EUROPEAN ASSESSMENT DOCUMENT

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METAL INJECTION ANCHORS FOR USE IN MASONRY

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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

This EAD covers the assessment of post-installed injection anchors placed into pre-drilled holes in masonry and anchored by bonding and mechanical interlock.

This EAD applies to injection anchors consisting of a threaded rod, deformed reinforced bar, internal threaded socket, or other shapes and the mortar, placed into drilled holes 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). Mesh sleeves made of metal or plastic are also covered in this EAD as part of the anchoring system (see Figure 2).

This EAD applies to anchors in which all the metal anchoring element directly anchored in the masonry and designed to transmit the applied loads are made either of carbon steel, stainless steel or malleable cast iron. If threaded rods are used as metal anchoring element, these threaded rods (including nuts and washers) can be delivered by the manufacturer or they can be 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.

Metal anchoring element, nuts, washers and sieve sleeve are described by the manufacturer by reference to dimensions (outer/inner diameter, thread length, etc.) and material properties (e. g. tensile and yield strength, fracture elongation including possible tolerances.

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

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

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

This EAD covers injection anchors in masonry with a maximum characteristic resistance of 12 kN.

The anchor may be specified by the manufacturer in terms of:
-    material of the embedded element (e.g. galvanized steel, stainless steel)
-    material grade of the embedded element (e.g. steel strength class 5.8, A4-70)
-    dimensions of the embedded element (e.g. diameter, shape)
-    type of the embedded element (e.g. threaded rod, internal threaded rod)
-    installation with or without sieve sleeve.

The specific anchor and the corresponding essential characteristic are given in the ETA.

Different versions of an anchor with respect to material, strength, type or dimensions are marked such that the relevant product characteristic may be allocated to the corresponding anchor type.

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

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. Sieve sleeve
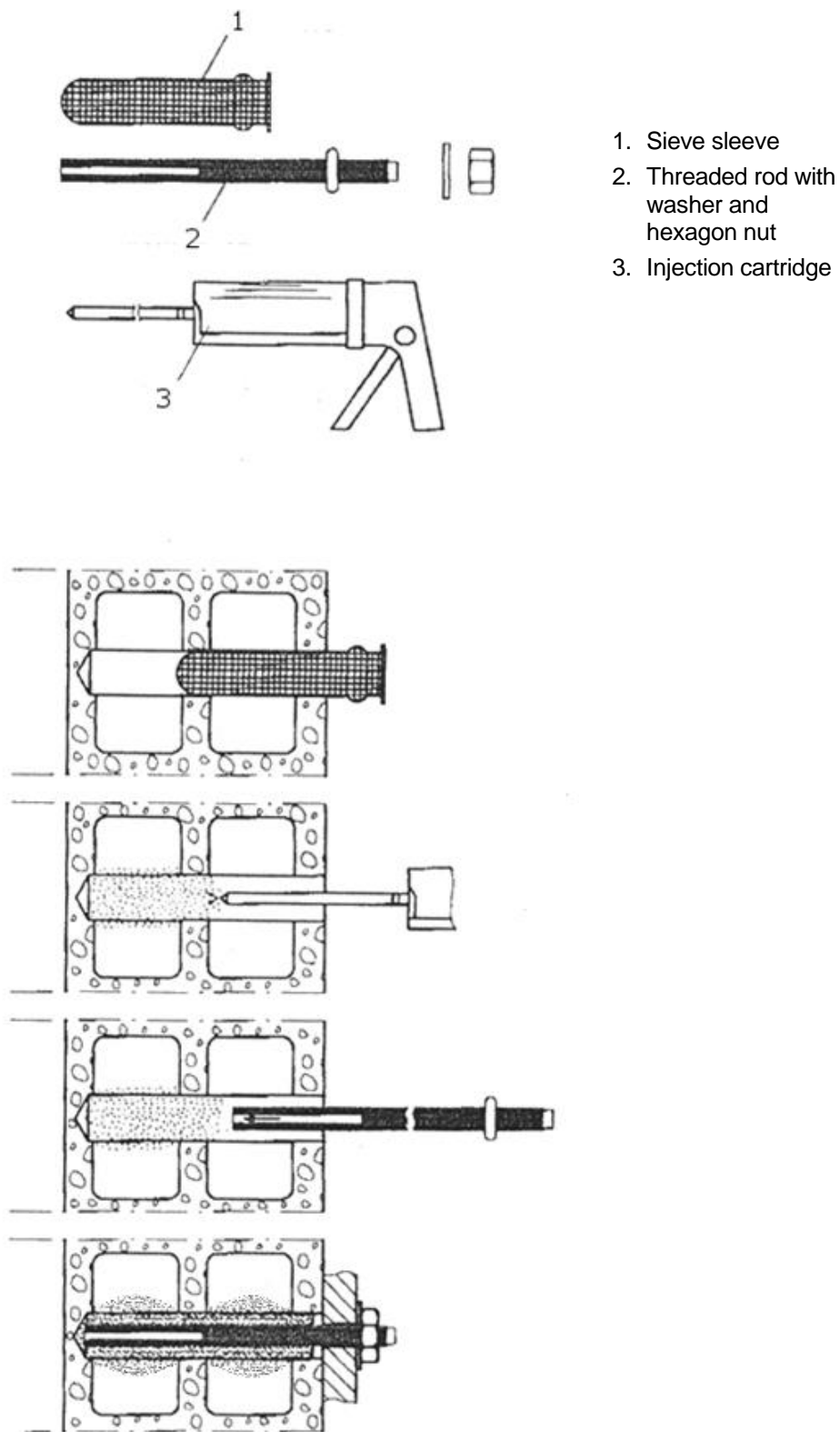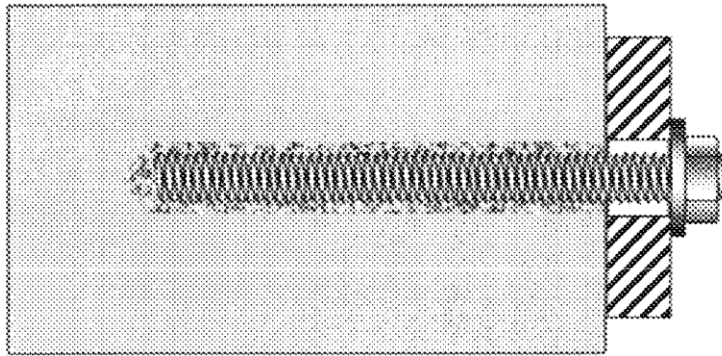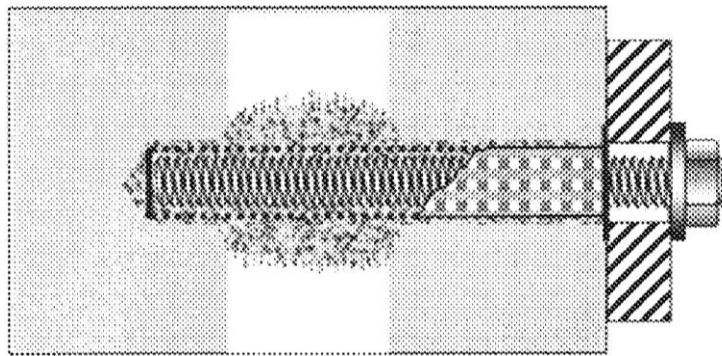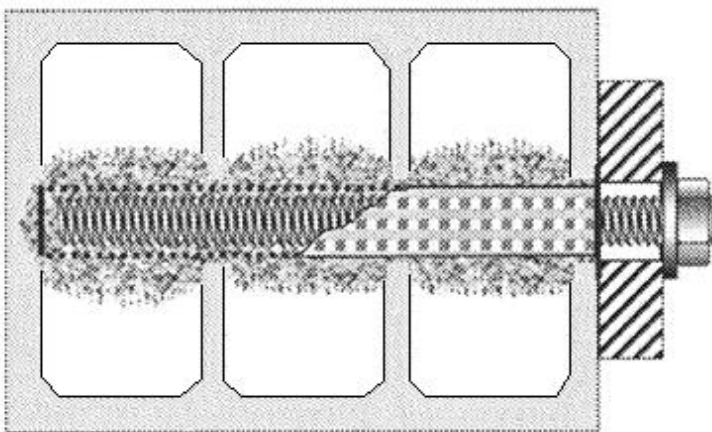2. Threaded rod with washer and hexagon nut
3. Injection cartridge

Figure 1 – Example of injection anchors

Threaded anchor rod set in solid brick using injection mortar

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

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

Figure 2 – Example of injection anchors

1.2 Information on the intended use of the construction product

1.2.1 Intended use

This EAD applies to the use of injection anchors in masonry units of clay, calcium silicate, normal weight concrete and lightweight aggregate concrete (solid and hollow or perforated format blocks), autoclaved aerated concrete or other similar materials.

