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METAL EXPANSION FASTENERS FOR USE IN AUTOCLAVED AERATED CONCRETE

The reference title and language for this EAD is English. The applicable rules of copyright refer to the document elaborated in and published by EOTA.

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 post-installed deformation-controlled expansion fasteners placed into pre-drilled holes perpendicular to the surface (maximum deviation 5°) in autoclaved aerated concrete (AAC) and anchored therein by mechanical interlock.

Metal expansion fasteners are made of galvanized and/or coated steel, stainless steel or high corrosion-resistant steel. This EAD covers only fasteners with steel strength less than 1000 N/mm^2 and hardness smaller than 350 HV referring to the total cross section for both surface and core hardness according to EN ISO 6507 [8]; < 36 HRC according to EN ISO 6508 [9].

The fasteners are described by the manufacturer by reference to dimensions (external/internal diameter, thread length, diameter of shaft, cone etc.) and mechanical properties (tensile and yield strength, fracture elongation) including possible tolerances.

This EAD applies to fasteners with the following dimensions:

- Minimum thread size of 6 mm (M6),
- Minimum setting depth h_{ef} = 50 mm.

This EAD covers fasteners with a maximum characteristic resistance of 12 kN.

The fastener consists of a cone with internal thread, a threaded bolt, an expansion sleeve, a washer and a hexagon nut. The fastener with threaded sleeve consists of a cone with internal thread, a threaded bolt, an expansion sleeve and a sleeve with internal thread. The cone and the threaded bolt may be made as one fastener part (conical bolt).

In a first step the conical bolt is pushed into the AAC member, in the second step the expansion sleeve is attached on the bolt and is pushed on the cone. The fastener is properly set, if the expansion sleeve is pushed into the member up to the marking of setting depth.

This EAD assesses the performance for fasteners that are only used once.

The fastener type for pre-positioned installation is set before the fixture is attached. The fastener for in-place installation is set through the clearance hole of the fixture.

Illustrations of the fastener versions and the installed products are given in following figures.

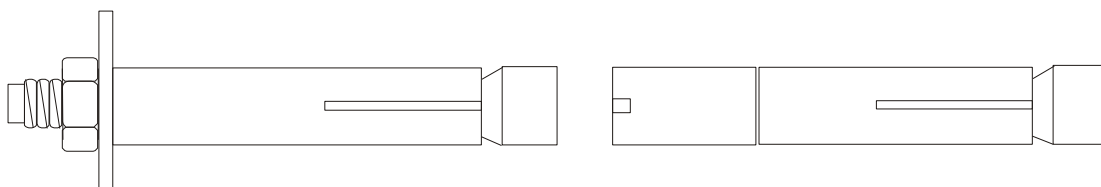**Figure 1.1 Fastener with threaded bolt, washer and hexagon nut or with internally threaded sleeve for pre-positioned installation**

marking of required setting depth

Figure 1.2 Fastener with internally threaded sleeve for in-place installation
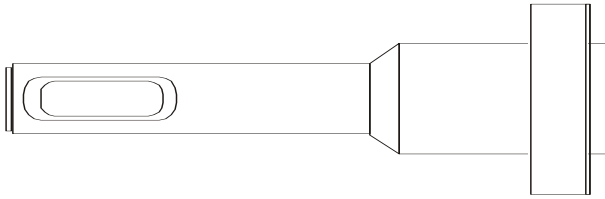
Figure 1.3   Example of setting tool

fixture   member
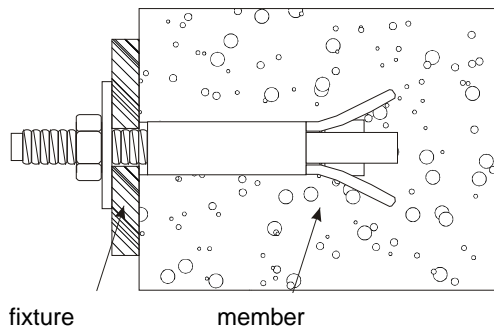
Figure 1.4   Installed fastener: Pre-positioned installation (The fastener is set before fastening of the fixture. The fixture bears on the threaded bolt.)

