EOTA®

EUROPEAN ASSESSMENT DOCUMENT

EAD 330083-00-0601

April 2015

Power-actuated fastener
for multiple use in concrete
for non-structural applications

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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 No (EU) 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

The power-actuated fasteners consist of a suitable nail made of metal which is placed into the concrete by use of a power-actuated fastening tool. The nail can be driven with or without previous drilling and anchored by sintering and mechanical interlock. The diameter of the nail is in the range of 3 mm to 5,5 mm. The minimum anchorage depth depends on the fastener type of the power-actuated fastening system and is given in Table 1.1. For positioning and guidance during the driving process an additional plastic or metal washer can be used.

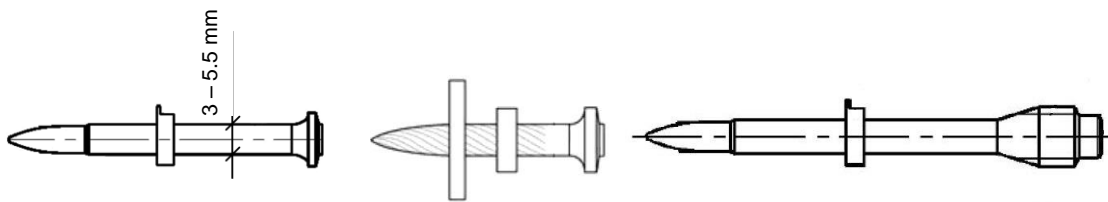Figure 1.1 shows examples of the product (with nail head or with external thread).

Figure 1.1 – Examples of a power-actuated fastener with washer

The product–types shall be determined by:
-   material (e.g. galvanized steel, stainless steel),
-   material grade (e.g. steel strength class),
-   dimensions (e.g. diameter, shape),
-   type (e.g. nail with head, nail with external thread).

Different versions of a fastener with respect to material, strength or dimensions are marked such that the relevant product characteristic is 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.

1.2   Information on the intended use of the construction product

1.2.1   Intended use

The power-actuated fasteners are intended for multiple use for non-structural applications in cracked or non-cracked normal weight concrete between strength classes C12/15 and C50/60 according to EN 206-1:2000 [12]. The fastener can also be used in composite slabs consisting of concrete and steel composite decking. The maximum thickness of the steel shell is 1,25 mm and its maximum steel grade is S350 according to EN 10346:2009 [6]. If the fastener is used in composite slabs, an automatic detection of setting defects has to be used.

A power-actuated fastening tool is used in order to install the fastener. The driving force of the fastening tool is provided by the power load of a cartridge in case of powder-actuated tools, compressed air in case of pneumatic tools and expanding gases in case of gas driven tools. The fastening tool (inclusive cartridge, piston, fastener guide and fastener magazine) is an integral part of the assessment regarding to its effects on the load-bearing capacity of the connection.

This EAD applies to applications where the minimum thickness of concrete members in which the fasteners are installed is $h = 2h_{ef}$ and at least h = 80 mm.

This EAD applies to anchorages in respect to durability for

- use in structures subjects to dry, internal conditions,
- use in structures subjects to external atmospheric exposure or exposure in permanently damp internal conditions, if no particular aggressive conditions exist or
- use in structures subject to external atmospheric exposure or exposure in permanently damp internal conditions or particularly aggressive conditions.

The power-actuated fasteners can be used in the temperature range -40 °C to + 80 °C without special assessment.

The fastener is to be used only for anchorages subject to static or quasi-static loading in reinforced or unreinforced concrete.

The fastener is to be used for anchorages in two-dimensional load-bearing structures (slabs and walls). Fasteners of type 1 (according to Table 1.1) can also be used in one-dimensional load-bearing structures (beams and columns) when the position of the existing reinforcement is known and the fastener will be driven without damaging of the reinforcement.

The power-actuated fastener is used for transmission of tensile loads, shear loads or a combination of both.

The definition of multiple fastener use depends on the Fastener type of the power-actuated fastening system and is given in Table 1.1.

Table 1.1   Types of power-actuated fastening systems

Fastener type	Minimum anchorage depth (1)	Definition of multiple fasteners
1	$\geq$ 25 mm	According to ETAG 001-6:2013, Annex 1 [5]: $n_1 \geq 4$; $n_2 \geq 1$ and $n_3 \leq 3,00$ kN or $n_1 \geq 3$; $n_2 \geq 1$ and $n_3 \leq 2,00$ kN
2	$\geq$ 18 mm	$n_1 \geq 4$; $n_2 = 1$ and $n_3 \leq 0,60$ kN

(1)   The minimum anchorage depth, given by the manufacturer, shall be bigger or equal to the 5%-fractile of the measured anchorage depth of each series (except for series F2 and F7 according to Table 2.4) by using a confidence level of 75 % and an unknown standard deviation. Series with the same concrete strength class can be evaluated together.

The minimum anchorage depth is given in the ETA and has to be checked after installation of the fastener in the works.

For multiple fastener use it is assumed that in the case of excessive slip or failure of one fastener the load can be transmitted to neighbouring fasteners without significantly violating the requirements on the fixture in the serviceability and ultimate limit state.