As far as the specification of the different masonry units is concerned, EN 771-1 to 5:2011 [2] may be taken as reference. The construction of masonry structures in which the injection anchors are to be anchored shall be comparable with the structural rules for masonry, such as EN 1996-1-1:2005+A1:2012, Clause 3 and 8 [6] and the relevant national regulations.

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

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

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

The base materials are divided into following groups:

Masonry 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)

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

Masonry Group **d**: Metal injection anchors for use in **autoclaved aerated concrete masonry**

Furthermore following use conditions in respect of installation and use are differentiated:

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

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

Condition **w/w**: **Installation 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 0 °C and +40°C.

The resistance and the displacements of an injection anchor shall not be adversely affected by temperatures in the base material near to the surface within a temperature range to be specified by the manufacturer which may be either:

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**: on manufacturer's request with - 40 °C to T1
(maximum short term: T1 > + 40 °C and maximum long term: 0,6 T1 to 1,0 T1)

The relevant structural rules for masonry, the masonry groups, the specific masonry units including consideration of plaster or similar materials, the use and installation conditions as well as the temperature range are given in the ETA. The relevant specifications of the installation instructions given by the manufacturer (especially concerning drilling technology, borehole cleaning, installation tools, torque and curing time) are stated in the ETA.

This EAD applies only to anchors subject to static or quasi-static actions in tension, shear or combined tension and shear or bending. The anchors are intended to be used in areas with no and very low seismicity as defined in EN 1998-1:2004 + AC:2009, Clause 3.2.1 [11]. This EAD covers applications only where the masonry members in which the anchors are embedded are subject to static or quasi-static actions.

The anchor is intended to be used for anchorages which are designed according to TR 054 [12] under the responsibility of an engineer experienced in anchorages and masonry work.

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 fastener for the intended use of 50 years when installed in the works (provided that the anchor 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[1].

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.

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[1] 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.

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)
c_{cr}	=	edge distance for ensuring the transmission of the characteristic resistance of a single injection anchor
c_{min}	=	minimum edge distance
d	=	anchor bolt/thread diameter
d_0	=	drill hole diameter
d_{cut}	=	cutting diameter of drill bit
$d_{cut,m}$	=	medium cutting diameter of drill bit
d_f	=	diameter of clearance hole in the fixture
d_{nom}	=	outside diameter of anchor
h	=	thickness of masonry member (wall)
h_{min}	=	minimum thickness of masonry member
h_0	=	depth of cylindrical drill hole at shoulder
h_1	=	depth of drilled hole to deepest point
h_{ef}	=	effective anchorage depth
h_{nom}	=	overall anchor embedment depth in the masonry
l_{unit}	=	length of the masonry unit
h_{unit}	=	height of the masonry unit
s	=	spacing of the injection anchor
s_{cr}	=	spacing for ensuring the transmission of the characteristic resistance of a single injection anchor
$s_{cr,\parallel}$	=	s_{cr} parallel to the horizontal joint
$s_{cr,\perp}$	=	s_{cr} perpendicular to the horizontal joint
s_{min}	=	minimum spacing
T	=	torque moment
T_{inst}	=	maximum installation torque moment allowed by the manufacturer
T_u	=	maximum torque moment during failure
t_{fix}	=	thickness of fixture
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 772-1:2011 [3]) given in the ETA
$f_{b,test}$	=	normalised mean compressive strength of the test masonry unit (according to EN 772-1:2011 [3]) at the time of testing
$f_{y,test}$	=	steel tensile yield strength in the test
f_{yk}	=	nominal characteristic steel yield strength
$f_{u,test}$	=	steel ultimate tensile strength in the test
f_{uk}	=	nominal characteristic steel ultimate strength

Loads / Forces

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

Tests / Assessment

F_{Ru}^{t}	=	ultimate load in a test
$F_{Ru,m}^{t}$	=	mean ultimate load in a test series
F_{Rk}^{t}	=	5 %-fractile of the ultimate load in a test series
n	=	number of tests of a test series
v	=	coefficient of variation
$\delta(\delta_N, \delta_V)$	=	displacement (movement) of the anchor at the masonry surface relative to the masonry surface in direction of the load (tension, shear) outside the failure area. The displacement includes the steel and masonry deformations and a possible anchor slip.
δ_0	=	displacement of the anchor under short term loading
δ_∞	=	displacement of the anchor under long term loading
α	=	reduction factor
β	=	reduction factor for all different influences
N_{Rk}, V_{Rk}	=	characteristic anchor resistance of a single anchor under tension or shear force
$N_{Rk,p}$	=	characteristic anchor resistance to pull out failure of a single anchor under tension load
$N_{Rk,b}$	=	characteristic anchor resistance to brick break out failure of a single anchor under tension load
$V_{Rk,b}$	=	characteristic anchor resistance to local brick failure of a single anchor under shear load
$V_{Rk,s}$	=	characteristic anchor resistance to steel failure of a single anchor under shear load
N_{Rk}^{g}, V_{Rk}^{g}	=	characteristic anchor resistance of an anchor group under tension or shear force
$V_{Rk,c}^{g}$	=	characteristic anchor resistance of an anchor group under shear force near the edge
$\alpha_{g,N}, \alpha_{g,V}$	=	group factor under tension or shear load

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:	Specified by the manufacturer 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 $\pm$ 3 °C (for test conditions only)
Open time:	The maximum time from end of mixing to when the insertion of the anchor into the bonding material shall be completed.
Installation ambient temperature:	The temperature range of the base material specified by the manufacturer for installation and during curing of the bonding material.
Anchor component installation temperature:	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.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 1 shows how the performance of this product is assessed in relation to the essential characteristics.

Table 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		
1	Characteristic values for resistance	2.2.1	
	Reduction factor		β [-]
	Characteristic resistance of a single anchor under tension loading		$N_{Rk,p}$, $N_{Rk,b}$ [kN]
	Characteristic resistance of an anchor group under tension loading		N_{Rk}^g [kN]
	Characteristic resistance of a single anchor under shear loading		$V_{Rk,b}$, $V_{Rk,s}$ [kN]
	Characteristic resistance of an anchor group under shear loading without and with edge influence		V_{Rk}^g, $V_{Rk,c}^g$ [kN]
	Characteristic edge distance and spacing		c_{cr}, s_{cr} [mm]
	Minimum edge distance and spacing		c_{min}, s_{min} [mm]
	Group factor under tension or shear loading		$\alpha_{g,N}$, $\alpha_{g,V}$ [-]
	Minimum member thickness		h_{min} [mm]
2	Displacements	2.2.2	δ_0, δ_∞ [mm]
3	Durability	2.2.3	Description
	Basic Works Requirement 2: Safety in case of fire		
4	Reaction to fire	2.2.4	Class (A1)
	Basic Works Requirement 3: Hygiene, health and the environment		
5	Content, emission and/or release of dangerous substances	2.2.5	Description

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

2.2.1 Characteristic values of resistance

The test program for the assessment consists of

- Basic service condition tests to assess basic values of characteristic resistance and

- Functioning tests to assess the characteristic resistance regarding variations of temperature, loading and installation for the relevant application range according to the intended use.

The required tests are given in Chapter 2.2.1.1 (functioning tests) und Chapter 2.2.1.2 (basic service condition tests). Test methodologies are given in Annex A. The assessment (evaluation) of the test results are given in Chapter 2.2.1.3 and the determination of the characteristic resistance is given in Chapter 2.2.1.4.

2.2.1.1 Functioning tests

The types of functioning tests, test conditions, the number of required tests and the criteria applied to the results shall be taken in accordance with Table 2 and Table 3.

