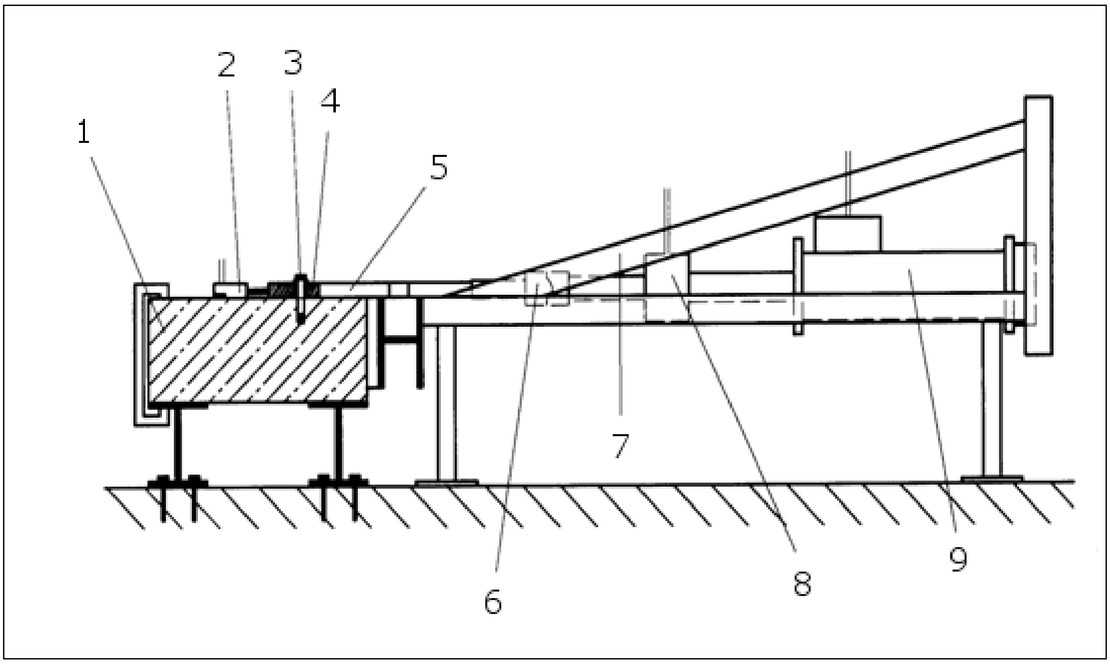
5 Socket

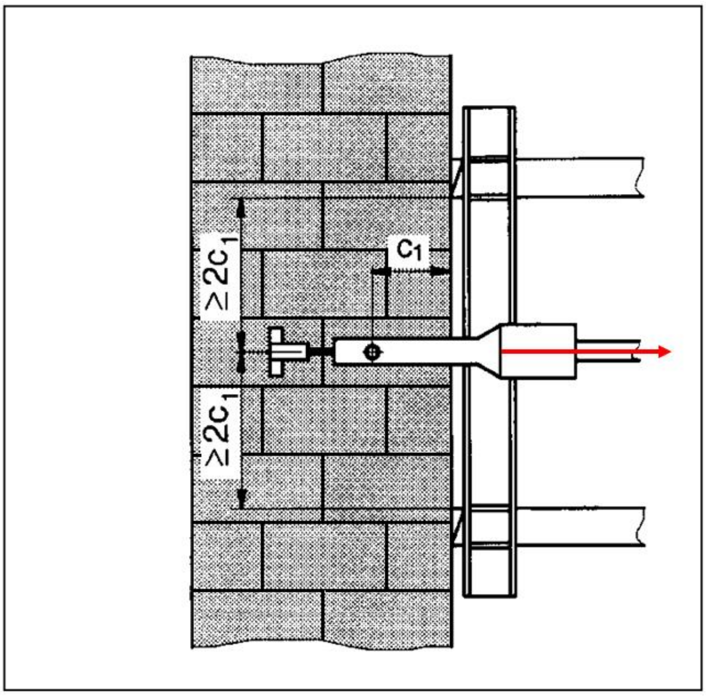
6 Steel plate

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 (tests perpendicular to the edge of masonry)

A.5 Test procedure

A.5.1 General

The basic tests shall be carried out in the base material for which the injection anchor is intended to be used at normal ambient temperature (+21 °C ± 3 °C) as unconfined tension test.

The reference tension tests shall be carried out for determination of the results of the functioning tests. The tests shall be carried out as confined tension tests in the same way as the corresponding functioning tests.

The functioning tests shall be carried out in the base material according to Table A.1.2. The tension tests shall be carried out as confined tension tests.

The tests in cracked AAC shall be undertaken in unidirectional cracks. Δw is the difference between the crack width when loading the anchor and the crack width at anchor installation. After installation of the anchor the crack shall be widened to the required crack width while the anchor is unloaded. The initial crack width shall be set to within +10 % of the specified value. However, the mean value of a series shall reflect the specified value.

Use one-sided tolerance for crack width.

Then the anchor shall be subjected to load while the crack width shall be controlled, either

- at a constant width, for example, by means of a servo system, or
- limited to a width close to the initial value by means of the reinforcement and depth of the test member.

In both cases the crack width at the face opposite to that through which the anchor is installed shall be maintained at a value larger than or equal to the specified value.

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).

The data shall be collected with a frequency of 3 Hz – 5 Hz.

A.5.2 Tension test

After installation, the injection anchor shall be 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.

When testing in cracked AAC, the crack width shall be regularly measured during the test on both sides of the anchor at a distance of approximately $1{,}0\ h_{ef}$ and at least on the face of the test member in which the anchors are installed.

A.5.3 Shear test

After installation, the injection anchor shall be 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 shall be 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.

When testing in cracked AAC, A.5.1 applies. However, the crack widths shall be measured at a distance of approximately h_{ef} behind the anchor. The load shall be applied in the direction of the crack towards the edge.

A.5.4 Functioning in dry or wet base material (test series F1)

(a) Functioning in dry base material

These tests shall be done for all use conditions as confined tension tests in dry solid bricks (dry conditions according to EN 772-1, 7.3.2 [3]).

Drill downwards to the depth required by the manufacturer.

Clean the hole with the equipment supplied by the manufacturer using two blowing operations by hand pump or compressed air and one brushing operations, i.e., either blow-brush-blow or blow-blow-brush or brush-blow-blow. The type of blowing and the order of brushing/blowing shall be done as 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, meaning twice the operations given above.

If the instructions specify less than this, then the above conditions (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 functioning tests shall be carried out without the brushing operation and one blowing only.

If the instruction recommends a vacuum cleaning instead of a blowing operation, the same procedure (including conditions and corresponding reduced operations) applies. If the vacuum cleaning is part of the drilling process, the drilling shall be done without venting (meaning, airing out the dust by periodically moving the drill bit out of the hole) during the drilling process. If the cleaning is performed with suction bit or a hollow drill bit, then the vacuum with the smallest specified maximum flow rate shall be used during the drilling process.

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

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

(b) Functioning in wet base material

Confined tension tests in wet solid bricks.

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

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

A.5.5 Influence of temperature (test series F2)

a) Effect of increased temperature

The confined tension tests shall be carried out at the following temperatures for the different temperature ranges given in 1.2.1:

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

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

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

Tests shall be 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 shall be performed with the maximum short-term temperature and the maximum long-term temperature resulting from intended use of the anchor 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.

Test procedure:

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 base material surface at ± 2 K of the required value, carry out the confined tension test.

b) Effect of low installation temperature

Drill and clean the hole according to the manufacturer's installation instructions then cool the test member to the lowest installation ambient temperature resulting from intended use of the anchor and the bonding material and embedded part to the lowest anchor component installation temperature resulting from intended use of the anchor. 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 base material surface at the specified lowest installation temperature ± 2 K.

c) Minimum curing time at normal ambient temperature

Perform tension tests at normal ambient temperature at the corresponding minimum curing time resulting from intended use of the anchor.

A.5.6 Tests under repeated loading (test series F3)

The injection anchor shall be 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_p and min.N_p according to Equation (A.5.6.1) and (A.5.6.2). The displacements shall be measured during the first loading up to max.N_p and either continuously or at least after 1, 10, 100, 1 000, 10 000 and 100 000 load cycles.

$$\max.N_p = 0{,}4 \cdot N_{um} \tag{A.5.6.1}$$

$$\min.N_p = 0{,}2 \cdot N_{um} \tag{A.5.6.2}$$

with: N_{um} = mean ultimate load in the test series A2 according to Table A.1.1

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 (test series F4)

The test shall be 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** (T = +50°C) and **Tc** (resulting from intended use of the anchor).

The anchor shall be installed at normal temperature.