marking of required setting depth
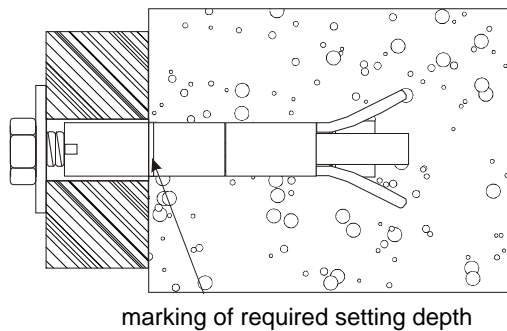
Figure 1.5   Installed fastener: in-place installation (The fastener is set through the clearance hole of the fixture. The fixture bears on the sleeve of the fastener.)

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 fastener is intended to be used under static and quasi-static actions in tension loading, shear loading and bending in:

− Prefabricated reinforced components of autoclaved aerated concrete according to EN 12602:2016 [1] (Use Condition "Slab", cracked and non-cracked AAC),

− Autoclaved aerated concrete masonry units according to EN 771-4:2011+A1:2015 [2] (Use Condition "Masonry", only non-cracked AAC).

The fasteners are intended to be used in areas with very low seismicity as defined in EN 1998-1:2004 + AC:2009, Clause 3.2.1 [10].

This EAD covers fasteners which are set in unplastered members.

The AAC strength class of the reinforced or non-reinforced member shall correspond to at least AAC 2 and to at maximum AAC 7 according to EN 12602:2016 [1].

The thickness of the AAC member in which the fastener is installed is $h \geq 2\ h_{ef}$ and $h \geq 100$ mm.

The covered temperature range of the fastening base AAC during the working life is within the range -40 °C to +80 °C.

Any manufacturer's installation instructions (e.g. drilling technology, hole cleaning, installation tools, torque moments) shall be reported in the ETA.

The fasteners are intended to be used for fastenings which are designed according to the Design method B of TR 054:2016-04 [3].

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 fastener is subject to appropriate installation. 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

1.3.1 Definitions

fastener	=	a manufactured component for achieving fastening between the base material (concrete) and the fixture; it may consist of assembled components
fastener group	=	several fasteners (working together)
fastening	=	an assembly comprising base material (concrete), fastener or fastener group and component fixed to the concrete
fixture	=	component fixed to the concrete with the use of fasteners
test member	=	concrete member in which the fastener is tested

1.3.2 Notation

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

Fasteners:

a	=	spacing between outer fasteners in adjoining fastenings
c	=	edge distance
c_{cr}	=	characteristic edge distance
c_{min}	=	minimum allowable edge distance
$c_{min,fi}$	=	minimum allowable edge distance under fire exposure
d	=	fastener bolt diameter
d_0	=	nominal drill hole 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
L	=	overall length of the fastener
s	=	spacing of the fasteners
s_{cr}	=	characteristic spacing
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

Loads/forces:

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

Assessment:

Δw	=	increase in crack width during loading of the fastener and crack width at the time of installing the fastener
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_{Rd}	=	design value of fastener resistance in any load direction
$F_{Rk,fi}$	=	characteristic fastener resistance in any load direction under fire exposure
$M_{Rk,s}$	=	characteristic resistance for steel failure with lever arm
$M_{Rk,s,fi}$	=	characteristic resistance for steel failure with lever arm under fire exposure

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	Resistance in any load direction without lever arm	2.2.1	F_{Rk} [kN]
2	Resistance under shear load with lever arm	2.2.2	$M_{Rk,s}$ [Nm]
3	Spacing, edge distance, member thickness	2.2.3	c_{cr}, s_{cr}, c_{min}, s_{min}, h_{min} [mm]
4	Displacements	2.2.4	δ_{N0}, $\delta_{N\infty}$, δ_{V0}, $\delta_{V\infty}$ [mm]
5	Durability	2.2.5	Description
Basic Works Requirement 2: Safety in case of fire			
6	Reaction to fire	2.2.6	Class A1
7	Fire resistance in any load direction without lever arm	TR 020 [5]	$F_{Rk,fi}$ [kN]
8	Fire resistance under shear load with lever arm		$M_{Rk,s,fi}$ [Nm]
9	Spacing, edge distance for fire resistance		$c_{min,fi}$, $s_{min,fi}$ [mm]

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

An overview of the test program and general details of tests for the assessment of the various essential characteristics of the product is given in Annex A.