Table 2: Base material for functioning tests for injection anchors to be used in masonry

	Purpose of test:	Masonry group **b** and **c**		Masonry group **d**
	Functioning	Solid clay	Solid calcium silicate	Autoclaved aerated concrete
1	(a) in dry substrate	x	x	x
	(b) in wet substrate			
2	(a) at increased temperature	(1)		x
	(b) at low temperature			
	(c) at minimum curing time			
3	under repeated loads			
4	(a) under sustained loads (normal temperature)			
	(b) under sustained loads (max. long term temp.)			
5	at maximum torque moment	Tests in all types of bricks as applied for		
6	under freeze/thaw condition	(1) (2)		
7	Checking durability of the bonding material	C20/25		

Notes to Table 2

(1) Tests in solid clay masonry units or solid calcium masonry units, resulting from reference tests according to Table 4, line 1 (the maximum resistance is decisive). If the same injection system is already assessed regarding the specified functioning in accordance with EAD 330499 [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 (see also A.5.9 of this EAD).

Table 3:　Functioning tests for injection anchors to be used in masonry

	Purpose of test	Ambient base material tempe-rature	Minimum number of tests for anchor size (2)					Criteria		Test procedure functioning tests described in Annex A
	Functioning		s	i	m	i	l	load/dis. behaviour	req. α (1)	
1	(a) in dry substrate	normal	5	-	5	-	5		≥ 0,8	A 5.4a)
	(b) in wet substrate (3)	normal	5	-	5	-	5		≥ 0,8	A 5.4b)
2	(a) at increased temperature	+50 °C(5)			5				≥ 1,0	A 5.5a)
		+80 °C(5)			5				≥ 0,8 (6)	
	(b) at low temperature	(4)			5			(1)	≥ 1,0	A 5.5b)
	(c) at minimum curing time	normal			5				≥ 0,9	A 5.5c)
3	under repeated loads	normal	-	-	5	-	-		≥ 1,0	A 5.6
4	(a) under sustained loads (b) under sustained loads	normal + 50 °C(5)	-	-	5	-	-		≥ 0,9	A 5.7
5	at maximum torque moment	normal	5	5	5	5	5			A 5.8
6	under freeze/thaw condition (7)	normal	-	-	5	-	-	(1)	≥ 0,9	A 5.9
7	Checking durability of the bonding material	see 2.2.3								

Notes to Table 3

(1)　　　See Clause 2.2.1.3

(2)　　　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 anchorage depth. If the injection anchors are used with two or more anchorage depths the tests have to be carried out at each depths.

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

(4)　　　Minimum installation temperature as specified by the manufacturer, larger or equal to 0°C

(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

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

2.2.1.2 Basic service condition tests

The types of basic service condition tests the tests conditions and the number of tests are given in Table 4.

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

All basic service condition tests shall be carried out according to Annex A in the base material for which the injection anchor is intended to be used.

The minimum edge distance c_{min} and minimum spacing s_{min} 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 standard values c_{cr} and s_{cr} according to Notes (3) and (4) of Table 4, then the performance will be assessed by the corresponding tests according to Table 4. In absence of manufacturer's instructions $c_{min} = c_{cr}$ and $s_{min} = s_{cr}$.

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

Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EN 1996-1-1:2005 + A1:2012 [6].

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

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

Table 4:   Basic service condition tests for injection anchors for use in masonry

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

Notes to Table 4

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

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

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

    The ETA shall clearly describe the conditions under which the specified product performance has been assessed (e. g. if the product performance has also been assessed taking into account setting in joints).

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

    Anchorages in solid masonry and AAC: c_{cr} = 1,5 h_{ef}

    Anchorages in hollow or perforated masonry: c_{cr} = max (100 mm; 6 d_0)

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

    Anchorages in solid masonry and AAC: s_{cr} = 3,0 h_{ef}

    Anchorages in hollow or perforated masonry: $s_{cr,\|}$ = l_{unit} (s_{cr} ‖ horizontal joint)

                                                                       $s_{cr,\perp}$ = h_{unit} (s_{cr} ⊥ horizontal joint)

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

(6)   Shear tests with single anchors in direction to the free edge of a wall to determine the characteristic resistance depending on the minimum edge distance c_{min}. This test can be omitted, if the resistance calculated according to TR 054 [12] is accepted.

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

    s_{min} shall be given in the European Technical Assessment (spacing of a group of anchors in the tests)

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

    Anchorages in solid masonry and AAC: s_{min} ≥ max (50 mm; 3 d_0)

    Anchorages in hollow or perforated masonry: s_{min} ≥ max (75 mm; 5 d_0)

    This test may be omitted if for s_{min} the value s_{cr} is accepted.

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

2.2.1.3 Assessment of test results

2.2.1.3.1 Determination of the 5%-fractile of the ultimate loads

The 5%-fractile of the ultimate loads is to 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) Conversion of ultimate loads measured in a test series according to 2.2.1.3.2

2) Determination the logarithmic values of the converted ultimate loads

$$\varphi_i \quad = \quad \ln\left(F_{Ru,i}\right) \tag{1a}$$

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

$$\varphi_m \quad = \quad \sum_{i=1}^{n}\left(\frac{\varphi_i}{n}\right) \tag{1b}$$

$$s(\varphi) \quad = \quad \sqrt{\frac{\sum_{i=1}^{n}\left(\varphi_m - \varphi_i\right)^2}{(n-1)}} \tag{1c}$$

$$\varphi_{5\%} \quad = \quad \varphi_m - k_s \cdot s(\varphi) \tag{1d}$$

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

$$F_{Rk}^{t} \quad = \quad F_{5\%} \quad = \quad e^{\varphi_{5\%}} \tag{1e}$$

with:

φ_i = logarithmic values of the converted ultimate loads

$F_{Ru,i}$ = converted ultimate loads of a test series

n = number of tests of a test series

φ_m = mean value of logarithmic values

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

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

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

                                                n = 10 tests: k_s = 2,57

F_{Rk}^{t} = 5%-fractile of ultimate loads in a test series

2.2.1.3.2 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:

$$F_{Ru}(f_b) \quad = \quad F_{Ru}^t \cdot \left(\frac{f_b}{f_{b,test}} \right)^{\alpha} \tag{2}$$

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 European Technical Assessment)

In the case of pull-out failure the influence of the unit strength on the failure load shall be established. In the absence of better information, Equation (2) 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 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 771-4:2011 using the factor of 0,9.

$$f_{ck} = 0,9 \, f_{c,decl} \tag{3}$$

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

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

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

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.

Conversion of ultimate loads to take into account the steel strength:

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

$$F_{Ru}(f_{uk}) \quad = F_{Ru}^t \cdot \frac{f_{uk}}{f_{u,test}} \tag{5}$$

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

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

2.2.1.3.3 Load/displacement behaviour

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

In all tension tests the load-displacement curves shall show a steady increase (see Figure 3); uncontrolled slip of injection anchors is not allowed.

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

$N_{u,adh}$ shall be evaluated for every test from the measured load displacement curve. In general the load at loss of adhesion is characterised by a significant change of stiffness, see Figure 3a). If the change in stiffness at a defined load is not so obvious e.g. the stiffness is smoothly decreasing, than the load at loss of adhesion shall be evaluated as follows:

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

If there is a peak in the load-displacement curve to the left side of this line which is higher than the load at intersection then $N_{u,adh}$ is taken as the peak load, see Figure 3c).

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 3d).

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

$$\alpha_1 \quad = \quad \frac{N_{u,adh}}{0,5 \cdot N_{Ru}} \quad \leq 1,0 \tag{6}$$

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

The minimum value of α_1 of all tests is decisive. If the value of α_1 is less than 1,0 then the characteristic resistance $N_{Rk,p}$ shall be reduced according to 2.2.1.4.

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

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)

In all tension tests the load-displacement curves shall show a steady increase (see Figure 3); uncontrolled slip of injection anchors is not allowed.

Uncontrolled slip is characterised by a significant change of stiffness according to Figure 4. The corresponding load when uncontrolled slip starts is called N_1.