For example, the design of the fixture may specify the number n_1 of fixing points to fasten the fixture and the number n_2 of fasteners per fixing point. Furthermore, by specifying the design value of actions N_{Ed} on a fixing point to a value $\leq n_3$ (kN) according to Table 1.1 up to which the strength and stiffness of the fixture are fulfilled and the load transfer in the case of excessive slip or failure of one fastener need not to be taken into account in the design of the fixture.

Fixtures and fasteners can be pre-assembled with metal or plastic components. In this case the fixture is part of the fastener and fixture and fastener shall be assessed together regarding anchorage in base material. The construction of the fixture can be assessed together with the power-actuated fastener or separately.

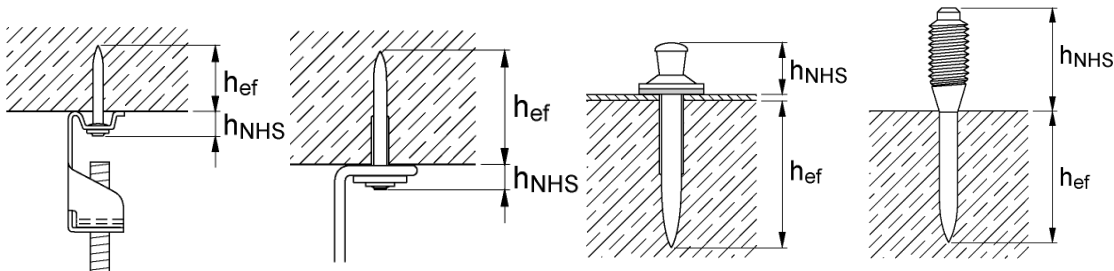Figure 1.2 shows examples of the installed product with different fixtures.

Figure 1.2 – Power-actuated fastener with different fixtures or external thread anchored in a concrete slab

The fastener is intend to be used for anchorages which are designed according to one of the design methods given in ETAG 001-C:2010 [5] or in prEN 1992-4:2013 [11]. For fasteners of Type 2 design method C of ETAG 001-C:2010 [5] is used.

1.2.2 Working life

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 fastener 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

General

Fastener = a manufactured, assembled component for achieving anchorage between the base material (concrete) and the fixture

Fixture = component to be fixed to the concrete member

Anchorage = an assembly comprising base material (concrete), fastener and component fixed to the concrete member

Suitability tests = Designation taken from ETAG 001-1:2013, 5.1.2 [5]

Tests for admissible service conditions = Designation taken from ETAG 001-1:2013, 5.1.3 [5]

Reference tests = Tests for evaluation of the results of the suitability tests to take into account the influence of certain parameters on the tension load resistance

Pre-qualification tests = Tests for determination of the required number of tests of suitability tests and tests for admissible service conditions, depending on the scatter of ultimate loads in these tests

Fasteners

The notations and symbols frequently used in this EAD are given below. Further particular notation and symbols are given in the text. The notations of ETAG 001-1:2013 [5] may also be noticed.

c = edge distance

c_{min} = minimum allowable edge distance

$c_{min,fi}$ = minimum allowable edge distance under fire exposure

d = fastener bolt diameter

d_{cut} = cutting diameter of drill bit

d_f = diameter of clearance hole in the fixture

h = thickness of concrete member

h_0 = depth of the drill hole

h_{min} = minimum thickness of concrete member

h_{ef} = effective anchorage depth

h_{NHS} = nail head standoff

L = overall length of the fastener

s = spacing of the fasteners

s_{min} = minimum allowable spacing

$s_{min,fi}$ = minimum allowable spacing under fire exposure

T = torque moment

T_{inst} = maximum installation torque moment

T_u = maximum torque moment during failure

t_{fix} = thickness of fixture

Base material (concrete) and metal parts of fastener

f_c = concrete compression strength measured on cylinders

$f_{c,cube}$ = concrete compression strength measured on cubes

$f_{c,test}$ = compression strength of concrete at the time of testing

f_{cm} = mean concrete compression strength

f_{ck} = nominal characteristic concrete compression strength (based on cylinder)

$f_{ck,cube}$ = nominal characteristic concrete compression strength (based on cubes)

$f_{y,test}$ = 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^t_{Ru} = ultimate load in a test

$F_{Ru,m}$ = mean ultimate load in a test series

F^t_{Rk} = 5 %-fractile of the ultimate load in a test series

Δw = increase in crack width during loading of the anchor and crack width at the time of installing the anchor

n = number of tests of a test series

v = coefficient of variation

$\delta(\delta_N, \delta_V)$ = displacement (movement) of the fastener at the concrete surface relative to the concrete surface in direction of the load (tension, shear) outside the failure area. The displacement includes the steel and concrete deformations and a possible fastener slip.

δ_0 = displacement of the fastener under short term loading

δ_∞ = displacement of the fastener under long term loading

α = ratio of test value / reference value, for instance

N_{Rk}, V_{Rk} = characteristic fastener resistance under tension or shear force

F_{Rk} = characteristic fastener resistance in any load direction

$F_{Rk,fi}$ = characteristic fastener resistance in any load direction under fire exposure

$M^0_{Rk,s}$ = characteristic resistance for steel failure with lever arm

$M^0_{Rk,s,fi}$ = characteristic resistance for steel failure with lever arm under fire exposure

Multiple use

n_1 = number of fixing points to fasten the fixture

n_2 = number of fasteners per fixing point

n_3 = design value of actions on a fixing point

2   ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1   Essential characteristics of the product

Table 2.1 shows how the performance of this product is assessed in relation to the essential characteristics.