The anchor shall then subjected to a tension load according to Equation (A.5.7.1) which shall be kept constant (variation within ± 5 %).

$$N_P = 0{,}4 \cdot N_{Ru,m} \tag{A.5.7.1}$$

with: $N_{Ru,m}$ = mean ultimate load in the test series according to Table A.1.1, series A2

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.

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 (test series F5)

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

Tests shall be performed in all types of bricks the anchor is intended for.

The tests shall be carried out at the most unfavourable setting position, which give the lowest failure torque moments.

A.5.9 Functioning under freeze/thaw conditions (test series F1)

The tests shall be carried out for injection anchors with a use condition in wet base material only. The tests shall be 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 shall be 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.5.7.1).

Carry out 50 freeze/thaw cycles as follows:

Raise the temperature of the chamber to +20 ± 2 °C within 1 hour and maintain the chamber temperature at +20 ± 2 °C for 7 hours.

Lower the temperature of the chamber to -20 ± 2 °C within 2 hours and maintain the chamber temperature at -20 ± 2 °C for 14 hours (total of 16 hours).

If the test is interrupted, the specimens 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 (test series F7)

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 or diamond core concrete cylinders from slabs can be used.

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 shall be carefully sawn into 30 mm thick slices (perpendicular to the axis of the cylinder) 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 shall be subjected to water with high alkalinity and condensed water with sulphurous atmosphere. For comparison, reference 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 shall be 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 shall be 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 [15]. The slices shall be put into the test chamber, however in contrast to EN ISO 6988 [15] 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 shall be measured and the metal segments of the bonded anchors shall be pushed out of the slice, in such a way that 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.5.11 Crack cycling under load (test series F9)

Experience has shown that the crack movements are difficult to steer with rebar in AAC. Therefore, it is recommended to steer the crack movements with a concrete slab as described in A.2.5. The AAC slab shall be cut and fixed undisplaceable to a cracked concrete slab such that the crack of AAC and concrete slab are directly above each other. The crack opening shall be created in the concrete slab whereas the measurement of the crack width shall be located on both sides of the AAC slab over the joint (see Figure A.5.11.1). The anchor shall be installed in the middle of the crack.

After installation of the anchor the maximum (max N_s) and minimum (min N_s) loads applied to the test member shall be determined such that the crack width under max N_s is Δw_1 = 0,3 mm and under min N_s is Δw_2 = 0,1 mm. To stabilize crack formation, up to 10 load changes varying between max N_s and min N_s may be applied. Then a tensile load N_p shall be applied to the anchor after opening the crack to Δw_1 = 0,3 mm by using an unconfined test setup.

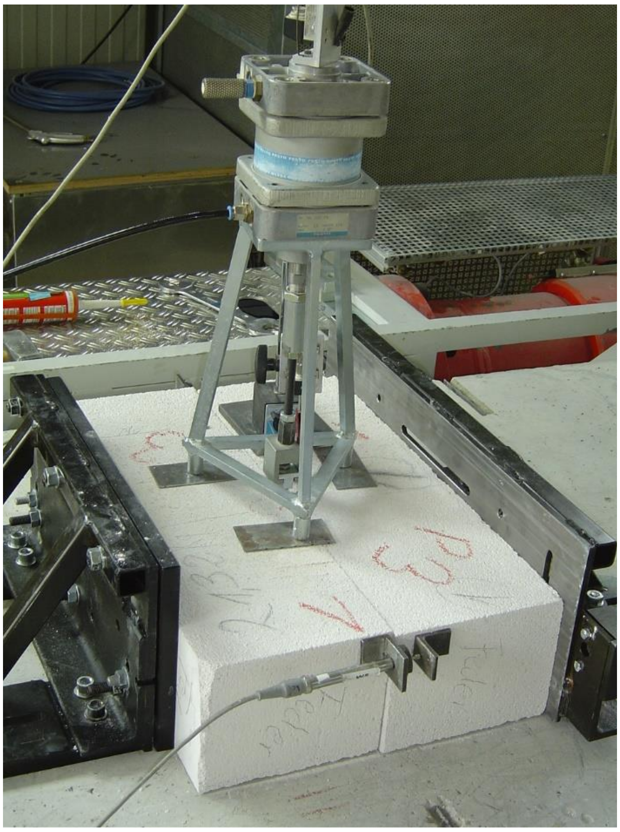
$$N_p = 0{,}4 \cdot N_{um} \qquad \text{(A.5.11.1)}$$

with: N_{um} = mean ultimate load in the test series according to Table A.1.1, series A2

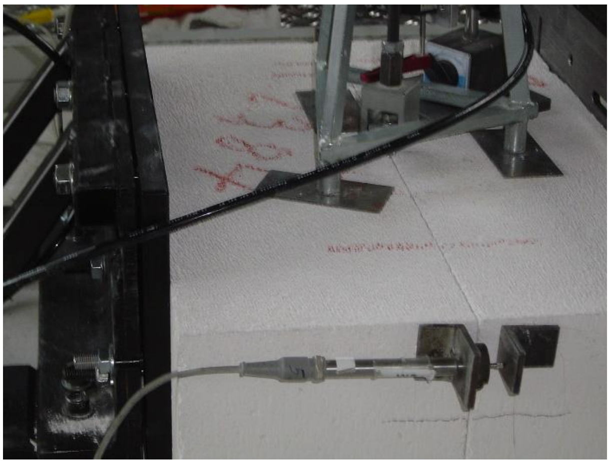
N_p shall remain constant during the test (variation ± 5%). Then the crack shall be opened and closed 1000 times (frequency approximately 0,2 Hz). During opening of the cracks, the crack width Δw_1 shall be kept approximately constant (see Figure A.5.11.2); for this purpose, the load max N_s applied to the test member may be reduced. The load min N_s shall be kept constant. Therefore, the crack width Δw_2 may increase during the test (see Figure A.5.11.2). The crack width difference Δw_1 - Δw_2, however, shall be ≥ 0,1 mm during the 1000 movements of the crack. If this condition cannot be fulfilled with Δw_1 = 0,3 mm, then either min N_s shall be reduced or Δw_1 shall be increased accordingly.

The load/displacement behaviour shall be measured up to the load N_p. Afterwards under N_p, the displacements of the anchor and the crack widths Δw_1 and Δw_2 shall be measured either continuously or at least after 1, 2, 5, 10, 20, 50, 100, 200, 500, 750 and 1000 crack movements.

After completion of the crack movements the anchor shall be unloaded, the displacement δ_1 measured and a tension test by using a confined test setup to failure performed with Δw = 0,3 mm.



a) Brackets for anchoring and an adhesive cartridge for additional fixation



b) Support, load application and displacement measurement

Figure A.5.11.1– Examples for test setup for test series F9

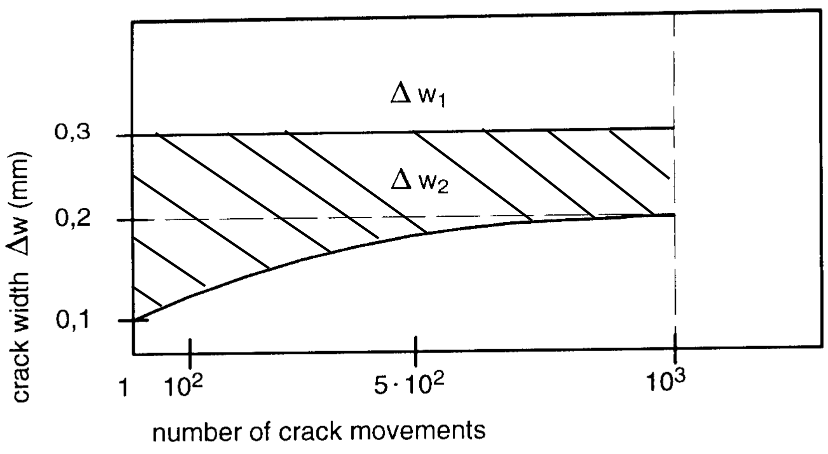


Figure A.5.11.2 - Allowable crack opening variations during the crack movement test

A.6 Test report

The report shall include at least the following information:

General

- Description and type of injection anchor
- Injection mortar (batch number, expiry date)
- Anchor dimensions, sieve sleeve dimensions/material, production method (if relevant)
- Anchor material properties (e.g., coating, tensile strength, yield strength, elongation at rupture)
- 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
- Mortar package: designation, size of package, type of cartridge
- Mortar: mass of components, density, viscosity, reactivity, infrared analysis