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

$$\alpha_1 \quad = \quad \frac{N_1}{0,5 \cdot N_{Ru}} \quad \leq 1,0 \tag{7}$$

with: N_1 = load at which uncontrolled slip of the anchor occurs (see Figure 4)
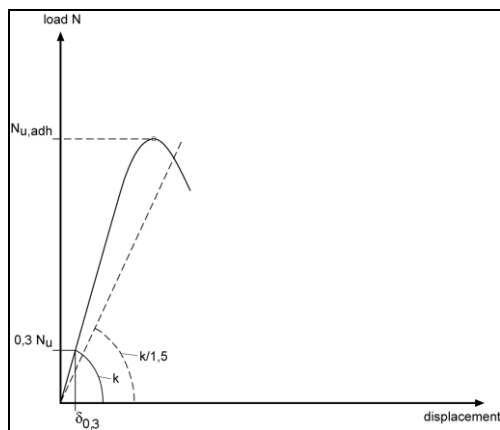 N_{Ru} = maximum load of single test

The minimum value of α_1 of all tests is decisive. If the value of α_1 is less than 1,0 then the characteristic resistance $N_{Rk,p}$ shall be reduced according to 2.2.1.4.
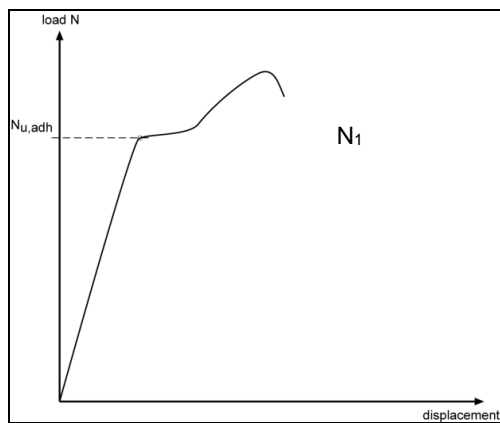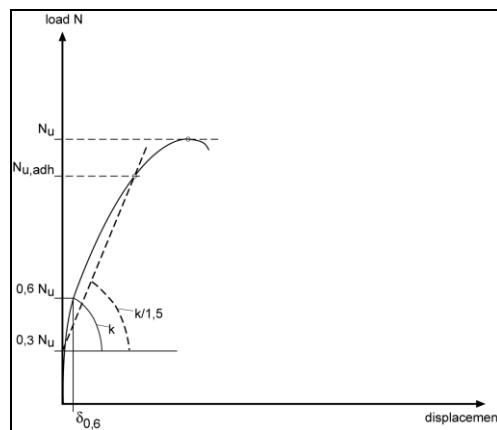
a) Load at loss of adhesion by a significant
   change of stiffness
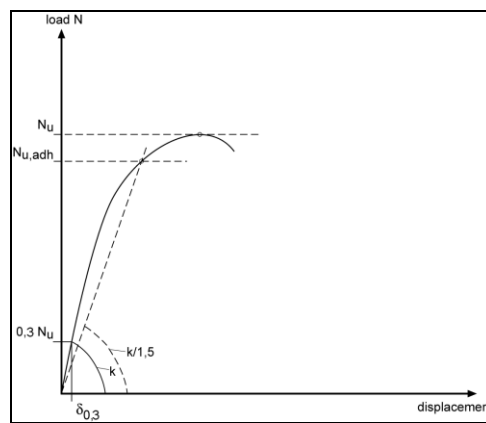
b) Evaluation of load at loss of adhesion

c) Evaluation of load at loss of adhesion

d) Evaluation of load at loss of adhesion

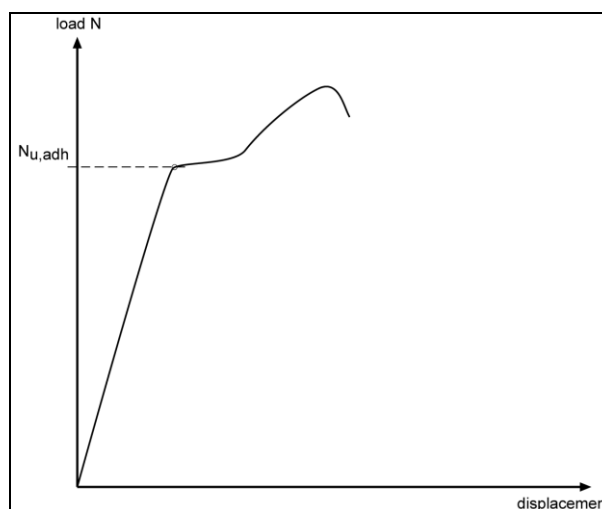**Figure 3 – Examples of load-displacement curves (solid masonry)**

Figure 4 – Example of load-displacement curve (hollow or perforated masonry)

2.2.1.3.4 Coefficient of variation of ultimate load

In general, in each test series, the coefficient of variation of the ultimate load shall be smaller than $v = 30\ \%$ in the functioning tests and $v = 20\ \%$ in the basic service condition tests.

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

$$\alpha_V \quad = \quad \frac{1}{1 + 0{,}03 \cdot (v[\%] - 30)} \quad \leq 1.0 \qquad\qquad (8)$$

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

$$\alpha_V \quad = \quad \frac{1}{1 + 0{,}03 \cdot (v[\%] - 20)} \quad \leq 1.0 \qquad\qquad (9)$$

2.2.1.3.5 Shear tests

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

2.2.1.3.6 Assessment of functioning tests

Reduction factor

In the functioning tests the factor α shall be larger than the value given in Table 3:

$$\alpha = \text{lesser value of} \quad \frac{N_{Ru,m}^{t}}{N_{Ru,m}^{r}} \qquad\qquad (10)$$

$$\text{and} \quad \frac{N_{Rk}^{t}}{N_{Rk}^{r}} \qquad\qquad (11)$$

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

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

Equation (11) is based on test series with a comparable number of test results in both series. If the number of tests in the two series is very different, then Equation (11) may be omitted when the coefficient of variation of the test series is smaller than or equal to the coefficient of variation of the reference test series or if the coefficient of variation in the functioning tests is $v \leq 15\ \%$.

If the criterion for the required value of α (see Table 3) is not met in a test series, then the factor α_2 shall be calculated.

$$\alpha_2 \quad = \quad \frac{\alpha}{req.\alpha} \leq 1{,}0 \qquad\qquad (12)$$

with:

α lowest value according to Equation (10) or (11) in the test series
req. α required value of α according to Table 3

Functioning in dry or wet substrate (test series Table 3, line 1)

The required α in the tests is $\geq 0{,}8$. If the requirements concerning α are not fulfilled, $\alpha_{2,line\ 1}$ shall be calculated according to Equation (12).

Influence of temperature on characteristic resistances (test series Table 3, line 2)

a) Effect of increased temperature

The required α for the tests at maximum long term temperature is 1,0.

The required α for the maximum short term temperature is 0,8.

If the requirements concerning α are not fulfilled in the tests at the maximum long term or maximum short term temperature, $\alpha_{2,\text{line 2}}$ shall be calculated according to Equation (12).

b) Effect of low installation temperature

The required α for the tests at the minimum installation temperature is 1,0.

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

c) Minimum curing time at normal ambient temperature

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

If this condition is not fulfilled, then the minimum curing time at normal ambient temperature shall be increased and the corresponding tests shall be repeated.

Repeated loading (test series Table 3, line 3)

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

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

The required α for the pull-out tests subsequent to the cycling loading is 1,0. If this condition is not fulfilled, $\alpha_{2,\text{line 3}}$ shall be calculated according to Equation (12).

Sustained loading (test series Table 3, line 4)

The displacements measured in the tests have to be extrapolated according to Equation (13) (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.

$$s(t) \quad = s_o + a \cdot t^b \tag{13}$$

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

The failure loads measured in the pull-out tests subsequent to the sustained loading at normal temperature shall be compared with the failure loads measured in the reference tension tests (Table 4, line 1).

The failure loads measured in the pull-out tests subsequent to the sustained loading at maximum long term temperature shall be compared with the failure loads measured in the functioning tests at maximum long term temperature (Table 3, line 2(a)).

The required α is 0,9. If this condition is not fulfilled for residual capacity after sustained loading at normal temperature and maximum long term temperature, $\alpha_{2,\text{line4}}$ shall be calculated according to Equation (12).

<u>Maximum torque moment (test series Table 3, line 5)</u>

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

The conditions may be assumed to be fulfilled if the following conditions are met. The ratio of the maximum torque moment T_u during failure to the maximum torque moment T_{inst} allowed 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.

<u>Functioning under freeze/thaw conditions (test series Table 3, line 6)</u>

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

The failure loads measured in the pull-out tests subsequent to the freeze/thaw cycles shall be compared with the failure loads measured in the reference tension tests (Table 4, line 1).

The required α is 0,9. If this condition is not fulfilled for residual capacity after freeze/thaw conditions, $\alpha_{2,line6}$ shall be calculated according to Equation (12).