Table 2.1   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	Characteristics for resistance	2.2.1	Level (F_{Rk} [kN])
			Level ($M^0_{Rk,s}$ [Nm])
			Level (c_{min}, s_{min} [mm])
			Level (h_{min} [mm])
2	Displacements	2.2.2	Level (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)
5	Resistance to fire	2.2.5	Level ($F_{Rk,fi}$ [kN])
			Level ($M^0_{Rk,s,fi}$ [Nm])
			Level ($c_{min,fi}$, $s_{min,fi}$ [mm])

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

Characterisation of the product to be assessed shall be done in accordance with available specifications, notably the fastener shall be characterised according to Table 2.2.

Table 2.2   Material and dimensions of the product

No	Product property	Test method
1	Dimensions (outer diameter, inner diameter, thread length, etc.)	Measuring or optical
2	Tensile Load (N_p) or tensile strength (f_{uk})	Similar to EN ISO 898-1 [14]
3	Yield strength (f_{yk} or $N_{p0.2}$)	Similar to EN ISO 898-1 [14]
4	Core hardness and Surface hardness (at specified functioning relevant points of the product) (where relevant)	Tests according to EN ISO 6507 [8] or EN ISO 6508 [9]
5	Zinc plating (where relevant)	x-ray measurement
6	Fracture elongation A_5	Similar to EN ISO 898-1 [14]

It is assumed that the installation of the product will be undertaken in line with the manufacturer's product installation instructions.

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

The essential characteristics are only valid if the following conditions are reflected in the ETA and fulfilled on jobsite:

- Holes are drilled perpendicular to the surface.
- Fasteners are installed perpendicular to the surface.
- All special drill bits (e.g. stopdrills) are in compliance with the manufacturer's specifications.
- Fasteners are installed not less than the specified embedment depth. Edge distances and spacing are kept, no minus tolerances are allowed.
- Drilling holes without damaging of the reinforcement.
- In case of aborted drill hole a new hole is drilled at a minimum distance away of twice the depth of the aborted hole.
- Damages on the concrete surface, caused by setting defects, have to be repaired according to technical rules, e.g. EN 1504 [13]. A new fastener is set at a minimum distance away of $\geq$ 150 mm and $\geq$ 3 h_{ef} of the edge of the damaged surface.
- Fastening tool and designation of relevant components (e.g. piston, fastener guide, magazine).
- Tools to install the power-actuated fastener have to be considered at designing and planning of the anchorage (Setting tool according to EN 15895 [10] or C.I.P. [7] approval).

2.2.1 Characteristic load bearing capacity

The test program for the assessment consists of

- Tests for admissible service conditions and
- Suitability tests.

The purpose of the admissible service condition tests is to determine the basic technical data required to predict the performance of the fastener under service conditions and derive corresponding design information.

Suitability tests are performed to assess the sensitivity of the fastener system regarding variations in the properties of the base material and foreseeable deviations from the manufacturer's installation instructions and establish a safe, effective and robust behaviour of the fastener system under normal and adverse installation conditions.

2.2.1.1 Suitability tests

The tests shall be performed as single fastener tests in concrete members without any influence by edge and spacing effects under tension loading. The fasteners should be installed according to the installation instructions of the manufacturer. The tests should be performed according to ETAG 001-A:2013 [5].

The load should increase in such a way that the average peak load of a test series is reached after 0,5 to 3,0 minutes. All tests should be performed later than 10 minutes after setting.

For evaluation of the general suitability of the fastener system pre-qualification tests are required. Pre-qualification tests are performed in order to determine the scatter of the ultimate load of the fastener system.

The fasteners should be driven with the energy recommended by the manufacturer. For powder-driven fasteners the cartridge recommendation and the corresponding tool energy settings should be observed. The stand-off tolerance range for the given fastener shall be observed.

Further details of tests are described in ETAG 001-A:2013 [5]. In all suitability tests displacements can be measured externally (e.g. by displacement transducers according to ETAG 001-A:2013 [5] or internally (e.g. measurement of piston stroke).

The single fasteners are tested in tension and loaded to failure.

The test conditions, the number of required tests and the criteria applied to the results should be taken in accordance with Table 2.3.

Table 2.3   Pre-qualification tests for power-actuated fasteners to be used in concrete

No	Purpose of test	Concrete	Crack width Δw (mm)	Thickness of fixture	Minimum number of tests	Criteria for the scatter of the measured ultimate loads	Scatter range
F0	Pre-qualification	C50/60 (1)	0	min. t_{fix}	50	$v \leq 20\ \%$	A
						$v > 20\ \%$	B

(1)   If there is an application for anchorages in concrete strength class less than C50/60 only: tests are required in concrete with a compressive strength $f_{ck,test} \geq f_{ck,used}$ + 20 MPa (in case of C20/25) and $f_{ck,test} \geq f_{ck,used}$ + 10 MPa (in case of C40/50), interim values can be interpolated linear

Further suitability tests, test conditions, the number of required tests and the criteria applied to the results should be taken in accordance with Table 2.4.