Provisions valid for all tests and general aspects of the assessment (determination of 5% fractile values of resistance, determination of reduction factors, criteria for uncontrolled slip, etc.) are also given in Annex A.

2.2.1　Resistance in any load direction without lever arm

2.2.1.1 Basic tension tests (Test series A1, A3 and A5)

These tests are performed to determine the tension capacity of a single fastener and thereby establishing the baseline values for the assessment of the performance under tension load.

The baseline value $N_{Rk,0}$ is taken as the 5% fractile (according to A.3.3) of failure loads in the tension test series according to Table A.1, line A1, A3 and A5.

2.2.1.2 Robustness to variations in use conditions (Test series F1)

These tests are performed to determine the sensitivity of the performance to foreseeable and unavoidable variations in the use conditions.

The tests are performed with a reduced fastener length or a reduced length of the setting tool taking into account the tolerances of the product and setting tool and possible abrasion of the setting tool. The reduction shall be at least 2 mm or 10 % of the length of the internal thread.

2.2.1.3 Setting in wet AAC (Test series F2)

If the fastener is intended to be set in wet AAC, this influence is checked.

Before installation, the test specimens are stored under water for 48 h and dropping off for 2 h while keeping side of later installation of fastener to the bottom.

2.2.1.4 Maximum crack width (Test series F3)

If the fastener is intended to be used in cracked AAC, the influence of increased crack width $\Delta w = 0.50$ mm in low strength AAC and high strength AAC is checked.

2.2.1.5 Crack cycling under load (Test series F4)

Fasteners intended for use in cracked AAC, in the long term, shall continue to function effectively when the width of the crack is subject to changes in the range covered by this EAD.

Experience has shown that the crack movements are difficult to steer with rebar in AAC. Therefore it is recommended to steer the crack movements with a concrete slab as described in TR 048:2016-08 [4]. The AAC slab shall be cut and fixed undisplaceable to a cracked concrete slab such that the crack of AAC and concrete slab are directly above each other. The crack opening is created in the concrete slab whereas the measurement of the crack width is located on both sides of the AAC slab over the joint. The fastener shall be installed in the middle of the slab.

After fastener installation the maximum (max N_s) and minimum (min N_s) loads applied to the test member shall be determined such that the crack width under max N_s is $\Delta w_1 = 0.3$ mm and under min N_s is $\Delta w_2 = 0.1$ mm. To stabilize crack formation, up to 10 load changes varying between max N_s and min N_s may be applied. Then a tensile load N_p according to following Equation is applied to the fastener after opening the crack to $\Delta w_1 = 0.3$ mm.

$$N_p \quad = \quad 0.75\, N_{Rk,p} / \gamma_{Mc} \qquad\qquad (2.1)$$

with $N_{Rk,p}$ = characteristic resistance according to Equation (2.5) as a result of test series A1 evaluated for the corresponding strength-class of AAC

          γ_{Mc} = 1,73 according to [2]

In each test the rate of increase of fastener displacements, plotted in a half-logarithmic scale (see Figure 2.1), shall either decrease or be almost constant: the criteria of the allowable displacement after 20 (δ_{20}) and 1000 (δ_{1000}) cycles of crack opening are graduated as a function of the number of tests as follows:

5 to 9 tests:	$\delta_{20} \leq 2$ mm and $\delta_{1000} \leq 3$ mm
10 to 20 tests:	$\delta_{20} \leq 2$ mm; one tests is allowed to 3 mm
	$\delta_{1000} \leq 3$ mm; one tests is allowed to 4 mm
> 20 tests:	$\delta_{20} \leq 2$ mm; 5% of tests are allowed to 3 mm
	$\delta_{1000} \leq 3$ mm; 5% of tests are allowed to 4 mm

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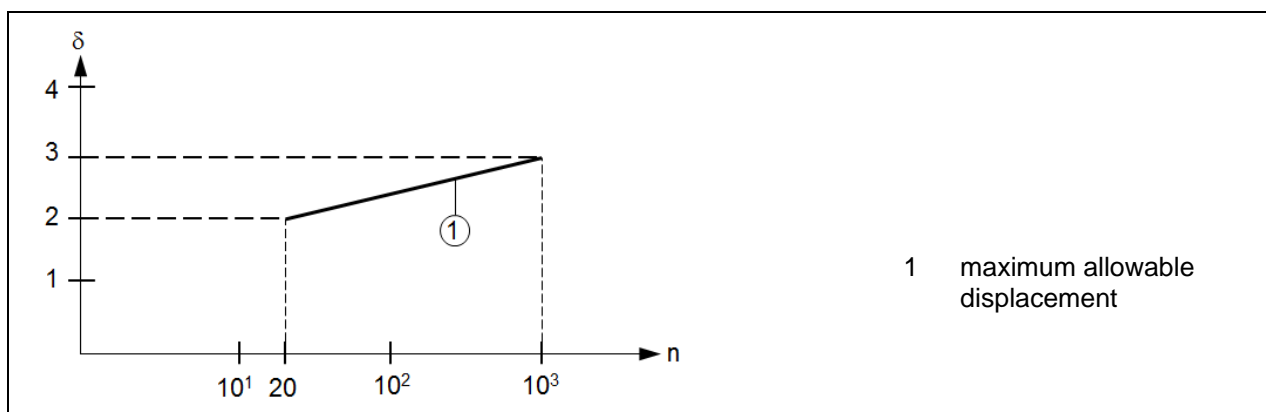

Figure 2.1   Criteria for results of tests with variable crack width

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

until the requirements are fulfilled. The characteristic resistance shall be reduced by applying the reduction factor $\alpha_p = N_{p,red}/N_p$.

2.2.1.6 Sustained loads (Test series F5)

These tests are performed to determine the performance of the fastener under sustained loads simulating service loads that are subject over time.

The fastener is subjected to a load according to Equation (2.2) and kept constant (variation within 0/+ 5 %).

$$N_p \quad = \quad 0,55 \; N_{Rk,p} \tag{2.2}$$

with $\quad N_{Rk,p} \quad =$ characteristic resistance according to Equation (2.5) as a result of test series A1 evaluated for the corresponding strength-class of AAC

The increase in displacement shall reduce with time in a manner indicating that failure is unlikely to occur.

If these requirements are not met, the test series shall be repeated with a reduced tension load $N_{p,red}$ until the requirements are fulfilled. The characteristic resistance shall be reduced by applying the reduction factor $\alpha_p = N_{p,red}/N_p$.

2.2.1.7 Repeated loads (Test series F6)

These tests are performed to determine the performance of the fastener under repeated loads simulating service loads that are subject to variation over time.

The 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:

$$\text{max } N \quad = \quad 0,60 \; N_{Rk,p} \tag{2.3}$$
$$\text{min } N \quad = \quad 0,25 \; N_{Rk,p}. \tag{2.4}$$

with $\quad N_{Rk,p} \quad =$ characteristic resistance according to Equation (2.5) as a result of test series A1 evaluated for the corresponding strength-class of AAC

During the repeated load portion of the test no failure is allowed to occur and the increase of displacements during the cycling shall stabilize in a manner 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 these requirements are not met, the test series shall be repeated with a reduced maximum tension load max N_{red} until the requirements are fulfilled. The characteristic resistance shall be reduced by applying the reduction factor $\alpha_p = \text{max } N_{red}/\text{max } N$.