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 and normalised value according to EN 772-1 [3])
- Mean gross dry density according to EN 772-13 [14]
- mean dry density and measured value of compressive strength at the time of testing (individual values and mean values) according to EN 12602 [6]
- 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 dispenser
- 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 h_{ef}
- Information on the direction of installation
- Installation time and testing time or other parameters for control of installation
- Type of attachment
- Position of the anchor over load transfer zone in the crack
- Verification method of anchor position in crack, e.g., borescope (sketch of crack formation over load transfer zone)

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 (Load-displacement curve)
- Any special observations concerning application of the load
- Failure load, load at loss of adhesion
- Failure mode
- Radius (maximum radius, minimum radius) and height of a cone produced in the test (where applicable)
- Particulars of repeated load tests (test series F3):
  - minimum and maximum load
  - frequency of cycles
  - number of cycles
  - displacements as function of the number of cycles
- Particulars of sustained load tests (test series F4):
  - 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 T_u (test series F5)
- Particulars of crack tests (test series F8 and F9):
  - crack opening mechanism (describe how the crack width in the area of the load transfer zone is ensured)
  - amount / type of crack width measurement (e.g., 4 / capacitive sensor)
  - position of the crack width sensors
  - determination of crack width at anchor
  - diagram containing: crack width at the anchor position for the top and bottom of the load transfer zone, plot the cycles in normal logarithmic scale, plot the upper and the lower crack width
  - measuring uncertainty for crack width transducers

ANNEX B GENERAL ASPECTS OF ASSESSMENT

B.1 Conversion of ultimate loads

Conversion of ultimate loads to take into account the 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 following Equation:

$$F_{Ru}(f_b) = F_{Ru}^{t} \cdot \left(\frac{f_b}{f_{b,test}} \right)^{\alpha} \qquad \text{(B.1.1)}$$

with:

$F_{Ru}(f_b)$	=	failure load at unit compressive strength f_b (given in the ETA)
α	=	0,5 for masonry units of clay or concrete and solid unit of calcium silicate
α	=	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 unit strength for the characteristic resistance)
$f_{b,test}$	=	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 f_b shall be given in the ETA)

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 (B.1.1) may be used as an approximation.

Conversion of ultimate loads to take into account the autoclaved aerated concrete unit strength:

The test results shall be converted as far as compressive strength and dry density are concerned.

Compressive strength:

For prefabricated reinforced AAC members the characteristic compressive strength f_{ck} of strength classes AAC 2 and AAC 7 given in EN 12602 [6] shall be used for conversion of test results.

For AAC blocks the characteristic compressive strength (used for conversion of ultimate loads) shall be determined from the declared characteristic value of compressive strength according to EN 771-4 [2] using the factor of 0,9.

$$f_{ck} = 0{,}9\ f_{c,decl} \qquad \text{(B.1.2)}$$

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: $\rho_{min} = 650\ kg/m^3$

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

$$F_{Ru}(f_{ck}) = F_{Ru}^{t} \cdot \frac{\rho_{min}^{3/4} \cdot f_{ck}}{\rho_{test}^{3/4} \cdot f_{c,test}} \qquad \text{(B.1.3)}$$

with:

$F_{Ru}(f_{ck})$	=	failure load at unit compressive strength f_{ck} (used for conversion)
ρ_{test}	=	dry density of the AAC blocks at the time of testing $\geq \rho_{min}$
ρ_{min}	=	dry density of the AAC blocks given in the ETA
$f_{c,test}$	=	compressive strength of the AAC blocks at the time of testing $\geq f_{ck}$

For the strength between low and high strength AAC the characteristic failure loads shall be determined by linear interpolation of the converted test results.

<u>Conversion of ultimate loads to take into account the steel strength:</u>

In case of steel failure the failure load shall be converted to the nominal steel strength by following Equation:

$$F_{Ru}\,(f_{uk}) = F^{t}_{Ru} \cdot \frac{f_{uk}}{f_{u,test}} \tag{B.1.4}$$

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

$f_{u,test}$ = steel ultimate strength at the time of testing ≥ f_{uk}

B.2 Determination of the 5%-fractile of the ultimate loads

The 5%-fractile of the ultimate loads shall be calculated according to statistical procedures for a confidence level of 90 %. A logarithmical normal distribution and an unknown standard deviation of the population shall be assumed and the following steps shall be carried out:

1) Determination the logarithmic values of the ultimate loads

$$\varphi_i = ln\left(F_{u,i}\right) \tag{B.2.1}$$

2) Perform the statistical analysis determining the fractile value based on logarithmic data

$$\varphi_m = \sum_{i=1}^{n}\left(\frac{\varphi_i}{n}\right) \tag{B.2.2}$$

$$s(\varphi) = \sqrt{\frac{\sum_{i=1}^{n}(\varphi_m - \varphi_i)^2}{(n-1)}} \tag{B.2.3}$$

$$\varphi_{5\%} = \varphi_m - k_s \cdot s(\varphi) \tag{B.2.4}$$

3) Determine the standard fractile value from the logarithmic fractile value

$$F_{5\%} = e^{\varphi 5\%} \tag{B.2.5}$$

with: φ_i = logarithmic values of the ultimate load of a test

$F_{u,i}$ = ultimate loads of a test, if needed: converted to nominal values according to B.1

n = number of tests of a test series

φ_m = mean value of logarithmic values of a test series

$s(\varphi)$ = standard deviation of logarithmic values of a test series

$\varphi_{5\%}$ = 5%-fractile of logarithmic values of a test series

k_s = statistical factor according to [31]

e. g.: n = 5 tests: k_s = 3,40

n = 10 tests: k_s = 2,57

$F_{5\%}$ = 5%-fractile of ultimate loads in a test series, if needed: converted to nominal values

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.

B.3 Coefficient of variation of ultimate load

If the coefficient of variation of the ultimate load in the functioning test is greater than 30 %, then the following α_V-value shall be taken into account:

$$\alpha_V = \frac{1}{1 + 0{,}03 \cdot (v[\%] - 30)} \leq 1{,}0 \tag{B.3.1}$$

If the coefficient of variation of the ultimate load in the basic test is greater than 20 %, then the following α_V-value shall be taken into account:

$$\alpha_V = \frac{1}{1 + 0{,}03 \cdot (v[\%] - 20)} \leq 1{,}0 \tag{B.3.2}$$

B.4 Reduction factor

In the functioning test series F1 to F4 and F6 according to Table A.1.2 the factor α shall be calculated as follows:

$$\alpha = \min ((F_{um,t} / F_{um,r}) ; (F_{5\%,t} / F_{5\%,r})) \quad \text{(B.4.1)}$$

with: $F_{um,t}$ = mean failure load in a test series

$F_{um,r}$ = mean failure load in the reference test series A1 according to Table A.1.1

$F_{5\%,t}$ = 5% fractile of failure loads of a test series according to B.1

$F_{5\%,r}$ = 5% fractile of failure loads in the reference test series A1 according to Table A.1.1 according to B.1

Equation (B.4.1) 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 evaluation of 5%-fractile values may be omitted when the coefficient of variation of the functioning 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 functioning test series is $v \leq 15$ %.

B.5 Load/displacement behaviour

<u>Anchors used in solid masonry units (bond between steel element, injection mortar and masonry)</u>

With injection anchors uncontrolled slip occurs when the bonding material 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 $N_{u,adh}$.

$N_{u,adh}$ 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 B.5.1a). If the change in stiffness at a defined load is not so obvious, e.g., the stiffness is smoothly decreasing, then the load at loss of adhesion shall be evaluated as follows:

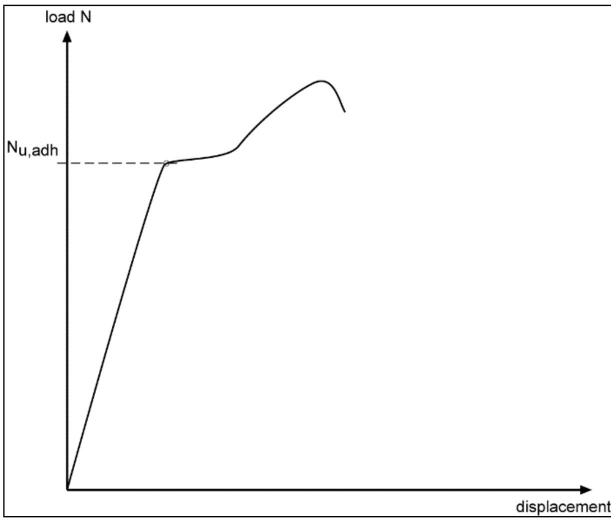
1) Compute the tangent to the load-displacement curve at a load 0,3 N_u (N_u = peak load in test). In general the tangent stiffness can be taken as the secant stiffness between the points (0/0) and (0,3 $N_u/\delta_{0,3}$) ($\delta_{0,3}$ = displacement at N = 0,3 N_u).
2) Divide the tangent stiffness 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 B.5.1b).
5) 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 $N_{u,adh}$ shall be taken as the peak load, see Figure B.5.1c).
6) 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 B.5.1d).