Table 2.4   Suitability tests for power-actuated fasteners to be used in concrete

No	Purpose of test	Concrete	Crack width Δw (mm)	Thick-ness of fixture	Scatter range (5)	Minimum number of tests	Criteria req. α (2)	Refe-rence test (4)
F1	Setting test	C50/60 max. aggregate size 32 (6) (7)	0	min.t_{fix}	A	10	$\geq 0,8$ (8)	F0
					B	20		
F2	Contact with reinforcement	C20/25	0	min.t_{fix}	A	5	$\geq 0,7$ (8)	A1
					B	10		
F3	Functioning in low strength concrete	C20/25 (1)	0,35	max.t_{fix}	A	5	$\geq 0,75$	A3
					B	10		
F4	Functioning under repeated loads	C20/25	0	max.t_{fix}	A	5	$\geq 1,0$	A1
					B	10		
F5	Maximum torque moment (3)	C20/25	0	max.t_{fix}	A	5	$\geq 0,9$	A1
					B	10		
F6	Sensitivity to brittle fracture	C20/25	0	min.t_{fix}	-	5	$\geq 0,9$ (9)	A1 (10)
F7	Checking durability	See 2.2.3						

(1)   If there is an application for anchorage in C 12/15; tests are also required in concrete with a compressive strength $f_{cm} \leq 20$ MPa (measured on cylinders) or $f_{cm} \leq 25$ MPa (measured on cubes).

(2)   For α, see ETAG 001-1:2013, Equation (6.2) [5].

(3)   Only for fasteners with external thread

(4)   Referenced to test series as described in Table 2.3 and Table 2.5; Reference tests shall be performed with the same fastener type and in the same slab or same concrete batch as in the corresponding suitability tests.

(5)   Scatter range according to Table 2.3.

(6)   If there is an application in composite slabs: tests are also required in composite slabs. The tested thickness, hardness and strength of the steel shell shall be given in the ETA.

(7)   If there is an application for anchorages in concrete strength class less than C50/60 only: tests are required in concrete with a compressive strength $f_{ck,test} \geq f_{ck,used} + 20$ MPa (in case of C20/25) and $f_{ck,test} \geq f_{ck,used} + 10$ MPa (in case of C40/50), interim values can be interpolated linear

(8)   Valid for $\gamma_2 = 1,2$; for other values of γ_2 see ETAG 001-1:2013, 6.1.2.2.2 [5]

(9)   For α: only comparison of the mean values is required, see ETAG 001-1:2013, Equation (6.2a) [5]

(10) If there are different setting conditions between series F6 and A1 (e.g. concrete batches or anchorage depth because of the isolation) additional reference tests with setting conditions of test F6 are possible

Test procedure F1: Setting test

The single fasteners are tested in tension and loaded to failure. Details of the test are described in ETAG 001-A:2013, Section 5.2.1 [5]. In deviation from ETAG 001-A:2013 [5] the maximum aggregate size of the concrete member shall be 32 mm and the grading curve A32 according to Figure 2.1 shall be used. The hardness of the aggregate of the grading 15 to 30 mm or 16 to 32 mm respectively shall be at least 5 Mohs mineral hardness (for example quartzite or granite).
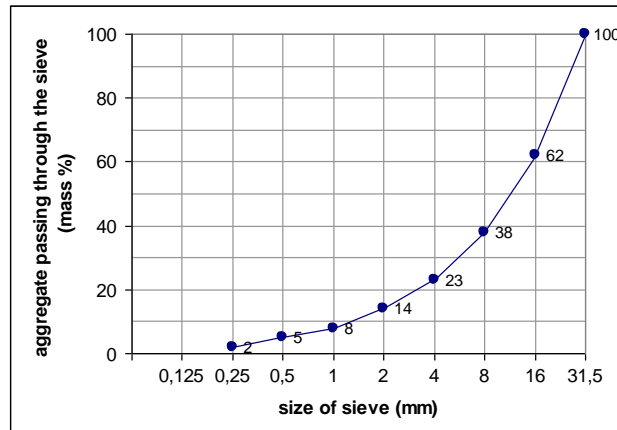
Figure 2.1:
Grading curve A32

Test procedure F2: Contact with reinforcement

For these tests a special concrete member with reinforcement without ribs of a diameter of 25 mm (f_{uk} = 500 N/mm^2) is used. The concrete cover should be chosen so, that the reinforcement is not touched by the previous drill. For power-actuated fasteners without previous drill the concrete cover should be 10 mm. The setting position in the quarter point of the reinforcing bar (shown in Figure 2.2) should be tested. The single fasteners are tested in tension and loaded to failure. Details of the test are described in ETAG 001-A:2013, 5.2.1 [5].
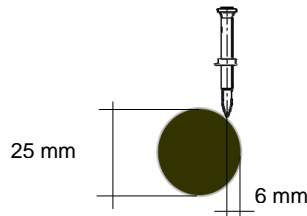
Figure 2.2:
Setting position for contact with reinforcement

Test procedure F3: Functioning in low strength concrete

The single fasteners are tested in tension and loaded to failure. Details of the test are described in ETAG 001-A:2013, 5.2.1 [5].

Test procedure F4: Functioning under repeated loads

The single fastener is subjected to 10^5 load cycles with a maximum frequency of approximately 6 Hz. During each cycle the load shall change as a sine curve between max N and min N with:

max N = 0,60 N_{Rk} and   (2.1)

min N = 0,25 N_{Rk}.   (2.2)

Further details of the test are described in ETAG 001-A:2013, 5.6 [5]. After completion of the load cycles the fasteners should be unloaded the displacement measured and a tension test to failure performed according to ETAG 001-A:2013, 5.2.1 [5].