2.2.1.4 Determination of the characteristic resistance of a single anchor

The characteristic resistances of the injection anchor for the different failure modes under tension and shear loading shall be evaluated by the corresponding tests to get the required values for the design method according to TR054 [12]. This evaluation considers the reduction factor resulting from the assessment.

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

Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EN 1996-1-1:2005 + A1:2012 [6].

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

The characteristic resistance of the injection anchor may be determined by "job site tests" according to TR053 [13], if the anchor has an European Technical Assessment with characteristic values for the same type of base material (e.g. clay, calcium silicate, lightweight aggregate or autoclaved aerated concrete) as on the construction works. Furthermore job site tests for use in solid masonry are possible only if the injection anchor has a European Technical Assessment for use in solid masonry and job site tests for use in hollow or perforated masonry are possible only if the metal injection anchor has a European Technical Assessment for use in hollow or perforated masonry.

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

$$\beta = \min (\min \alpha_1 \; ; \; \min \alpha_{2, \text{line } 1,3,4,6}) \cdot \min \alpha_{2, \text{line } 2} \cdot \min \alpha_3 \cdot \min \alpha_{V,N} \qquad (14)$$

with:

$\min \alpha_1$	=	minimum value α_1 according to Equation (6) or (7) Reduction factor from the load/displacement behaviour of all tests
$\min \alpha_{2,\text{line } 2}$	=	minimum value α_2 according to Equation (12) Reduction factor from the ultimate loads in the functioning tests according to Table 3, line 2 (temperature)
$\min \alpha_{2,\text{line } 1,3,4,6}$	=	minimum value α_2 according to Equation (12) Reduction factor from the ultimate loads in the functioning tests according to Table 3, line 1, 3, 4 and 6
$\min \alpha_{V,N}$	=	minimum value α_V according to Equations (8) or (9) Reduction factor from the coefficient of variation of the ultimate loads in the functioning and basic service condition tension tests
$\min \alpha_3$	=	reduction factor according to 2.2.3 Reduction factor from the durability behaviour of all tests

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

$$N_{Rk,p} = N_{Rk,b} = N_{Rk,0} \cdot \beta \qquad (15)$$

with:

$N_{Rk,p}$	=	characteristic resistance of pull out failure of the anchor
$N_{Rk,b}$	=	characteristic resistance of brick break out failure
$N_{Rk,0}$	=	minimum characteristic resistance evaluated from the results of tests according to Table 4, line 2 and Table 4, line 4
β	=	according to Equation (14)

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

$$V_{Rk,b} = V_{Rk,0} \cdot \min \alpha_1 \cdot \min \alpha_{V,V} \qquad (16)$$

with:

$V_{Rk,b}$	=	characteristic resistance of local brick failure independent of the failure mode
$V_{Rk,0}$	=	minimum characteristic resistance evaluated from the results of tests according to Table 4, line 3 and Table 4, line 5
$\min \alpha_1$	=	minimum value α_1 according to Equation (6) or (7) Reduction factor from the load/displacement behaviour of all tests
$\min \alpha_{V,V}$	=	minimum value $\alpha_{V,V}$ according to Equations (9) Reduction factor from the coefficient of variation of the ultimate loads in the basic service condition shear tests

In case of steel failure in the tests according to Table 4, line 3, $V_{Rk,s}$ (characteristic resistance of steel failure of the anchor) according to following Equation shall be given in the ETA.

$$V_{Rk,s} = \min (V_{Rk,b} \; ; \; 0,5 \cdot A_s \cdot f_{uk}) \qquad (17)$$

with:

$V_{Rk,b}$	=	characteristic resistance of local brick failure independent of the failure mode
A_s	=	decisive cross section of the anchor
f_{uk}	=	nominal characteristic steel ultimate strength

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

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

2.2.1.5 Determination of the characteristic resistance of an anchor group

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

$$N_{Rk}^g \quad = \quad \alpha_{g,N} \cdot N_{Rk} \tag{18}$$

with: N_{Rk}^g = characteristic resistance of the anchor group under tension loading and under defined spacing $s_{min,II}$ and/or $s_{min,\perp}$ and under defined edge distances c_{min}, given in the European Technical Assessment

N_{Rk} = $N_{Rk,p}$ or $N_{Rk,b}$ according to Equation (15)

$\alpha_{g,N}$ = smaller value of $\dfrac{N_{Ru,m}^{t,g}}{N_{Ru,m}^r}$ and $\dfrac{N_{Rk}^{t,g}}{N_{Rk}^r}$,

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

$N_{Ru,m}^{t,g}$; $N_{Rk}^{t,g}$ = mean value or 5 %-fractile of the ultimate loads of an anchor group in the test series according to Table 4, line 6

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

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

$$V_{Rk}^g \quad = \quad \alpha_{g,V} \cdot V_{Rk} \tag{19}$$

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

V_{Rk} = $V_{Rk,b}$ according to Equation (16)

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

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

$V_{Ru,m}^{t,g}$; $V_{Rk}^{t,g}$ = mean value or 5 %-fractile of the ultimate loads of an anchor group in the test series according to Table 4, line 7

$V_{Ru,m}^r$; V_{Rk}^r = mean value or 5 %-fractile of ultimate loads of a single anchor in the relevant reference test according to Table 4, line 3 (if $c_{min} = c_{cr}$) or line 5 (if this optional test is performed)

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

2.2.2 Displacement behaviour

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

$$F = \frac{F_{Rk}}{\gamma_F \cdot \gamma_M} \tag{20}$$

with:

F_{Rk} = characteristic resistance N_{Rk} or V_{Rk} according to 2.2.1.4

γ_F = 1,4

γ_M = corresponding material partial safety factor according to TR 054 [12]

The displacements under short term tension loading (δ_{NO}) are evaluated from the tests with single anchors without edge or spacing effects according to Table 4, line 2. The value derived shall correspond to the 95 %-fractile for a confidence level of 90 %.

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

The displacements under short term shear loading (δ_{VO}) are evaluated from the corresponding shear tests with single anchors without edge or spacing effects according to Table 4, line 3. The value derived shall correspond to the 95 %-fractile for a confidence level of 90 %.

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

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.

2.2.3 Durability

Metal parts (corrosion)

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

(X1) Anchor intended for use in structures subject to dry, internal conditions:

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

(X2) Anchor for use in structures subject to external atmospheric exposure (including industrial and marine environments), or exposure in permanently damp internal conditions, if no particular aggressive conditions according to (X3) exist:

Metal parts of the anchor made of stainless steel material 1.4401, 1.4404, 1.4578, 1.4571, 1.4362, 1.4062, 1.4162, 1.4662, 1.4439, 14462 or 1.4539 according to EN 10088-4 and 5:2014 [5] are considered to have sufficient durability.

These anchors may also be used in (X1) conditions.

(X3) Anchor for use in structures subject to external atmospheric exposure or exposure in permanently damp internal conditions or particularly aggressive conditions such as permanent or alternate immersion in seawater or the splash zone of seawater, chloride atmosphere of indoor swimming pools or atmosphere with extreme chemical pollution (e.g. in desulfurization plants or road tunnels, where de-icing materials are used):

Metal parts of the anchor of stainless steel material 1.4529, 1.4565 and 1.4547 according to EN 10088-4 and 5:2014 [5] are considered to have sufficient durability.

These anchors may also be used in (X1) and (X2) conditions.

Bonding material

The durability of the bonding material (except for cementitious mortar) 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 are required 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 characteristic resistance is calculated according to Equation (14) with $\alpha_3 = 0,3$
- joints of masonry units made out of clay or calcium silicate filled with cementitious mortar, if the characteristic resistance of the anchor for the corresponding masonry unit given in the ETA is $N_{Rk} \leq N_{Rk}$ (concrete brick) with N_{Rk} (concrete brick) calculated according to Equation (14) with $\alpha_3 = 0,5$ or the mortar is carbonated over the anchorage depth of the anchor.
  Carbonated mortar may be assumed if the structure is sufficiently old (e.g. ≥ 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.

To show compliance with this requirement of the slice tests the factor α_3 shall be calculated according to following Equation.

$$\alpha_3 = \frac{\tau_{um(stored)}}{\tau_{um,dry}} \leq 1,0 \qquad (21)$$

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

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

The bond strength in the slice tests shall be calculated according to following Equation:

$$\tau_u = \frac{N_u}{\pi \cdot d \cdot h_{sl}} \qquad (22)$$

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

If the value α_3 is less than req.α_3, i. e. 1,0 for the tests in alkaline fluid and 0,9 for tests in sulphurous atmosphere, the characteristic resistance N_{Rk} shall be reduced according to 2.2.1.4 applying the reduction factor min α_3 as the smaller fraction α_3/req.α_3 for the two durability conditions.