For all tests the factor α_1 shall be calculated according to following Equation:

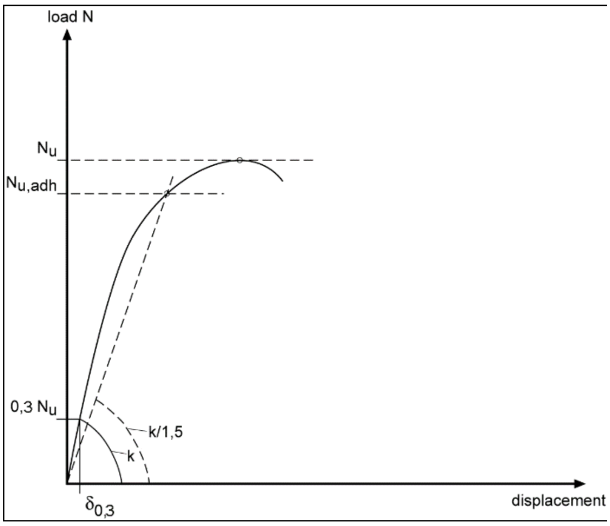
$$\alpha_1 = \frac{N_{u,adh}}{0{,}5 \cdot N_{Ru}} \leq 1{,}0 \quad \text{(B.5.1)}$$

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

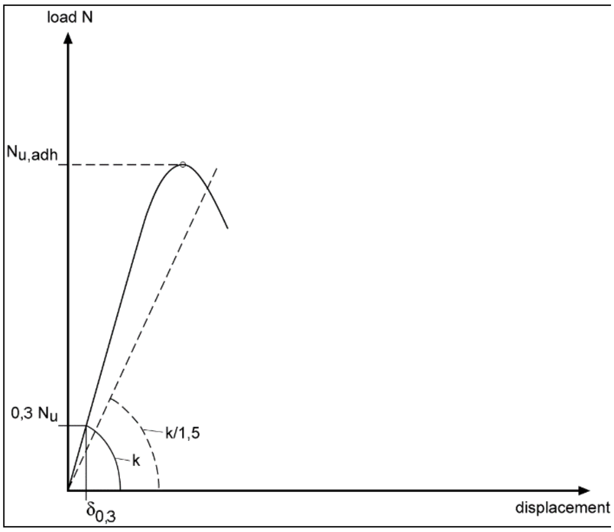
The evaluation of the load at loss of adhesion is not required when failure occurs between mortar and embedded part along the entire embedment depth (see definition of uncontrolled slip). In this case the factor α_1 may be taken as 1,0.



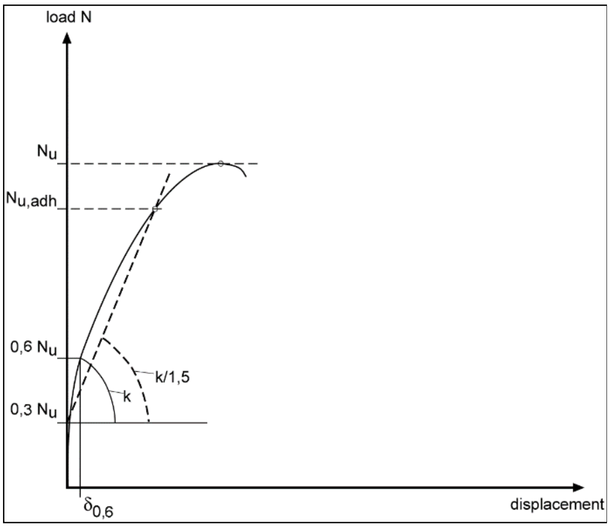
a) Load at uncontrolled slip by a significant change of stiffness



b) Evaluation of uncontrolled slip



c) Evaluation of uncontrolled slip



d) Evaluation of uncontrolled slip

Figure B.5.1 – Example of load-displacement curve (solid masonry)

<u>Anchors used in hollow or perforated masonry units and solid masonry with open structure (porous) material (mechanical interlock of the mortar with parts of the masonry)</u>

Uncontrolled slip is characterised by a significant change of stiffness according to Figure B.5.2. The corresponding load when uncontrolled slip starts is called N_1.

For all tests, the factor α_1 shall be calculated according to the following Equation:

$$\alpha_1 = \frac{N_1}{0{,}5 \cdot N_{Ru}} \leq 1{,}0 \qquad \text{(B.5.2)}$$

with: N_1 = load at which uncontrolled slip of the anchor occurs (see Figure B.5.2)
N_{Ru} = maximum load of single test

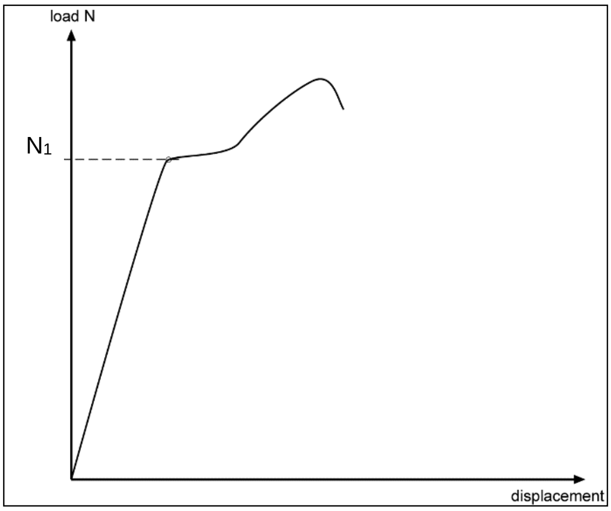


Figure B.5.2 – Example of load-displacement curve (hollow or perforated masonry)

ANNEX C DETAILS OF TESTS FOR DETERMINATION OF SEISMIC RESISTANCE AND GENERAL ASPECTS OF ASSESSMENT

C.1 Scope

This Annex covers details of tests for metal injection anchors for use in masonry made of solid units under seismic actions.

The compressive strength of the masonry unit $f_{b,test}$ used in this document shall consistently represent the value measured according to EN 772-1 [3]. The compressive strength of the masonry mortar $f_{m,test}$ used in this document shall consistently represent the value measured according to EN 1015-11 [30]. If necessary, the masonry unit compressive strength or the masonry mortar compressive strength shall be converted accordingly (see section C.3.5).

C.2 Abbreviation and Notation

The specific terms for assessment under seismic action are listed in section 1.3.

C.3 Test methods

C.3.1 Test program

The additional tests for metal injection anchors in masonry under seismic actions are given in Table C.3.1.1. All tests shall be performed for each brick type according to the intended use.. Corresponding monotonic tests according to Table A.1.1, test series A2 (tension loading) and A3 (shear loading) in walls with the same brick and mortar type made in the same way concerning brick bond pattern shall be available (compare B.3.2).

Test series M1-R and M1 shall be performed with the same steel strength and embedment depths - as defined in C.3.3.2 and C.3.3.3 - and tension test set-up as unconfined tests, see C.3.2.2. Test series M2-R and M2 shall be performed with the same steel strength and embedment depths - as defined in C.3.3.2 and C.3.3.3 - and shear test set-up, see C.3.2.2.

Table C.3.1.1: Tests for qualification of metal injection anchors in masonry made of solid bricks under seismic actions

<table>
<tr><th></th><th>Purpose of test</th><th>Base material (brick type)</th><th>Crack width Δw [mm]</th><th>Size (diameter)</th><th>Minimum number of tests</th><th>Embedment depth h_{ef}</th><th>Anchor location</th></tr>
<tr><td>M1-R</td><td>Reference tension tests</td><td rowspan="4">Brick of masonry group b or d</td><td rowspan="4">0,5</td><td>All</td><td>5</td><td rowspan="4">as requested (1)</td><td rowspan="4">T-joint</td></tr>
<tr><td>M2-R</td><td>Reference shear tests</td><td>s/m/l</td><td>5</td></tr>
<tr><td>M1</td><td>Functioning under increasing tension displacement amplitudes</td><td>All</td><td>5</td></tr>
<tr><td>M2</td><td>Functioning under increasing shear displacement amplitudes</td><td>s/m/l</td><td>5</td></tr>
</table>

<u>Notes to Table C.3.1.1</u>

(1) Value(s) shall comply with basic tests according to Table A.1.1. If multiple embedment depths are specified only the minimum and maximum embedment depth need to be tested. For intermediate embedment depth the minimum seismic reduction factor obtained from these tests shall be taken.