2.2.1.8 Maximum torque moment (Test series F7)

The installation of the fastener shall be practicable without steel failure, turn-through in the hole or failure of the fastening.

The 95%-fractile of the tension force generated in the torque tests at a torque moment $T = 1,3 \; T_{inst}$ shall be smaller than the nominal yield force ($A_s \cdot f_{yk}$) of the bolt or screw. At the end of the test, the connection shall be capable of being unscrewed.

2.2.1.9 Characteristic pull-out resistance under tension loading

The characteristic pull-out resistance under tension loading is calculated as follows:

$$N_{Rk,p} \quad = \quad N_{Rk,0} \cdot \text{min } \alpha_{u,F1} \cdot \text{min } \alpha_{u,F2-F7} \cdot \text{min } \alpha_{CV} \cdot \text{min } \alpha_p \cdot \text{min } \alpha_1 \tag{2.5}$$

with: $\quad N_{Rk,0} \quad =$ 5% fractile (according to A.3.3) of failure loads in following tension test series according to Table A.1:

Line A1 resistance of a single fastener with $s \geq s_{cr} = 4 \; h_{ef}$ and $c \geq c_{cr} = 2 \; h_{ef}$

Line A3 resistance of a single fastener at the edge with $c \geq c_{min}$

Line A5 resistance of a single fastener at the corner $c1 = c2 \geq c_{min}$

Line A7 resistance of an fastener group with $s \geq s_{min}$ and $c \geq c_{min}$

min $\alpha_{u,F1}$ = minimum value α_u (reduction factor according to A.3.4 for test series F1)

min $\alpha_{u,F2\text{-}F6}$ = minimum value α_u (reduction factor according to A.3.4 for test series F2 to F6)

min α_{CV} = minimum value α_{CV} (according to A.3.2) to consider the criteria regarding scatter of failure loads

min α_p = minimum value α_p (according to 2.2.1.5, 2.2.1.6 and 2.2.1.7)

min α_1 = minimum value α_1 (according to A.3.5) to consider the criteria regarding uncontrolled slip

2.2.1.10 Characteristic shear resistance of a single fastener under shear loads without lever arm

The characteristic resistance to steel failure $V_{Rk,s}$ is determined for the cross-section of the fastener:

$$V_{Rk,s} = \alpha \cdot A_s \cdot f_{uk} \tag{2.6}$$

with: α = 0,5

A_s = stressed cross-section of the fastener without sleeve
(for fasteners with a significantly reduced section along the length of the bolt, the minimum cross section shall be used for calculation)

f_{uk} = characteristic tensile strength of the fastener

The characteristic resistances to AAC failure $V_{Rk,c}$ of single fastener under shear loading is calculated as follows:

$$V_{Rk,c} = V_{Rk,0} \cdot \min \alpha_{CV} \tag{2.7}$$

with: $V_{Rk,0}$ = 5% fractile (according to A.3.3) of failure loads in following shear test series according to Table A.1:

Line A2 resistance of a single fastener with $s \geq s_{cr} = 4\,h_{ef}$ and $c \geq c_{cr} = 2\,h_{ef}$

Line A4 resistance of a single fastener at the edge with $c \geq c_{min}$

Line A6 resistance of a single fastener at the corner $c1 = c2 \geq c_{min}$

Line A8 resistance of an fastener group with $s \geq s_{min}$ and $c \geq c_{min}$

α_{CV} = minimum value α_{CV} (according to A.3.2) to consider the criteria regarding scatter of failure loads

2.2.1.11 Resistance of a single fastener in any load direction without lever arm

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 $F_{Rd,min}$.

$$F_{Rd,min} = \min (N_{Rk,p} / \gamma_{Mc};\ V_{Rk,s} / \gamma_{Ms};\ V_{Rk,c} / \gamma_{Mc}) \tag{2.8}$$

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

γ_{Mc} = 1,73 for Use Condition Slab according to EN 12 602:2008+A1:2013, Annex D [2]

= 2,00 for Use Condition Masonry according to TR 054:2016-04 [3]