Test procedure F5: Maximum torque moment

For fasteners with external thread the torque moment is applied with a calibrated torque wrench. Details of the test are described in ETAG 001-A:2013, 5.10 [5].

The single fastener is subjected to a torque moment. The torque moment is applied with a calibrated torque wrench up to the double installation torque moment T_{inst}. After this a tension test to failure shall be performed according to ETAG 001-A:2013, 5.2.1 [5].

Test procedure F6: Sensitivity to brittle fracture

Sensitivity to brittle failure should be tested in accordance with ETAG 001-3:2013, 5.1.2.5 [5]:

<u>Purpose and method of testing</u>

This test for power-actuated fasteners can be omitted if fasteners are made of stainless steel (exception martensitic steel).

Fasteners of high strength can be sensitive to brittle fracture due to hydrogen embrittlement caused by the production process or by corrosion during (even short-time) exposure to moisture. The test is designed to detect fasteners with a high susceptibility to hydrogen induced brittle fracture and will be performed under conditions of constant mechanical load and hydrogen evolution on the surface of the fastener. For this purpose an electrolyte similar to concrete pore solution (saturated calcium hydroxide solution) will be applied while the sample is kept under constant and defined electrochemical conditions (at constant potential of −955 mV vs. normal hydrogen electrode (NHE)) by potentiostatic control or by other appropriate means. The potential is measured controlled by means of a reference electrode. The test setup is shown schematically in Figure 2.3.

<u>Preparation of samples</u>

The fasteners shall be driven into the concrete by means of the respective power-actuated tool.

<u>Test conditions:</u>

Test member: concrete strength C20/25

Test solution: saturated solution (in distilled water) of calcium hydroxide with small excess of $Ca(OH)_2$ powder to obtain a milky appearance. The pH will then attain about 12,6 (± 0,1) at 25 °C and remain almost constant during the test. Calcium hydroxide powder should be kept in an air-tight containment and should not be stored longer than one year.

The test solution should be filled into a bottomless container covering an area of at least 96 cm^2 with a height of at least 25 mm, which shall be affixed to the concrete (see Figure 2.3). During the test the head of the fasteners shall be submerged in the fluid.

Sustained load:

$$N_{HE} = N_{Rk} \hspace{6cm} (2.3)$$

with: N_{Rk} -   characteristic resistances in C20/25 under tension loading according to
2.2.1.4 (without reduction factor from suitability test F6)

<u>Electrochemical conditions:</u>

Potential: -955 mV vs. NHE.

Reference electrode: any kind of „second order" electrode (calomel, silver/silver chloride etc.) can be used. The potential value shall be corrected according to the reference value given by the manufacturer, e.g. for a saturated calomel electrode with E_{cal}= +245 mV vs. N_{HE} the correct potential will be

E = −955 − 245 = -1200 mV (±10 mV).

Counter electrode: stainless steel or activated titanium (used as anode for cathodic protection)

Temperature range: 20 to 25 °C

Duration of test: 100 hours. Following the test, after unloading the fastener, an unconfined tension test to failure shall be performed.

<u>Test Criteria:</u>

During the constant load portion of the test (100 hours), no fastener shall fail. The failure load of residual load bearing capacity shall be compared to reference tension tests according to reference tests in C20/25. The reduction factor shall fulfil req. $\alpha \geq 0,9$.
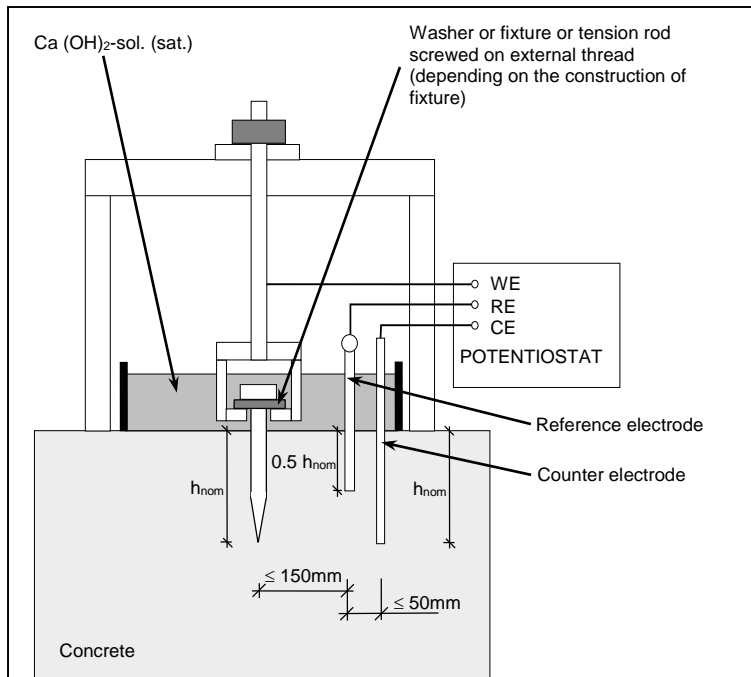
Figure 2.3 – Test setup (schematic)

Note: If possible the working electrode (WE) should be connected directly to the fastener and the fastener should be electrically isolated from the pulling device.