C.3.2 General testing conditions

As far as applicable, Annex A shall be followed for test members, test setup and details of tests. Modifications are addressed in the following of section C.3, which overrule incompatible provisions in Annex A.

C.3.2.1 Test members

The tests shall be performed in a wall. At the beginning of testing the test specimens shall be at least 21 days old. The thickness of the joints shall be about 10 mm and the joints shall be completely filled with mortar of the same type and strength class used for the basic tests according to this EAD (i.e., strength class M2.5 with a strength ≤5 N/mm², unless otherwise applied for by the manufacturer and specified in the ETA). It is noted that according to EN 1998-1 [11], section 9.2.3, for design of masonry buildings in seismic areas, the recommended value for the minimum mortar strength is 5 N/mm². Thus, tests can be conducted in such members. In all cases, the minimum mortar strength covered shall be given in the European Technical Assessment.

To avoid any premature damage to the members, they may be lightly pre-stressed (about 0,2 N/mm² compressive pre-stressing) in the vertical direction to facilitate handling and transportation of the member. Similarly, for crack creation and crack steering during testing the members shall be pre-stressed by about 0,2 N/mm² at maximum (see section C.3.2.3). To achieve a uniform distribution of stress in the member, the pre-stressing force should be applied in the quarter points of the member using adequate stiff girders for load distribution.

The minimum thickness of the test member shall comply with the intended use given by the manufacturer under consideration of the conditions according to section A.2.

The width of the test member shall be large enough to avoid any influence of the free member edges on the anchor behaviour. This condition is considered to be fulfilled if for unconfined tension testing the masonry breakout body does not intersect with an edge or the edge distance of the anchor in all directions is $c \geq 2h_{ef}$.

An example for a test setup with test members and pre-stressing frame is given in Figure C.3.2.1.1.

The tests shall be carried out on test members with unidirectional cracks in the horizontal masonry mortar joint with the anchor located at the intersection of vertical and horizontal joint (aka “T-joint”) as shown in Figure C.3.2.1.12. In a masonry test member, one or more crack planes may be created. However, in the latter the cracks should be spaced in a manner that precludes influence on individual anchors placed in a crack from adjacent cracks. Further details concerning crack width, crack creation and steering are given in section C.3.2.3.

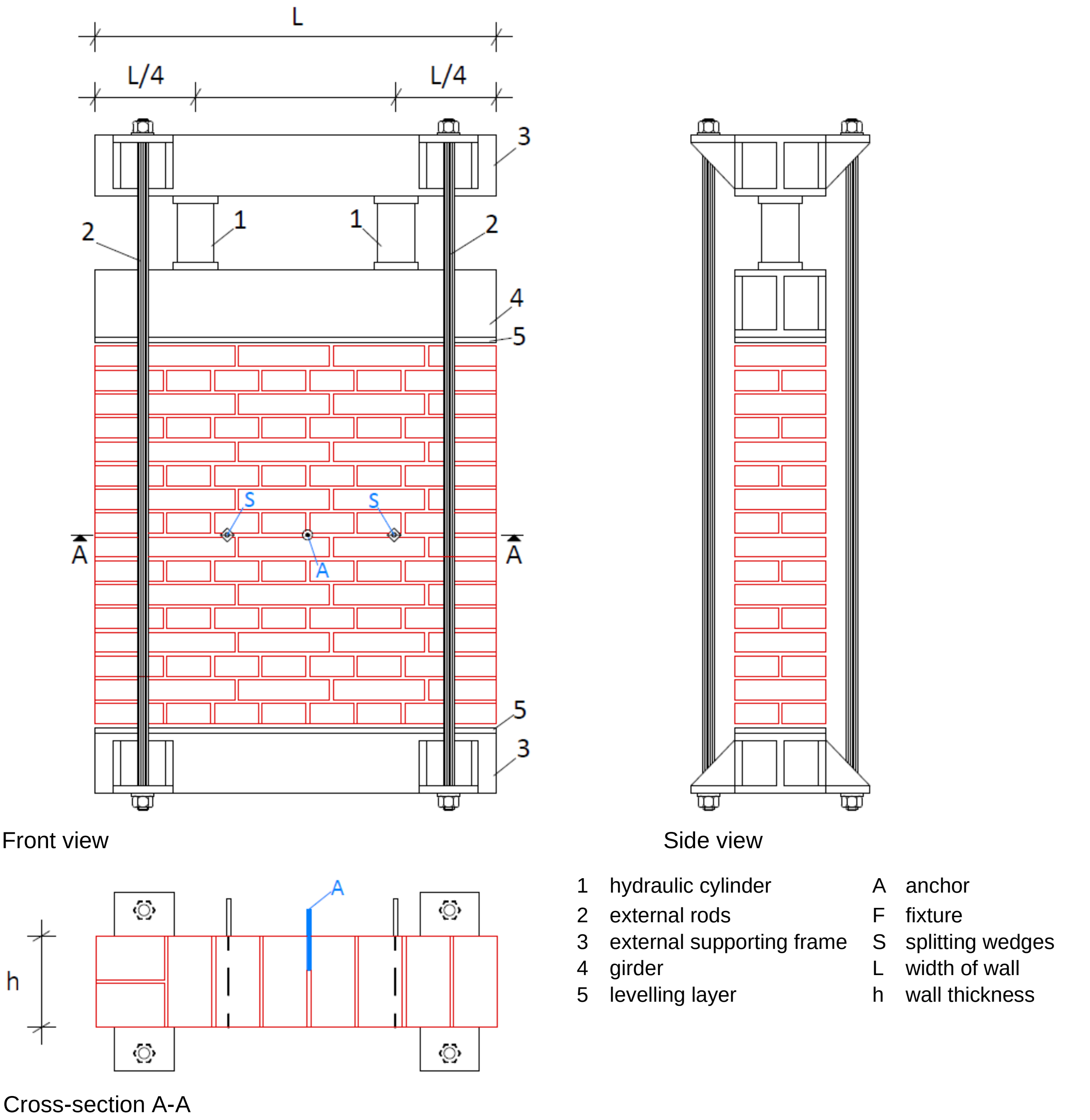


Figure C.3.2.1.1: **Example for test setup with test member and pre-stressing frame for cracked masonry testing (no external restraints given)**

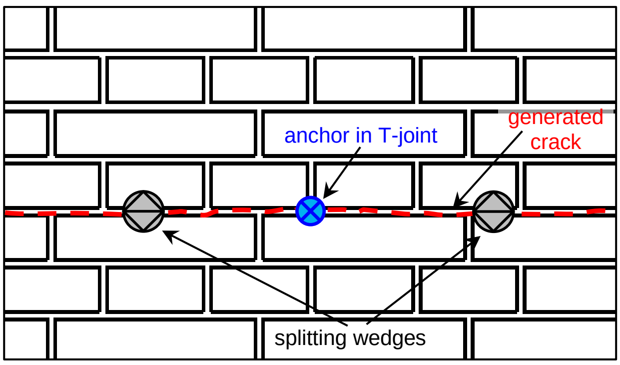


Figure C.3.2.1.2: **Horizontal crack, placement of wedges and anchor location for seismic testing**

C.3.2.2 Test setup

All tension tests shall be performed as unconfined tests according to section A.4, and section C.3.4. It shall be ensured that in both tension series (according to Table C.3.1.1, test series M1-R and M1) and both shear series (according to Table C.3.1.1, test series M2-R and M2), the same setup for measuring the displacements is used (i.e., for example the same fixture thickness, clearance hole in the fixture and same measuring location with respect to the anchor) to ensure the same conditions concerning the applied displacement steps in the cyclic series.

In shear tests uplift of the fixture (steel plate) shall be restrained such that no significant friction forces are induced. Such friction forces are avoided if for example a setup as shown in Figure C.2 is used, which prevents the uplift, limits friction by roller bearing and does not actively apply a compression force. Furthermore, the maximum allowed annular gap of the clearance hole (see Annex A.4, Table A.4.1) shall be selected in the shear tests. For anchors with a specified smaller gap or without an annular gap (e.g., realized by specific measures are prescribed in the MPII, such as filling of the gap with injection mortar), both of which shall be stated in the ETA, the specific anchor system may be tested.

All tests shall be performed at normal ambient temperature (21°C ± 3°C).

Note C.3.2.2.1: The effect of high loading rates on the anchor behaviour is conservatively neglected.