γ_{Ms} = $1{,}0 / (f_{yk}/f_{uk}) \geq 1{,}25$ for $f_{uk} \leq 800\ \text{N/mm}^2$ and $f_{yk} / f_{uk} \leq 0{,}8$

= 1,5   for $f_{uk} > 800\ \text{N/mm}^2$ and $f_{yk} / f_{uk} > 0{,}8$

f_{uk} = nominal characteristic steel ultimate strength of the fastener

f_{yk} = nominal characteristic steel yield strength of the fastener

The characteristic resistance shall be determined by following Equation:

$$F_{Rk} = F_{Rd,min} \cdot \gamma_M \tag{2.9}$$

with: $F_{Rd,min}$ according to Equation (2.8)

γ_M depends on decisive failure mode according to Equation (2.8)

The value of the characteristic resistance F_{Rk} 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

2.2.2 Resistance under shear loads with lever arm

The characteristic resistance $M_{Rk,s}$ is determined for the cross-section of the fastener:

$$M_{Rk,s} = 1.2 \cdot W_{el} \cdot f_{uk} \tag{2.10}$$

with: W_{el} = section modulus of the fastener (for fasteners with a significantly reduced section along the length of the bolt, the minimum cross section shall be used for calculation)

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

f_{uk} = nominal characteristic steel ultimate strength of the fastener

2.2.3 Spacing and edge distances and member thickness

For characteristic spacing and edge distances the following values may be used without testing (standard values according to current experience):

spacing $s_{cr} = 4\ h_{ef}$
edge distance $c_{cr} = 2\ h_{ef}$

The minimum edge distance c_{min} and minimum spacing s_{min} are based on the manufacturer's instructions.

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}, then the performance is assessed by the corresponding tests according to Table A1.

The minimum edge distance c_{min} shall be evaluated from the results of tests according to Table A.1, line A3 to A6. The minimum spacing s_{min} shall be evaluated from the results of tests according to Table A.1, line A7 to A8.

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

The minimum member thickness h_{min} shall be evaluated from the results of tests according to Table A.1, line A3 to A8.

2.2.4 Characteristic displacements

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

$$F = F_{Rk} / (\gamma_F \cdot \gamma_M) \tag{2.11}$$

with: F_{Rk} = characteristic resistance

γ_F = partial safety factor for actions = 1,4

γ_M = depends on decisive failure mode according to Equation (2.8)

The displacements δ_{N0} and δ_{V0} under short-term loading are evaluated from test series Table A.1, line A1 and line A2. The value derived shall correspond to the 95 %-fractile for a confidence level of 90 %.

In the absence of other information $\delta_{N\infty}$ may be calculated as follows:

For fasteners to be used in non-cracked and cracked concrete the long term displacements under tension loading, $\delta_{N\infty}$, shall be calculated from the results of crack cycling tests (see Table A.1, line F4) according to following Equation.

$$\delta_{N\infty} = \delta_{m1} / 1,5 \tag{2.12}$$

With $\delta_{N\infty}$ = long term tension displacement

δ_{m1} = mean fastener displacement after 10^3 crack movements

For fasteners to be used in non-cracked concrete only, the long term displacements under tension loading, $\delta_{N\infty}$, shall be calculated from the results of repeated load (see Table A.1, line F6) according to following Equation.

$$\delta_{N\infty} = \delta_{m2} / 2,0 \tag{2.13}$$

With δ_{m2} = mean displacement in the repeated load tests after 10^5 load cycles or the sustained load tests after terminating the tests respectively. The larger value is decisive.

The displacements $\delta_{V\infty}$ under long-term shear loading may be assumed to be approximately equal to 1.5-times the value 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.

2.2.5 Durability

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

(1) 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) 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 fastener 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 [6] are considered to have sufficient durability.

(3) 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 fastener of stainless steel material 1.4529, 1.4565 and 1.4547 according to EN 10088-4 and 5:2009 [6] are considered to have sufficient durability.