2.2.4   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 the provisions of EC Decision 96/603/EC (as amended) without the need for testing on the basis of its listing in that Decision.

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

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

2.2.5 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[2] after identifying the release scenarios (in accordance with EOTA TR 034 [21]) 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.

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

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

2.2.5.1 SVOC and VOC

For the intended use covered by the release scenario IA2 semi-volatile organic compounds (SVOC) and volatile organic compounds (VOC) are to 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 is performed by use of a solid brick 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 specified by the manufacturer shall be used. The embedment depth shall be at least 4d.

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[2]   The manufacturer may be asked to provide to the TAB the REACH related information which he must 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.

Once the test specimen has been produced, as described above, it should immediately be placed in the emission test chamber. This time is considered the starting time of the emission test.
The test results have to 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/m³] and stated in the ETA.

2.2.5.2 Leachable substances

For the intended use covered by the release scenario S/W1 the performance of the bonding material concerning leachable substances has to be assessed. A leaching test with subsequent eluate analysis must take place, each in duplicate. Leaching tests of the bonding material are conducted according to CEN/TS 16637-2:2014 [23]. The leachant shall be pH-neutral demineralised water and the ratio of liquid volume to surface area must be (80 ± 10) l/m².

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 ISO 15799 [25]
- Luminescent bacteria test according to EN ISO 11348-1 [26], EN ISO 11348-2 [27] or EN ISO 11348-3 [28]

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.

Determined toxicity in biological tests must be expressed as EC20-values for each dilution ratio. Maximum determined biological degradability must be expressed as "…% within …hours/days". The respective test methods for analysis must 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 product in the procedure of assessment and verification of constancy of performance are laid down in Table 5. Table 5 is an example only; the control plan depends on the individual manufacturing process and has to be established between notified body and manufacturer for each product.

Table 5   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.)	Caliper and/or gauge	Laid down in control plan	3	Every manufacturing batch or 100.000 elements or when raw material batch has been changed (The lower control interval is decisive)
2	Tensile Load or tensile strength	EN ISO 6892-1 [20], EN ISO 898-1 [8], EN ISO 3506-1 [4]		3	
3	Yield strength			3	
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]		3	
5	Fracture elongation A_5 (where relevant)	EN ISO 6892-1 [20] EN ISO 898-1 [8]		3	
Injection mortar					
6	Check of batch number and expiry date	visual check	Laid down in control plan	1	Each batch
7	Components / mass	check material and the mass of components acc. to recipe		1	
8	Specific gravity / Density	Standardized method proposed by the manufacturer		1	Every shift or 8 hours of production per machine
9	Viscosity			1	
10	Reactivity (gel time, where relevant: max. reaction temperature, time to max reaction temperature)			1	Each batch
11	Properties of raw material	(e.g. by infrared analysis)		1	initial testing and each change of batch
12	Performance of the cured bonding material	(e.g. tension test to failure)		3	Each batch
Sieve sleeve					
13	Dimensions (length, diameter, hole size, hole configuration etc.)	Measuring or optical	Laid down in control plan	3	Every shift or 8 hours of production per machine
14	Material	Depending on the material: method proposed by the manufacturer		3	

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 the product are laid down in Table 6.

Table 6   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	Ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the injection anchor.	-	Laid down in control plan	-	1
Continuous surveillance, assessment and evaluation of factory production control					
2	Verifying that the system of factory production control and the specified automated manufacturing process are maintained taking account of the control plan.	-	Laid down in control plan	-	1/year

3.4   Special methods of control and testing used for the verification of constancy of performance

If the metal parts are commercial standard parts supplied by another party than the assessment holder (e.g. manufacturer of threaded rods) then material, dimensions and mechanical properties of the metal parts (threaded rod, washer, nut) given in the ETA shall be confirmed by inspection certificate 3.1 according to EN 10204:2004 [9].

If commercial threaded rods can be used with acceptance of the manufacturer, the ETA should include this information and should define the required verification (3.1 certificate).

The material of stainless steel shall be given according to EN 10088:2014 [5] and the mechanical properties are given according to EN ISO 898-1 and 2:2013 [8] (galvanised steel) and according to EN ISO 3506-1 and 2:2009 [4] (stainless steel).

4   REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment is of relevance.

[1]   Regulation (EU) No 305/2011 of the European Parliament and of the council of 9 March 2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/ECC

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

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

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

[5]   EN 10088-4 and 5:2014 Stainless steels – Part 4: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes; Part 5: Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes

[6]   EN 1996-1-1:2005 + A1:2012: Design of masonry structures. Part 1-1: General rules for reinforced and unreinforced masonry structure

[7]   EOTA: Technical Report TR 020: Evaluation of Anchorages in Concrete concerning Resistance to Fire Edition May 2004

[8I   EN ISO 898-1 and 2:2013 Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified properly classes – coarse thread and fine pitch thread; Part 2: Nuts with specified properly classes – coarse thread and fine pitch thread

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

[10]   EAD 330499: Bonded fasteners for use in concrete

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

[12]   EOTA: Technical Report TR 054: Design methods for anchorages with metal injection anchors for use in masonry

[13]   EOTA: Technical Report TR 053: Recommendations for tests of metal injection anchors for use in masonry to be carried out on construction works

[14]   EOTA: Technical Report TR 048: Details of tests for post-installed fasteners in concrete

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

[16]   ISO 5468:2006: 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 21968:2005 Non-magnetic metallic coatings on metallic and non-metallic basis materials - Measurement of coating thickness - Phase-sensitive eddy-current method

[20]   EN ISO 6892-1:2016 Metallic materials - Tensile testing - Part 1: Method of test at room temperature

[21]   EOTA: Technical Report TR 034: General checklist for EADs/ETAs – Content and/or release of dangerous substances in construction products

[22]   EN 16516:2017, 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 6341:2013-01, Water quality - Determination of the inhibition of the mobility of Daphnia magna Straus (Cladocera, Crustacea) - Acute toxicity test (ISO 6341:2012)

[25]   ISO 15799:2003-11, Soil quality - Guidance on the ecotoxicological characterization of soils and soil materials

[26]   EN ISO 11348-1:2009-05, 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 11348-2:2009-05, 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 11348-3:2009-05, 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)

ANNEX A: DETAILS OF TESTS

If details are not given in the following, these details shall be taken from EOTA TR 048 [14].

A.1   Test samples

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

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

A.2   Test members

A.2.1 General

The tests shall be performed in single units or in a wall. If tests are done in a wall, the thickness of the joints shall be about 10 mm and the joints shall be completely filled with mortar of strength class M2.5 with a strength ≤ 5 N/mm^2. If tests are performed with a mortar strength greater than M2.5 then the minimum mortar strength shall be given in the European Technical Assessment. The units for test members of AAC may be glued together.

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

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

A.2.2 Test member for solid masonry material (Masonry 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 basic service condition tests according to Table 4, line 1 and 2 for shall be performed with single injection anchors approximately in the centre of the unit under tension loading. The shear tests according to Table 4, line 3, shall be performed with single injection anchors approximately in the centre of the unit or in the wall under shear loading not influenced by edge effects. The tension tests according to this EAD, Table 4, line 4 and the shear tests according to Table 4, line 5 shall be performed at the free edge of a unit (tests in units) or the wall (tests in a wall) with an edge distance $c=c_{min}$.