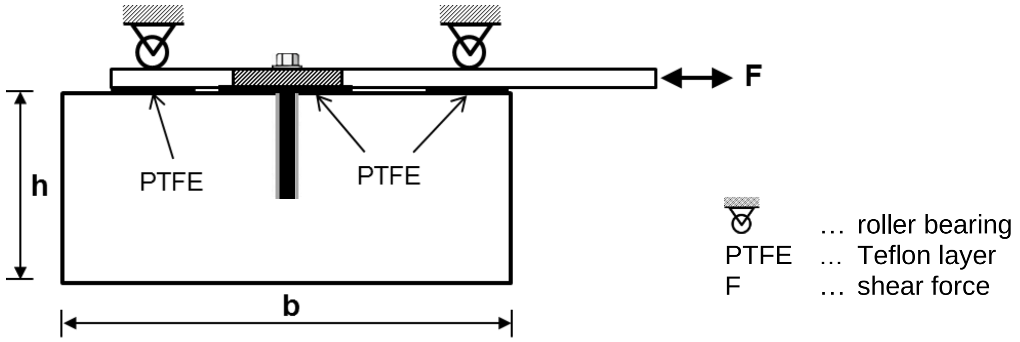


Figure C.2.2.2.1: Sketch of example for shear test setup with no significant friction forces

C.3.2.3 Crack creation and control

C.3.2.3.1 Generation of cracks in test members

The following methodology shall be followed for crack initiation and opening:

- Apply a prestress of at maximum 0,2 N/mm². The prestress limits the initial crack opening and stabilizes the process.
- At the designated T-joint location (compare Figure) drill the hole with the drill bit diameter required for the size of the tested injection anchor. Drilling of the hole for the anchor prior to crack initiation is intended to facilitate the crack propagation in the desired plane.
- For crack creation steel wedges running in expansion steel sleeves shall be used. Space pilot holes for the wedges approximately equidistant and symmetrically to the anchor location (T-joint) within each bed joint where cracking is desired. The number of wedges shall ensure a uniform crack propagation and thus depends on the test member dimensions. At least 2 wedges shall be used, one on each side of the anchor. Drill pilot holes with diameter equal to the outer diameter of the expansion steel sleeves in the centre of the horizontal mortar joints and through the thickness (h) of the test specimen. The pilot holes shall be placed at bricks next to those bricks adjoining the anchor or at least $2h_{ef}$ away from the anchor axis (see Figure).
- Initiate hairline cracks by inserting expanding semi-cylindrical steel sleeves into the pilot holes and driving the steel wedges through the sleeves. After crack initiation, check if the crack propagation is along the desired plane along the horizontal joint with the crack intersecting the anchor's drill hole along its axis, e.g., by means of a boroscope or a similar device.
  If the crack does not follow the desired path or does not intersect the anchor drill hole, this location shall not be used.
  If the crack follows the desired path, remove the wedges and install the anchor to be tested in the T-joint. For removal of the steel wedges the prestress may be lowered.

- After curing of the injection mortar, apply a prestress of maximum 0,2 N/mm² to the wall, replace and re-drive the wedges into the expanding sleeve until the specified crack width for the relevant test series is reached. Before loading the anchor, the average crack width, measured as described in section C.3.2.3.2, shall be equal to or greater than the specified crack width for the test series.

C.3.2.3.2 Crack measurement, control and tolerance on crack width

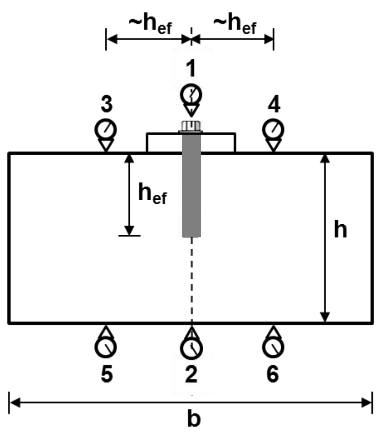
The crack width shall be measured continuously during the test with a measuring error not greater than 0,02 mm. The following information refers to the crack width after anchor installation and before load application.

In tension tests the crack width Δw_{hef} shall be determined as follows:

- The placement of the measurement devices for the crack width is shown in Figure C.3.2.3.2.1. The crack widths shall be measured at the top (used here to describe the side at which the anchor is installed) and bottom (used here to describe the averted side from anchor installation) of the test member either at the anchor axis (location 1 (Δw_{top}) at the anchor installation side and location 2 (Δw_{bot}) at the averted side) or symmetrically and as close as possible to the anchor at a maximum distance no larger than h_{ef} (locations 3 & 4 and 5 & 6). If the crack widths are measured symmetrically on both sides, the mean value of the crack width measurements at locations 3 and 4 represents Δw_{top} and the mean value of the crack width measurements at locations 5 and 6 represents Δw_{bot}. The crack width Δw_{hef} shall be obtained by linear interpolation of the top and bottom crack widths, i.e., Δw_{top} and Δw_{bot}, respectively.

In shear tests the crack width shall be measured within a distance of approximately 1,0 h_{ef} in front of and behind the anchor (and the mean value shall be determined) or directly at the anchor location where possible.

The mean of the measured crack widths Δw_{hef} for each test series determined for each anchor shall be equal to or greater than the specified crack width for the test series. Individual crack widths should be within a tolerance of ± 15 percent of the specified crack width.



… crack measurement device

h … thickness of wall

Figure C.3.2.3.2.1: Measurement of crack width

The crack width before load application to the anchor shall be approximately constant throughout the member thickness. This condition is considered to be fulfilled if

a) the crack width Δw_{hef} at the level of the embedment depth h_{ef} is equal to or greater than the required value, and
b) the crack width Δw_{top} at the top side of the test member (i.e., the side in which the anchor is installed) is equal to or larger than Δw_{hef}.

During loading of the anchor, the crack width shall be recorded but not controlled (steered).

C.3.2.4 Installation of anchors

C.3.2.4.1 Anchor location

The anchor shall be located at the intersection of vertical and horizontal masonry mortar joints (compare Figure). It shall be verified that the anchor is located in the middle of the T-joint in or next to the hairline crack over its entire embedment depth, h_{ef}, e.g., by use of a borescope.

C.3.2.4.2 Installation procedure

Install the anchor in a hairline crack as described in section C.3.2.4.1, and in the manufacturer's printed installation instructions (MPII), except for the installation torque. No installation torque T_{inst} shall be applied in the tests according to Table C.3.1.1 to represent adverse conditions and account for effects of different fixture types and relaxation. Anchors shall only be finger-tightened prior to testing. Test internally threaded anchor with the bolt specified by the manufacturer and report the bolt type in the test report.

Use drill bits with a diameter $d_{cut,m}$ (medium) in accordance with Section A.3.

C.3.3 Anchor types to be tested

In general, the tests described in C.3.4 shall be performed with all anchor diameters, embedment depths, steel types (galvanised steel, stainless steel, high corrosion resistant steel) and grades (strength classes and lowest rupture elongation), production methods, types of inserts (threaded rod, threaded sleeve or rebar), different mortar versions as well as drilling methods to be assessed for use in seismic applications. The number of variants to be tested may be reduced as described below. It shall be allowed to perform additional tests beyond the minimum number of tests described below to verify anchor characteristics for additional parameters (e.g., tests at different embedment depths).

Testing shall be performed on anchors manufactured with the same material batch and production lot. All measured values concerning manufacturer's specifications shall be included in the test reports.

Loosening of the nut or screw shall not occur during testing.

If certain reference tension tests, which are required in the context of this assessment, have not been performed in the assessment under static loading according to this EAD, these tests shall be performed.

C.3.3.1 Type of insert

C.3.3.1.1 Tension tests

If the characteristic resistance under static and quasi-static loading is statistically equivalent for different types of inserts (threaded rod, rebar, internal threaded sleeve etc.) tests can be performed with the most adverse type of insert and the results shall be applied to all other types of inserts. If the characteristic resistance is different, all types of inserts shall be tested.

C.3.3.1.2 Shear tests

Shear tests (test series M2.R and M2) need to be performed for the smallest, medium and largest diameters only. For intermediate sizes the smaller performance $\alpha_{V,seis}$ of the neighbouring tested sizes shall be used.

C.3.3.2 Steel type, steel grade and production method

C.3.3.2.1 Tension tests

Only one steel type needs to be tested. The steel type with the highest strength shall be selected. The measured displacements shall be applied to anchor of all steel types and grades.

C.3.3.2.2 Shear tests

All steel types and steel grades shall be tested, except if the reduction of the characteristic steel shear resistance due to simulated seismic shear testing (according section 2.2.10) shall be determined from tests carried out with anchors made of the highest grade and lowest rupture elongation steel (percentage of elongation after fracture, A, see EN ISO 898-1 [8]), and accepted for all steel types and steel grades.

The measured displacements shall be applied to the anchors made from other steel types, steel grades or by other production methods.

C.3.3.3 Embedment depth

C.3.3.3.1 Tension tests

If multiple embedment depths are specified for a diameter, only the minimum and maximum embedment depths need to be tested. In this case, for intermediate embedment depth the minimum reduction factor $\alpha_{N,seis}$ according to Equation (2.2.9.17) from these tests shall be taken.