2.2.6 Reaction to fire

The 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.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) 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 96/582/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 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 shift or 8 hours of production per machine
2	Tensile Load (N_p) or tensile strength (f_{uk})	According to EN ISO 898-1 [7]		3	
3	Yield strength (f_{yk} or $N_{p0.2}$)	According to EN ISO 898-1 [7]		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	According to EN ISO 898-1 [7]		3	
7	Hard metal tip of fastener (where relevant)	Geometry: Measuring or optical Material: According to EN ISO 898-1 [7]		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 fasteners are laid down in Table 3.2.

Table 3.2 Control plan for the notified body

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 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] EN 12602:2016: Prefabricated reinforced components of autoclaved aerated concrete, Annex D: Recommended values for partial safety factors

[2] EN 771-4:2011+A1:2015: Specification for masonry units – Part 4: Autoclaved aerated concrete masonry units

[3] EOTA TR 054:2016-04: Design methods for anchorages with metal injection fastener for use in masonry

[4] EOTA TR 048:2016-08: Details of tests for post-installed fasteners in concrete

[5] EOTA TR 020:2004-05: Evaluation of Anchorages in Concrete concerning Resistance to Fire

[6] 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

[7] 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

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

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

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

ANNEX A   TEST PROGRAM AND GENERAL ASPECTS OF ASSESSMENT

A.1   Test program

The test program for the assessment consists of
- Basic tension tests and basic shear tests to assess basic values of characteristic resistance and
- Any other tests to assess the characteristic resistance regarding various effects for the relevant application range according to the intended use.

Table A.1 Test program

	Purpose of test	Strength class of AAC (1)	Crack width Δw [mm] (3)	Size (2)	Number of tests	Conditions / Criteria
Basic tension and shear tests on single fasteners not influenced by edge and spacing effects						
A1	Tension tests (also used as reference tests for F1-F6)	Low High	0,3 and 0 0,3 and 0	all	10 10	$c > c_{cr}$ $h \geq h_{min}$
A2	Shear tests	Low High	0,3 (6) 0,3 (6)	all	5 5	$c > c_{cr}$ $h \geq h_{min}$
Basic tension and shear tests on single fasteners influenced by edge effects (4)						
A3	Tension tests at the edge	Low	0	all	5	$c = c_{min}$ $h = h_{min}$
A4	Shear tests at the edge	Low	0	all	5	$c = c_{min}$ $h = h_{min}$
A5	Tension tests at the corner	Low	0	all	8	$c_1 = c_{min}$ $c_2 = c_{min}$ $h = h_{min}$
A6	Shear tests at the corner	Low	0	all	8	$c_1 = c_{min}$ $c_2 = c_{min}$ $h = h_{min}$
Basic tension and shear tests influenced by edge and spacing effects (5)						
A7	Tension tests on double or quadruple fastener groups	Low	0	all	5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$
A8	Shear tests on double or quadruple fastener groups	Low	0	all	5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$
Resistance to pull-out failure (tension tests on single fasteners)						
F1	Robustness to variations in use conditions	Low	0,3	s / m / l	5 / 5 / 5	req. $\alpha \geq 0,95$
F2	Wet AAC	Low	0	s / m / l	5 / 5 / 5	req. $\alpha \geq 0,8$
F3	Maximum crack width	Low High	0,5 0,5	s / m / l s / m / l	5 / 5 / 5 5 / 5 / 5	req. $\alpha \geq 0,8$
F4	Crack cycling under load	Low	0,1-0,3	s / m / l	5 / 5 / 5	req. $\alpha \geq 0,9$
F5	Sustained loads	Low	0	m	5	req. $\alpha \geq 0,9$
F6	Repeated loads	Low High	0 0	m m	3 3	req. $\alpha \geq 1,0$
Resistance to steel failure and turn through in the hole during setting (torque tests on single fasteners)						
F7	Maximum torque moment	Low	0	s / m / l	5 / 5 / 5	-

(1)   Low: Minimum strength class of AAC, for which the ETA is applied for (e.g. AAC 2)
    High: Maximum strength class of AAC, for which the ETA is applied for (e.g. AAC 7)

(2)   s: smallest fastener size, m: medium fastener size, l: largest fastener size

(3)   If only use condition "Masonry" (non-cracked AAC) is requested, tests with w > 0 mm can be omitted.