A.2.3 Test member for hollow or perforated bricks and hollow blocks (Masonry group c)

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

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

A.2.4   Test member for autoclaved aerated concrete (Masonry group d)

A.2.4.1   Requirements for test specimens

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

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

A.2.4.2 Definition of test specimens/samples

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

Samples: Samples (cubes/cylinders) are taken from the test specimen for determination of the material characteristics (see Figure A.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.
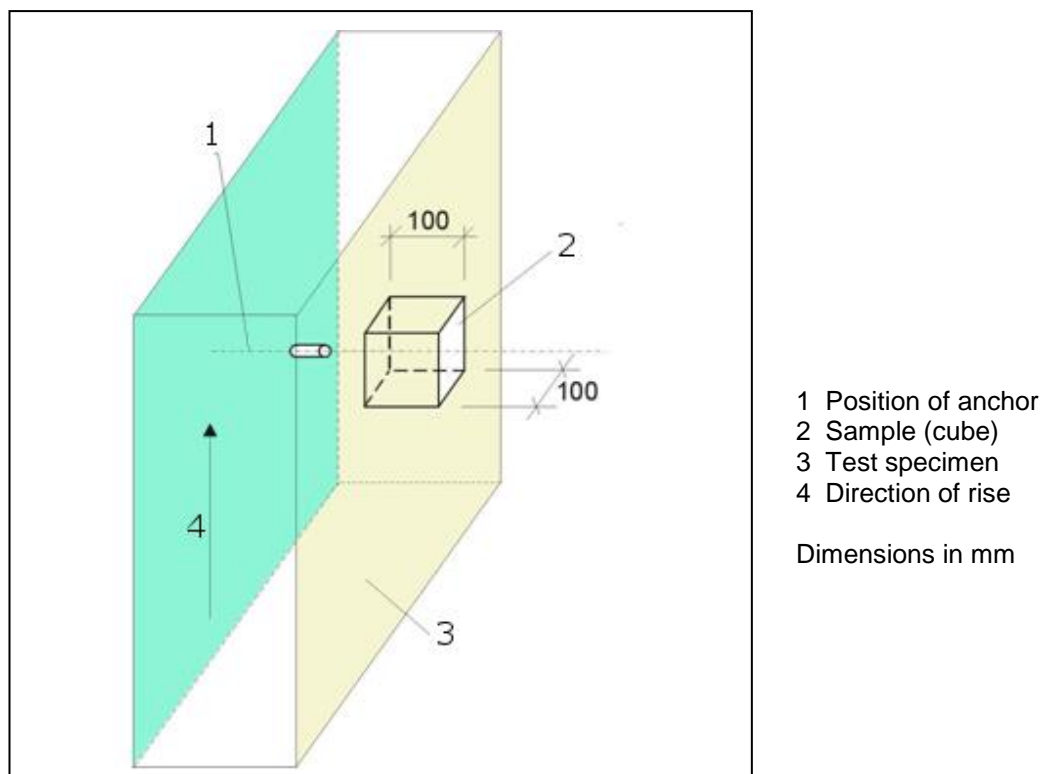

1 Position of anchor
2 Sample (cube)
3 Test specimen
4 Direction of rise

Dimensions in mm

Figure A.1 - Taking of samples for autoclaved aerated concrete (AAC)

A.2.4.3 Material characteristics

For determination of the material characteristics the following conditions apply:

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

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

Determination of the material characteristics (compressive strength, dry density) and moisture content is always carried out on the sample (cube/cylinder) or an AAC block. The characteristics shall be determined on at least 5 samples (cube/cylinder) or blocks. The compressive strength shall be determined as the mean value. Testing of the compressive strength is performed in the direction of metal injection anchor setting (see Figure A.1).

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 substrate special conditions are specified in this EAD.

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

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

If the ETA is to cover 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 required, these bits shall meet the requirements of the standards (e.g. ISO 5468:2006 [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.1. In all tests (functioning tests and basic service condition tests) the cylindrical hole is drilled with a medium diameter ($d_{cut,m}$) of the drill bit.

Table A.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

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.2) and confined tests (see Figure A.3). 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), 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.2. To reduce friction, smooth sheets (e.g. PTFE) with a maximum thickness of 2 mm shall be placed between the fixture and the test member.

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

In torque tests the torque moment during installation until failure is measured. For this a calibrated torque moment transducer with a measuring error < 3 % throughout the whole measuring range shall be used.
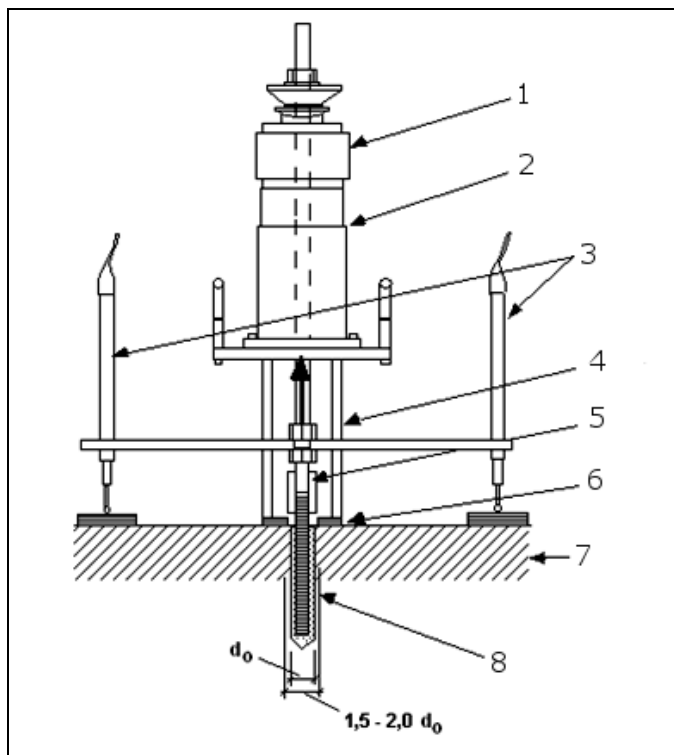
Table A.2 Diameter of clearance hole in the fixture

External diameter d or d_{nom} (mm)	6	8	10	12	14	16	18	20	22	24	30
Diameter of clearance hole in the fixture d_f (mm)	7	9	12	14	16	18	20	22	24	26	33
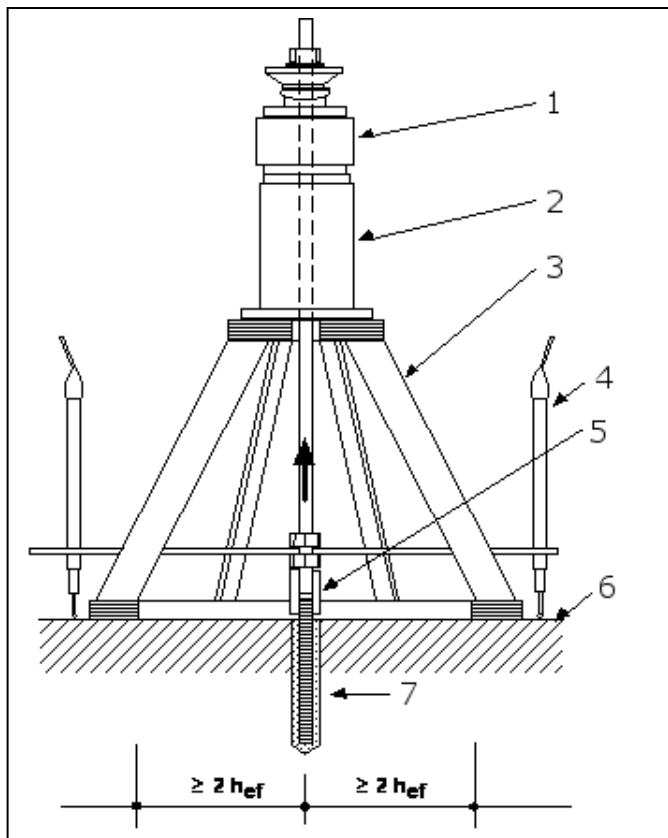
1 Load cell
2 Load cylinder
3 Support
4 Displacement transducer
5 Socket
6 Test member
7 Injection anchor