C.3.3.3.2 Shear tests

If there is more than one embedment depth specified for an anchor diameter, tests need to be performed for the minimum and maximum embedment depth only. If in the tests with minimum embedment depth steel failure occurs, tests at the maximum embedment depth may be omitted, if the reduction factor $\alpha_{V,seis}$ according to Equation (2.2.10.19) is applied to all embedment depths.

C.3.3.4 Drilling method

For tension loading, all drilling methods prescribed in the MPII shall be tested.

For shear loading, a reduction of the number of drilling methods to be tested is allowed as follows. The hole shall be drilled with the drilling method giving most adverse results under tension loading, which in many cases will be diamond coring. If the most adverse drilling method cannot be determined, tests will all of them are required.

C.3.4 Tests

C.3.4.1 General regulations for all series

All test series shall be performed in masonry specimen with the same layout (masonry bond pattern) made with the same batches of bricks, masonry mortars and anchors (steel element and injection mortar). All tests shall be performed as unconfined tests with a support diameter of at least $3h_{ef}$ at the middle of the intersection of the horizontal and vertical masonry joints (T-joint; see Figure) in cracked condition with a crack width as specified in Table C.3.1.1.

C.3.4.2 Reference tension and shear tests (test series M1-R and M2-R)

The tension test series M1-R and shear test series M2-R shall be performed in accordance with A.4 and A.5.1, as well as C.3.2 and C.3.4.1. In the shear test the loading shall be applied parallel to the direction of the crack (i.e., in line with the horizontal joint).

C.3.4.3 Stiffness values for determination of displacements

For the determination of the displacements under seismic action, the initial tangent stiffness from the reference series shall be used as basis for both, tension and shear loading, these values shall be defined by the same procedure. Therefore, in the following the loads shall be denominated P_i, which in the case of tension tests (M1.R) refers to the respective tension loads N_i and in the case for shear tests (M2.R) to the shear loads V_i.

The initial tangent stiffness k_{tan} shall be evaluated according Equation (C.3.4.3.1) as the mean value of all tests of a series. As no installation torque shall be applied in the tests (compare C.3.2.4.2), it is assumed that the load-displacement curves start at the origin. Therefore, for simplification the basic initial stiffness $k_{tan,i}$ of each test shall be calculated as secant stiffness between the origin and a load $P_{tan,i}$ in the linear-elastic range of the load-displacement curve with corresponding displacement $\delta(P_{tan,i})$ as given by Equation (C.3.4.3.2). In general, this load can be assumed as $P_{tan,i} = 0{,}3F_{u,i}$ (for tension loading compare Figure B.1b and Figure B.1c), unless otherwise justified.

$$k_{tan} = \frac{1}{n}\sum_{i=1}^{n} k_{tan,i} \qquad \text{(C.3.4.3.1)}$$

with:

$$k_{tan,i} = \frac{P_{tan,i}}{\delta(P_{tan,i})} \qquad \text{(C.3.4.3.2)}$$

$P_{tan,i}$	=	load in linear-elastic range of load-displacement curve representative for calculation of initial stiffness
$\delta(P_{tan,i})$	=	displacement corresponding to load $P_{tan,i}$ of test i
n	=	number of tests in series

C.3.4.4 Tests under pulsating tension load (test series M1)

The tests shall be performed according to C.3.2, C.3.4.1 and C.3.4.2 with the following modifications:

Open the crack by Δw = 0,5 mm. The tension loading shall be applied quasi-statically under displacement-controlled conditions. Subject the anchor to the tension displacement amplitudes specified in Table C.3.4.4.1 and Figure C.3.4.4.1 with a cycling frequency no greater than 0,5 Hz. Each displacement step consists of 3 cycles. In the unloading phase of the anchor the displacement shall only be reduced until the corresponding load level in the anchor reaches zero and the anchor does not experience compressive stresses. This means that for displacements steps exceeding the linear elastic range residual displacements at the end of each cycle will occur.

All anchors in a test series shall follow the pulsating tension displacement history specified in Figure C.3.4.4.1 and Table C.3.4.4.1 as long as, when increasing the displacement, the measured first cycle load has dropped to a level equal to or below 80% of the overall ultimate load measured in the same test. After reaching this point the the displacements shall be increased as residual loading until failure of the anchor. The purpose of this test is to reach the ultimate load at or after the fourth displacement step (i.e., after ≥ 10 cycles in total).
If the ultimate load is reached earlier (i.e., below 10 cycles), additional tests shall be conducted with reduced spacing between incremental displacement steps until the aforementioned requirement is reached. This minimum number of cycles before reaching ultimate load guarantees that a sufficient number of datapoints in the evaluation of the reduction factor $\alpha_{N,2}$ is available.
If the ultimate load or a drop in the load-displacement behaviour to a level equal to or below 80% of the ultimate load of the test has not occurred after displacement step 9, testing shall be continued with additional displacement steps (3 cycles per step) as given in Table C.3.4.4.1 (i > 9) until a load drop to a load level of 80% or below of the ultimate load of the test has occurred. Then the displacements shall be increased as residual loading until failure of the anchor.
A series shall comprise at least 5 tests according to these criteria.

For loading triangular or sinusoidal cycles may be used. The bottom of the tension displacement cycles may be taken in a way to lead to corresponding anchor forces being slightly greater than zero to avoid servo control problems but the force shall not exceed N_{min}, with N_{min} being the maximum of 0,02 · $N_{u,m,M1.R}$ (for $N_{u,m,M1.R}$ see section 2.2.9/2) and 200 N. The crack width shall be monitored during load cycling.

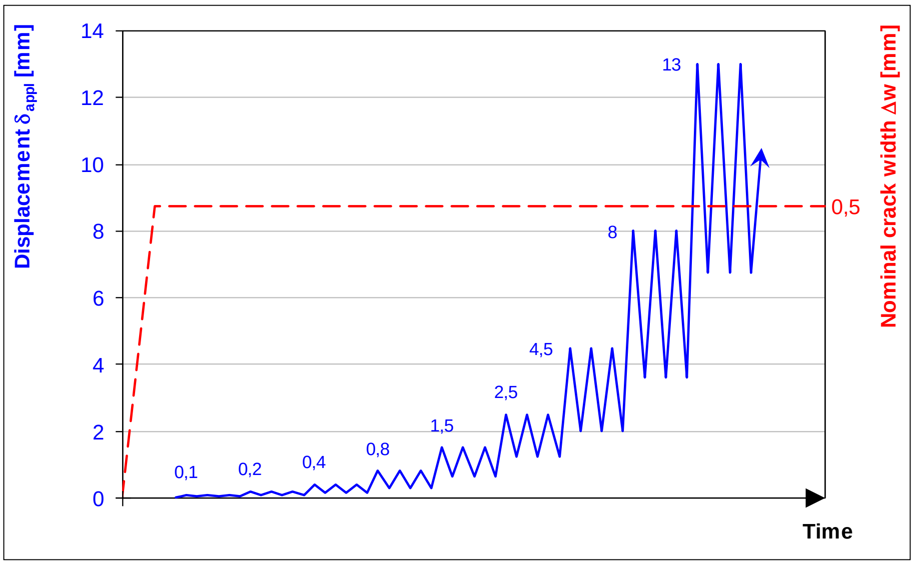


Figure C.3.4.4.1: Schematic test procedure - displacement steps for test series M1

Table C.3.4.4.1: Displacement amplitudes δ_{appl} for test series M1

Displacement Step	Displacement amplitude δ_{appl} [mm]	Number of cycles	Crack width Δw [mm]
1	0,1	3	0,5
2	0,2	3	
3	0,4	3	
4	0,8	3	
5	1,5	3	
6	2,5	3	
7	4,5	3	
8	8	3	
9	13	3	
i > 9 [1)]	$\delta_{appl,i-1}$ + 5	3	
[1)] Only required, if the load in a single test did not drop below $0,8N_{Ru}$ until previous displacement step (i-1).			

Record the crack width, applied anchor displacement and tension load continuously during the simulated seismic tension cycles. Plot the load-displacement response. Report the maximum load at maximum displacement and the crack width as a function of the number of loading cycles.

C.3.4.5 Tests under alternating shear load (test series M2)

The tests shall be performed according to C.3.2, C.3.4.1 and C.3.4.2 with the following modifications:

Open the crack by Δw = 0,5 mm. The shear loading shall be applied quasi-statically under displacement-controlled conditions. Subject the anchor to the shear displacement amplitudes specified in Table and Figure with a cycling frequency no greater than 0,5 Hz. The given displacement steps are valid for fixtures without annular gap. In case of an annular gap, they shall be increased accordingly. Each displacement step consists of 3 cycles.