If no electric isolation is made and the working electrode (WE) is connected to the pulling equipment, the electrical resistance need to be compensated by the potentiostatic control. The potential between the fastener and the normal hydrogen electrode needs to be measured and documented for each sample.

2.2.1.2 Tests for admissible service conditions

The tests shall be performed as single fastener tests for each size in concrete members without any influence by edge and spacing effects under tension or shear loading. The fasteners should be installed according to the installation instructions of the manufacturer.

The load should increase in such a way that the average peak load of a test series is reached after 0,5 to 3,0 minutes. All tests should be performed later than 10 minutes after setting.

The types of tests for admissible service conditions, test conditions, the number of required tests and the criteria applied to the results should be taken in accordance with Table 2.5.

Table 2.5   Tests for admissible service conditions

No	Purpose of test	Concrete	Crack width Δw (mm)	Thick-ness of fixture	Load direc-tion	Scatter range (3)	Number of tests
A1	Characteristic resistance to tension loading	C20/25 (1)	0	max.t_{fix}	N	A	10
						B	20
A2	Characteristic resistance to tension loading	C50/60 (2)	0	max.t_{fix}	N	A	10
						B	20
A3	Characteristic resistance to tension loading	C20/25 (1)	0,2	max.t_{fix}	N	A	10
						B	20
A4	Characteristic resistance to tension loading (4)	C50/60 (2)	0,2	max.t_{fix}	N	A	10
						B	20
A5	Characteristic resistance to shear loading	C20/25	0	max.t_{fix}	V	A	5
						B	10

(1)   If there is an application for anchorage in C12/15; tests are also required in concrete with a compressive strength $f_{cm} \leq 20$ MPa (measured on cylinders) or $f_{cm} \leq 25$ MPa (measured on cubes).

(2)   If there is an application for anchorage in concrete strength class less than C50/60 only; tests are required in concrete with a compressive strength $f_{ck,test} \geq f_{ck,used} + 20$ MPa (in case of C20/25) and $f_{ck,test} \geq f_{ck,used} + 10$ MPa (in case of C40/50), interim values can be interpolated linear

(3)   Scatter range according to Table 2.3

(4)   If $F_{Ru,m,A4} / F_{Ru,m,A2} > F_{Ru,m,A3} / F_{Ru,m,A1}$ than also test F3 according to Table 2.4 is required in concrete strength class C50/60.

Smaller spacing and edge distances than the limits given in 2.2.1.5 have to be tested and assessed according to ETAG 001-1:2013, 5.1.4 and 6.2.2.3 to 6.2.2.7 [5].

Test procedure for characteristic resistance to tension loading

The tension tests are carried out at concrete members with normal strength C20/25 and in C50/60 (or the maximum grade the anchorage is applied for), cracked and non-cracked concrete according to ETAG 001-A:2013, 5.2.1 [5]. Displacements of series A2, A3 and A4 can also be measured internally (e.g. measurement of piston stroke). Reference tension tests for determination of the results of the suitability tests have to be carried out at the same concrete as it is given for the corresponding suitability tests (compressive strength).

Test procedure for characteristic resistance to shear loading

The shear tests are carried out at concrete members with normal strength C20/25, non-cracked concrete according to ETAG 001-A:2013, 5.3.1 [5].

2.2.1.3 Assessment of test results

5%-fractile of the ultimate loads:

The 5%-fractile of the ultimate loads measured in a test series is to be calculated according to statistical procedures for a confidence level of 90 % using logarithmical normal distribution of the single test results and unknown standard deviation of the population.

$$F^t_{Rk} = F_{ln5\%} = F_{Ru,m\,ln(x)} - k_s \cdot s_{ln(x)} \tag{2.4}$$

e.g.:   n = 5 tests: k_s = 3,40
         n = 10 tests: k_s = 2,57
         n = 20 tests: k_s = 2,21

with: $F_{ln5\%}$ =   5%-logarithmic fractile of the ultimate load calculated by the logarithmic test values

$F_{Ru,m\,ln(x)}$ =   mean value of ultimate load in a test series calculated by the logarithmic test values

k_s =   statistical factor

$s_{ln(x)}$ =   standard deviation calculated by the logarithmic test values

note: setting defects which can visually not be recognised (e.g. failure during installation of the test equipment) should be considered by F_{Ru} = 0,001 kN

Conversion of ultimate loads to take account of concrete and steel strength:

In some cases it can be necessary to convert the results of a test series to correlate with a concrete strength different from that of the test member (e.g. when comparing the results of repeated load tests with results of static tension tests performed on a different test member). When doing so, the type of failure shall be taken into account.

Normalize test results for the influence of the concrete compressive strength in accordance with Equation:

$$F_{Ru}(f_c) = F^t_{Ru}(f_c / f_{c,test})^n \tag{2.5}$$

with: $F_{Ru}(f_c)$ =   failure load at concrete compression strength f_c

F^t_{Ru} =   failure load at a test

$f_{c,test}$ =   concrete compression strength at a test

n   =   0,5 for concrete breakout and splitting failure,

in the case of pull out failure the influence of concrete strength on the failure load should be established from tests F0 and A1. In the absence of better information, the exponent 0,5 can be used as an approximation.