Figure A.2 - Example of a tension test rig for <u>unconfined</u> 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.3 - Example of a tension test rig for <u>confined</u> tests
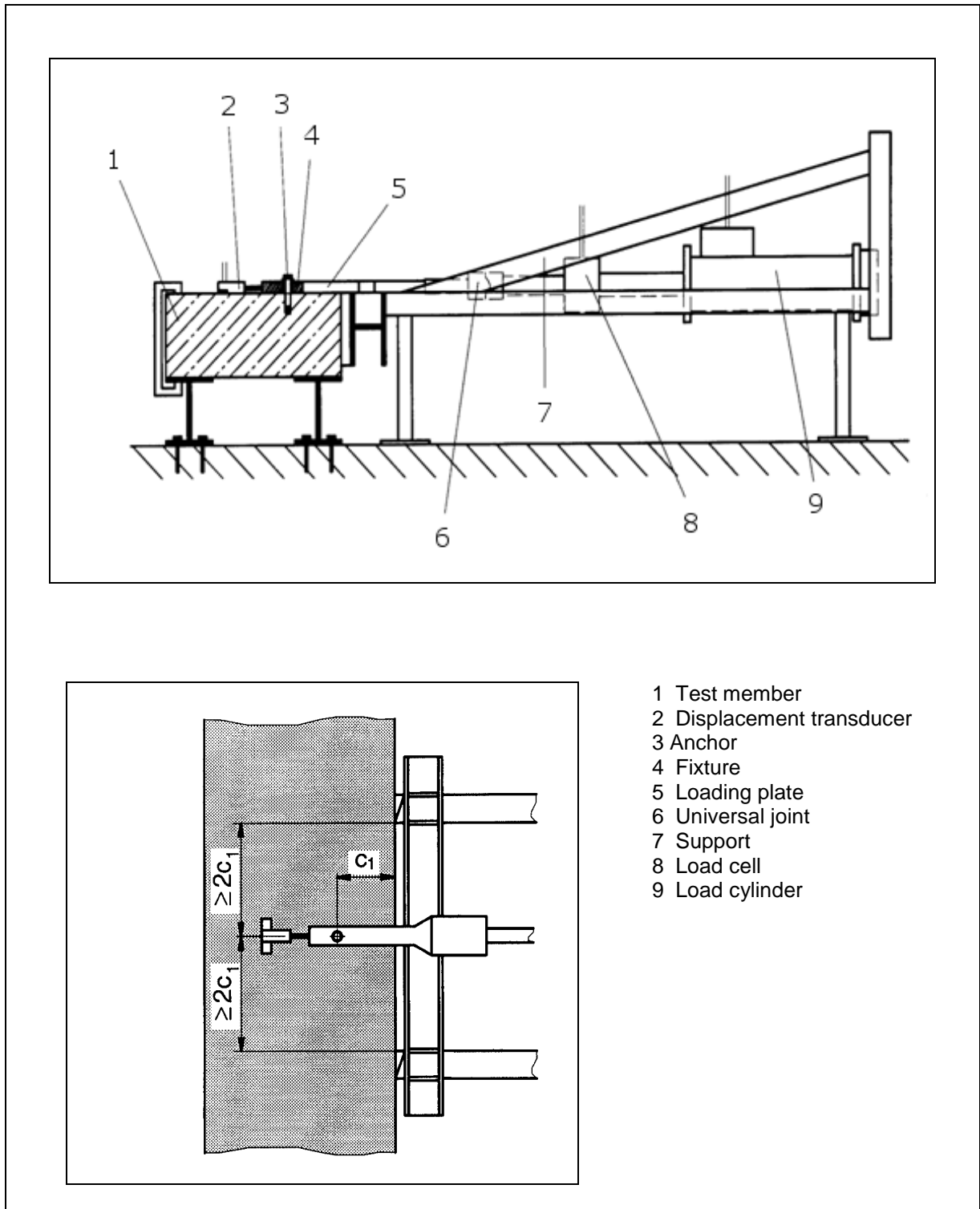
Figure A.4 Example of a shear test rig

1 Test member
2 Displacement transducer
3 Anchor
4 Fixture
5 Loading plate
6 Universal joint
7 Support
8 Load cell
9 Load cylinder

A.5   Test procedure

A.5.1   General

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

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

The <u>functioning tests</u> shall be carried out in the base material according to 2.2.1.1. The anchors shall be installed according to the installation instructions of the manufacturer (except the functioning tests in dry and wet substrate, see A.5.4) in a horizontal direction in the centre of the brick. The tension tests shall be carried out as confined tension tests.

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

A.5.2   Tension test

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

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

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

A.5.3   Shear test

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

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

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

A.5.4   Functioning in dry or wet substrate

(a) Functioning in dry substrate

These tests have to be done for all use conditions as confined tension tests in dry solid bricks (dry conditions according to EN 772-1:2011, 7.3.2 [3].

Drill downwards to the depth required by the manufacturer.

Clean the hole with the hand pump and brush supplied by the manufacturer, using two blowing and one brushing operations in the order prescribed in the manufacturer's installation instructions. This test procedure is valid only if the manufacturer's installation instructions specify hole cleaning with at least four blowing and two brushing operations. If the instructions specify less than this, then the above requirement (2 blows + 1 brush) shall be reduced proportionally 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 <u>without</u> the brushing operation.

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

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

(b) Functioning in wet substrate

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

Confined tension tests in wet solid bricks.

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

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

A.5.5   Influence of temperature on characteristic resistances

a) Effect of increased temperature

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

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

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

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

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

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

Test are performed with the maximum short term temperature and the maximum long term temperature specified by the manufacturer within the range of 0,6 times to 1,0 times the maximum short term temperature and at temperatures between +21 °C and maximum short term temperature with an increment of $\leq$ 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 substrate 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 specified by the manufacturer, and the bonding material and embedded part to the lowest anchor component installation temperature specified by the manufacturer. Install the anchor and maintain the temperature of the test member at the lowest installation ambient temperature for the curing time quoted by the manufacturer at that temperature.

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

c) Minimum curing time at normal ambient temperature

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

A.5.6   Tests under repeated loading

The injection anchor is subjected to 1×10^5 load cycles with a maximum frequency of approximately 6 Hz. During each cycle the load shall be varied as a sine curve between max N and min N according to Equation (A.1) and (A.2). The displacements shall be measured during the first loading up to max N and either continuously or at least after 1, 10, 100, 1 000, 10 000 and 100 000 load cycles.

$$\max N \ = 0{,}4 \cdot N_{Ru,m} \tag{A.1}$$

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

with: $N_{Ru,m}$ = mean ultimate load in the test series according to Table 4, line 2

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

A.5.7   Tests under sustained loading

The test is performed at normal temperature (T= +21 °C ± 3 °C) for temperature range **Ta**, **Tb** and **Tc** and at maximum long term temperature for temperature range **Tb** (T = +50°C) and **Tc** (Temperature as specified by the manufacturer).

The anchor shall be installed at normal temperature.

The anchor is then subjected to a tension load according to Equation (A.3) which is kept constant (variation within ± 5 %). Maintain the load and temperature and measure the displacements until they appear to have stabilised, but at least for three months.

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

$$N_P \ = 0{,}4 \cdot N_{Ru,m} \tag{A.3}$$

with: $N_{Ru,m}$ = mean ultimate load in the test series according to Table 4, line 2

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

A.5.8   Maximum torque moment

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

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

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

A.5.9   Functioning under freeze/thaw conditions

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

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

Load anchor to N_p according to Equation (A.3).

Carry out 50 freeze/thaw cycles as follows:

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

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

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

The displacements shall be measured during the temperature cycles.

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

A.5.10   Durability of the bonding material

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

The slice tests shall be carried out in concrete.

Test specimen:

The concrete compressive strength class shall be C20/25. The diameter or side length of the concrete specimen shall be equal to or exceed 150 mm. The test specimen may be manufactured from cubes or cylinders or may be cut from a larger slab. They can be cast 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 are carefully sawn into 30 mm thick slices with a diamond saw. The top slice shall be discarded.

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

Storage of the test specimen under environmental exposure:

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

High alkalinity:

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

Sulphurous atmosphere:

The tests in sulphurous atmosphere shall be performed according to EN ISO 6988:1994 [15]. The slices are put into the test chamber, however in contrast to EN ISO 6988:1994 [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 is measured and the metal segments of the bonded anchors are pushed out of the slice, then the slice is placed centrally to the hole of the steel rig plate. If slices are unreinforced, splitting may be prevented by confinement. Care shall be taken to ensure that the loading punch acts centrally on the anchor rod.

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

A.6   Test report

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

General

- Description and type of injection anchor
- 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, elastic limit, fracture elongation)
- Injection mortar: Designation, size of package, type of cartridge, Mass of components, density, viscosity, reactivity, infrared analysis, type of dispenser and other tools, if any
- 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	Designation, size of package, type of cartridge	xy injection mortar – fast curing version, side by side cartridge xxx ml
	Mass of components, density, viscosity, reactivity, infrared analysis	
	Type of dispenser and other tools, if any	e.g. Manual dispenser xy, piston plug size xx

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 772-1:2011[3])
- Dimensions of test member, for perforated units also the hole configuration
- Nature and positioning of any reinforcement (for AAC only)
- Direction of concrete pouring (for AAC only)

Anchor installation

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

Measured values

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