All anchors in a test series shall follow the alternating shear displacement history specified in Figure and Table as long as the the measured first cycle load has dropped to a level equal to or below 80% of the overall ultimate load measured in the test. After reaching this point the the displacements shall be increased as residual loading until failure of the anchor. The purpose of this test is to reach the ultimate load at or after the fourth displacement step (i.e., after ≥ 10 cycles in total)
If the ultimate load is reached earlier (i.e., below 10 cycles), additional tests shall be conducted with reduced spacing between incremental displacement step spacing until the aforementioned condition is reached. This minimum number of cycles before reaching ultimate load guarantees that a sufficient number of datapoints in the evaluation of the reduction factors $\alpha_{V,2}$ and $\alpha_{V,3}$ are available.
If the ultimate load or a drop in the load-displacement behaviour to a level equal to or below 80% of the ultimate load of the test has not occurred after displacement step 9, testing shall be continued with additional displacement steps (3 cycles per step) as given in Table (i > 9) until a load drop to or below 80% of the ultimate load of the test has occurred. Then the displacements shall be increased as residual loading until failure of the anchor.
A series shall comprise a least 5 tests according to these criteria.

The load shall be applied parallel to the direction of the crack (i.e., parallel to horizontal joint). To reduce the potential for uncontrolled slip during load reversal, an approximation by two half-sinusoidal load cycles at the required frequency connected by a reduced speed, ramped load (see Figure b) or simply triangular loading cycles (see Figure c) may be used in place of sinusoidal cycles (see Figure a). The crack width shall be monitored during load cycling.

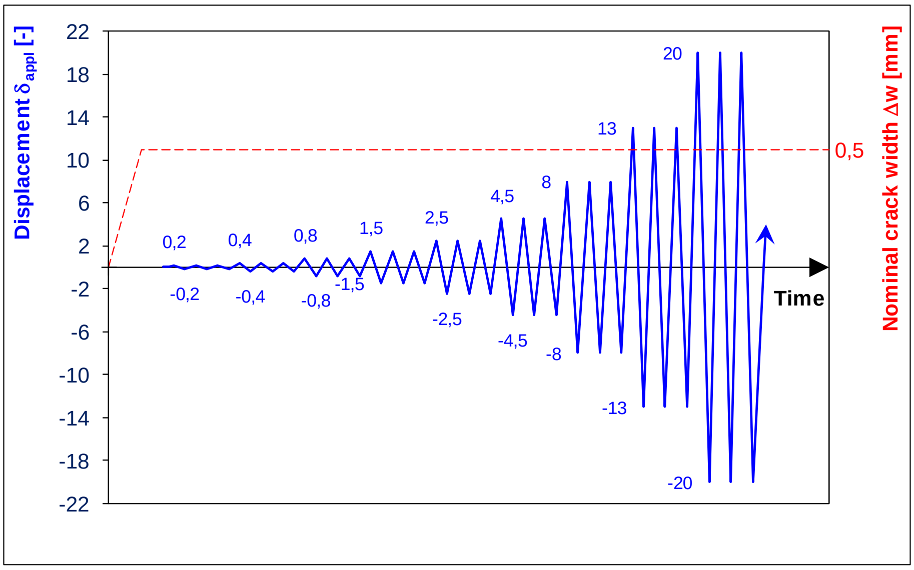
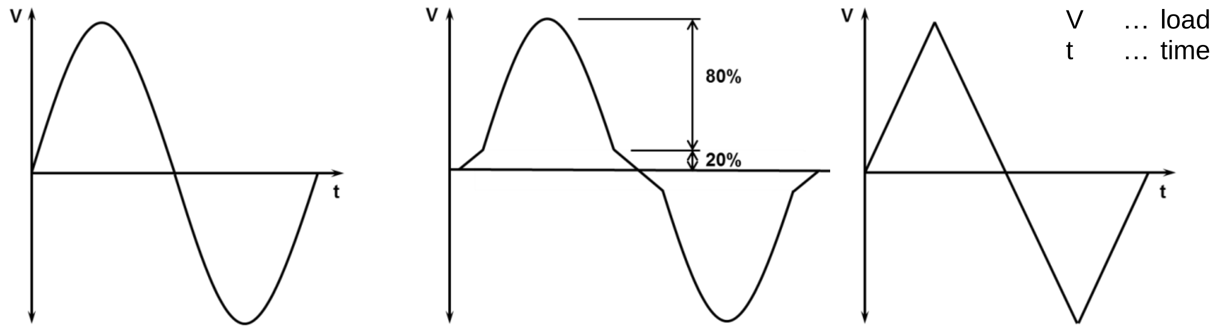


Figure C.3.4.5.1: Schematic test procedure for test series M2

Table C.3.4.5.1: Displacement amplitudes δ_{appl} for test series M2

Displacement Step	Displacement amplitude δ_{appl} [mm]	Number of cycles	Crack width Δw [mm]
1	0,2	3	0,5
2	0,4	3	
3	0,8	3	
4	1,5	3	
5	2,5	3	
6	4,5	3	
7	8	3	
8	13	3	
9	20	3	
i > 9 [1)]	$\delta_{appl,i-1} + 7$	3	

[1)] Only required, if the load in a single test did not drop below $0{,}8N_{Ru}$ until previous displacement step (i-1).



a) sinusoidal b) half sinusoidal with ramp c) triangular

Figure C.3.4.5.2: Permitted seismic shear cycle in series M2

Record the crack width, applied anchor displacement and shear load continuously during the simulated seismic shear cycles. Plot the load-displacement response. Report the minimum and maximum load at minimum and maximum displacement, respectively, and the crack width as a function of the number of load cycles.

Note C.3.4.5.1: During the shear load cycling test failure may occur in the embedded portion of the anchor. If such a failure occurs close to the embedded end of the anchor the ultimate capacity may not be significantly affected. Hence, in this case failure of the anchor during cycling may easily be overlooked. Attention should be paid to this aspect.

C.3.5 Normalization of test results

The test results shall be normalised to nominal material values by converting the ultimate loads according to section B.1 (i.e., Equation (B.1.4), if steel failure occurred in the reference tests, and according to Equations (C.3.4.3.1) or (B.3.5.1), if failure is correlated with the masonry unit) or by Equation (C.3.5.1) given below, if failure is dominated by the masonry mortar.

$$F_{Ru}\,(f_m) = F^t_{Ru} \cdot \left(\frac{f_m}{f_{m,test}}\right) \qquad \text{(C.3.5.1)}$$

with:

$F_{Ru}\,(f_m)$ = failure load at masonry mortar nominal compressive strength f_m (given in the ETA)

$f_{m,test}$ = compressive strength of the masonry mortar at the time of testing, with $f_{m,test} > f_m$(if $f_{m,test} < f_m$, then $f_{m,test}$ or the next smaller strength f_m shall be given in the European Technical Assessment)

Adjustment for different steel strengths is not required if the metal anchoring elements in all tests are taken from the same production lot.

If mixed failure modes occur in a test series, the normalization shall be performed assuming that the more frequently occurring failure mode occurred in all tests.

C.4 Seismic Test report

In addition to the minimum information listed in section A.6, the report shall include at least the following information regarding the seismic tests:

Test members

- Age of wall specimen at date of testing
- Drawing of test member with brick layout and nominal dimensions
- Masonry mortar mix
- Measured value of joint thicknesses of vertical and horizontal (bed) joint at the testing location
- Measured value of masonry mortar compressive strength according EN 1015-11 **Error! Reference source not found.**]

Anchor installation information

- Verification of crack intersecting the drill hole and applied method (e.g., borescope)
- Thickness of fixture [mm]
- Clearance hole [mm]
- min / max temperature of test member over curing time
- (hairline) crack width before and after anchor installation

Test characteristics

- Description of crack opening equipment and procedure
- Compressive pre-stress applied on wall
- Description of displacement measuring location (e.g., at top of anchor for tension, in front of or behind fixture for shear)
- Amount and type of crack width measurement
- Position of crack width sensors
- Determination of crack width at anchor (e.g., linear interpolation)
- Measuring uncertainty for crack width transducer
- Minimal and maximal frequency during the test
- Type of loading cycles (sinusoidal or triangular) in test series M1 and M2

Test results

- Diagrams containing:
    - Crack width at anchor location during testing
    - Complete load-displacement curve
    - Load-displacement envelope curves for 1st,2nd and 3rd cycles of cyclic series M1 and M2
- Applied number of displacement steps and number of cycles at ultimate load and in total
- Displacement amplitudes for series M1 and M2 according to Table C.3.4.4.1 and Table C.3.4.5.1.