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

$$F_{Ru}(f_{uk}) = F^t_{Ru} \cdot f_{uk} / f_{u,test} \tag{2.6}$$

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

F^t_{Ru} =   failure load at a test

$f_{u,test}$ =   steel ultimate strength at a test

Load/displacement behaviour

The requirement on the load/displacement curves in ETAG 001-1:2013, 6.1.1.1 (a) [5] applies. However, a reduction in load and /or a horizontal or near-horizontal part in the curve by uncontrolled slip of the fastener is not acceptable up to a load of:

$$N_1 = 0,4\,N_{Ru} \quad \text{(instead of 0,7 } N_{Ru} \text{ according to Equation (6.1a) [5])} \tag{2.7}$$

There are no requirements on the scatter of the load/displacement curves.

Coefficient of variation of ultimate load

In each test series for methods according to Table 2.4 and 2.5 exceptional for maximum torque moment and sensitivity to brittle failure, the coefficient of variation of the ultimate load shall be calculated and should be smaller than $v_{u,S} = 20\%$. If the requirements for the scatter are not fulfilled by the tension tests, a reduction factor α_v for each test series shall be calculated according to:

$$\alpha_v = 1 / (1 + 0{,}03 \cdot (v_u\,[\%] - 20)) \qquad\qquad (2.8)$$

with: v_u = coefficient of variation of ultimate load of tests according Table 2.4 and 2.5

Reduction factor α

For test series F1, F2, F3, F4 and F6 according to Table 2.4 the factor α according to ETAG 001-1:2013, 6.1.1.1 (d) [5] shall be calculated. The factor α should be larger than req.α given in Table 2.4 of this EAD. If the requirements on the ultimate load in the suitability tests are not fulfilled in one or more test series, then the reduction factor α_u shall be calculated according to:

$$\alpha_u = \alpha / \text{req. } \alpha \qquad\qquad (2.9)$$

with: α =   lowest value according to ETAG 001-1:2013, Equation (6.2) [5] of test series F1- F4 and F6

req. α =   required α according to Table 2.4

The value α should be calculated according ETAG 001-1:2013, Equation (6.2) [5] as a comparison of the 5%-fractile or mean value of the suitability tests with the adequate values of reference tests.

Functioning under repeated loads

The increase of displacement during cycling shall stabilize in a manner indicating that failure is unlikely to occur after some additional cycles.

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

Maximum torque moment

For test series F5 according to Table 2.4 the factor α according to ETAG 001-1:2013, 6.1.1.1 (d) [5] shall be calculated. The factor α shall be larger than req.α given in Table 2.4 of this EAD. If the requirements on the ultimate load in the suitability tests are not fulfilled in one or more test series, then the installation torque moment T_{inst} have to be reduced accordingly.

2.2.1.4 Evaluation of the characteristic resistance of a single fastener

Pull-out failure under tension load

The characteristic resistances of single fasteners in C20/25 under tension loading should be calculated as follows:

$$N_{Rk,p} = N_{Rk,0} \cdot \min \alpha_u \cdot \min \alpha_V \qquad\qquad (2.10)$$

with: $N_{Rk,0}$ =   characteristic resistance evaluated from the results of tests according to Table 2.5, line 1, 2, 3 and 4

min α_u =   minimum α_u (reduction factor from the ultimate loads in the suitability tests) according to 2.2.1.4 for suitability tests F1, F2, F3, F4 and F6 according to Table 2.4; ($\leq 1{,}0$),

min α_v =   minimum α_v to consider a coefficient of variation of the ultimate loads in the suitability and admissible service condition tests larger than 20 % according to 2.2.1.4; ($\leq 1{,}0$).

Steel failure under shear load without lever arm

The characteristic resistance $V_{Rk,s}$ should be determined for the cross-section of fastener as follows:

$$V_{Rk,s} = \alpha \cdot A_s \cdot f_{uk} \tag{2.11}$$

with: α = 0,5

   A_s = stressed cross-section of the fastener

   f_{uk} = characteristic tensile strength of the fastener

Concrete failure under shear load

The characteristic resistances of single fasteners in C20/25 under shear loading should be calculated as follows:

$$V_{Rk,c} = V_{Rk,0} \cdot \alpha_V \tag{2.12}$$

with: $V_{Rk,0}$ = characteristic resistance evaluated from the results of tests according to Table 2.5, line 5

   α_v = value α_v to consider a coefficient of variation of the ultimate loads in the admissible service condition tests larger than 20 % according to 2.2.1.4; ($\leq 1{,}0$).

Characteristic resistance in any load direction

For determination of the characteristic resistance in any load direction the characteristic resistance is controlled by the failure mode resulting to the minimum design strength $F_{Rd,min}$.

$$F_{Rd,min} [kN] = \min (N_{Rk,p} / \gamma_{Mc}; V_{Rk,s} / \gamma_{Ms}; V_{Rk,c} / \gamma_{Mc}) \tag{2.13}$$

with: $N_{Rk,p}$; $V_{Rk,s}$; $V_{Rk,c}$ according to Equations above

   γ_{Mc}; γ_{Ms} according to ETAG 001-C:2010, 3.2.2 [5]

The characteristic resistance (in kN) shall be determined by following Equation and rounded down to zero or five on the second place after the decimal point:

$$F_{Rk} [kN] = F_{Rd,min} \cdot \gamma_M \tag{2.14}$$

with: $F_{Rd,min}$ according to Equation above

   γ_M depends on decisive failure mode (see Equation 2.13)

Steel failure under shear load with lever arm

The characteristic resistance $M^0_{Rk,s}$ should be determined for the cross-section of the fastener as follows:

$$M^0_{Rk,s} = 1{,}2 \cdot W_{el} \cdot f_{uk} \tag{2.15}$$

with: W_{el} = section modulus of the fastener

   W_{el} = $\pi \cdot r^3/4$

   f_{uk} = characteristic tensile strength of fastener

2.2.1.5 Spacing and edge distances

Tests for determination of required spacing and edge distances can be omitted if the following limits are observed:

spacing s_{min} = max (200 mm; 4 h_{ef})

edge distance c_{min} = max (150 mm; 3 h_{ef})

thickness of concrete member h_{min} = max (80 mm; 2 h_{ef})

Smaller spacing end edge distances have to be tested and assessed according to ETAG 001-1:2013, 5.1.4 and 6.2.2.3 to 6.2.2.7 [5].

2.2.2 Characteristic displacements

The characteristic displacements for short-term and quasi-permanent loading are specified for the load F in accordance with following equation:

$$F = F_{Rk} / (\gamma_F \cdot \gamma_M) \tag{2.16}$$

with: F_{Rk} = characteristic resistance

γ_F = partial safety factor for actions = 1,4

γ_M = partial safety factor for material according ETAG 001-C:2010, 3.2.2 [5]

The displacements δ_{N0} and δ_{V0} under short-term loading are evaluated from test series Table 2.5, line 1 and line 5. They should correspond to the mean value of these test series. The displacements (in mm) should be rounded up to zero or five on the first place after the decimal point.

The displacements $\delta_{N\infty}$ under long-term tension loading are assumed to be approximately equal to 2,0-times the displacements δ_{N0}. The displacements $\delta_{V\infty}$ under long-term shear loading are assumed to be approximately equal to 1,5-times the displacements δ_{V0}. Under shear loading, the displacements might increase due to a gap between fixture and fastener. The influence of this gap is taken into account in design.

2.2.3 Durability

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:

(1) Power-actuated fastener 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.

(2) Power-actuated fastener 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 (3) 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 5:2009 [3] can be used.

(3) Power-actuated fastener 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 5:2009 [3] can be used.

2.2.4 Reaction to fire

The power-actuated fastener is 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.

2.2.5 Resistance to fire

The suitability of a power-actuated fastener for use in a system that is required to provide a specific fire resistance class, shall be tested and assessed according to the EOTA TR 020 [4].

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 1997/463/EC

The system is: 2+

3.2   Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of verification of constancy of performance are laid down in Table 3.1.

Table 3.1 is an example only; the control plan depends on the individual manufacturing process and has to be established between notified body and manufacturer for each product.

Table 3.1   Control plan for the manufacturer of the fastener; 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.)	Measuring or optical	Laid down in control plan	3	Every manufac-turing batch or 100000 fasteners
2	Tensile Load (N_p) or tensile strength (f_{uk})	Similar to EN ISO 898-1[14]		3	
3	Yield strength (f_{yk} or $N_{p0.2}$)	Similar to EN ISO 898-1[14]		3	
4	Core hardness and Surface hardness (at specified functioning relevant points of the product; where relevant)	Tests according to EN ISO 6507 [8] or EN ISO 6508 [9]		3	
5	Zinc plating (where relevant)	x-ray measurement		3	
6	Fracture elongation A_5	Similar to EN ISO 898-1[14]		3	
7	Hydrogen embrittlement (where relevant)	According to the control plan		3	

3.3   Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of verification of constancy of performance for the product are laid down in Table 3.2.

Table 3.2   Control plan for the notified body; cornerstones

Nr	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 fastener	-	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

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 harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/ECC

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

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

[4]   EOTA TR 020:2004: Evaluation of Anchorages in Concrete concerning Resistance to Fire, Edition May 2004

[5]   EOTA ETAG 001: Guideline for European technical approvals of Metal anchors for use in concrete,

         ETAG 001-1:2013:   Part 1: Anchors in general

         ETAG 001-3:2013:   Part 3: Undercut Anchors

         ETAG 001-6:2013:   Part 6: Anchors for multiple use for non-structural applications

         ETAG 001-A:2013:   Annex A: Details of tests

         ETAG 001-C:2010:   Annex C: Design methods for anchorages

[6]   EN 10346:2009: Continuously hot-dip coated steel flat products - Technical delivery conditions

[7]   C.I.P. Permanent International Commission for the Proof of small-arms: Comprehensive edition of adopted C.I.P. decisions, Edition 2001

[8]   EN ISO 6507:2005: Metallic materials – Vickers hardness test

[9]   EN ISO 6508:2005: Metallic materials – Rockwell hardness test

[10]   EN 15895:2011 Cartridge-operated hand-held tools – Safety requirements – Part 1: Fixing and hard marking tools

[11]   prEN 1992-4:2013, Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete

[12]   EN 206-1:2000 Concrete – Part 1: Specification, performance, production and conformity

[13]   EN 1504: Products and systems for the protection and repair of concrete structures – Definitions, requirements, quality control and evaluation of conformity

[14I   EN ISO 898-1:2013: 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