(4)   Tests may be omitted if $c_{min} = c_{cr} \geq 2\, h_{ef}$

(5)   Tests may be omitted if $c_{min} = c_{cr} \geq 2\, h_{ef}$ and $s_{min} = s_{cr} \geq 4\, h_{ef}$

(6)   If only use condition "Masonry" (non-cracked AAC) is requested, tests with w = 0 mm

Prefabricated reinforced components are assumed to represent cracked concrete. Due to the production process, the width of the components is limited to less than about 700 mm, because the AAC is risen in direction of the width of the component.

Tests for the resistance of the members made of AAC due to the loads introduced by the fastenings are not required, if all of the following restrictions are kept:

- The design value of shear stresses in the member caused by the fastening are less or equal to 40% of the design values of resistance of the member in the critical cross section.
- The distance to the edges of the slabs of width ≤ 700 mm are ≥ 150 mm.
- The spacing a between fixing points are ≥ 600 mm. Fixing points are single fasteners, or fastener groups of 2 or 4 fasteners.

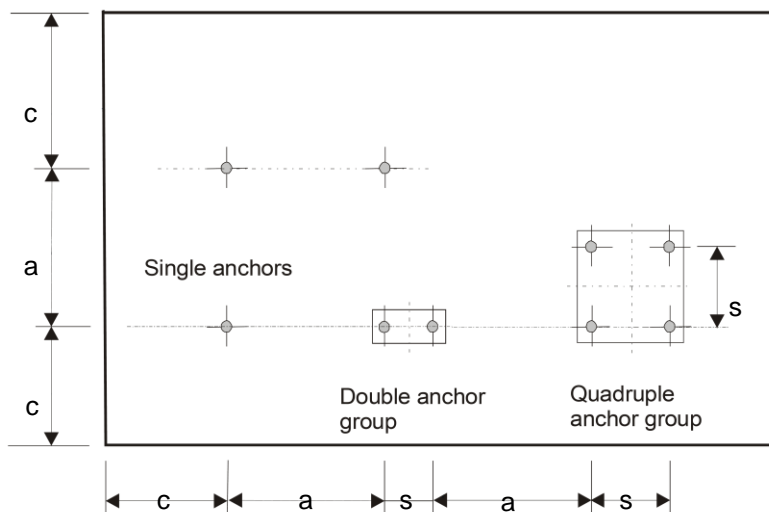The definition of spacing and edge distances is given in Figure A.1 and Figure A.2.

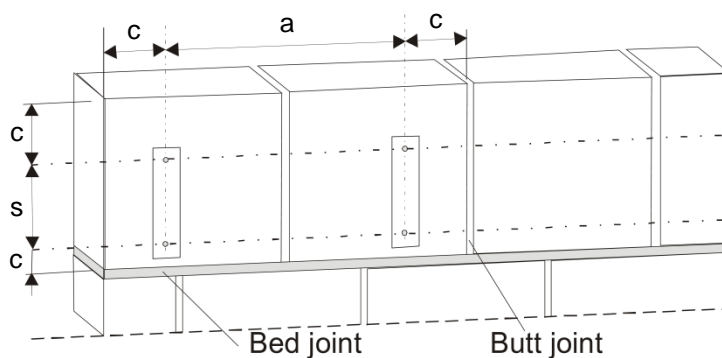**Figure A.1 Edge distances and spacing in prefabricated reinforced AAC components**

Figure A.2 Edge distances and spacing in AAC masonry units

A.2   Test details

All tests are performed on the final product. The fastener is set following the manufacturer's instructions, if no other setting instructions are specified in this document.

As far as applicable the TR 048:2016-08 [4] shall be followed for the test setup and performance of the tests.

In the test program prefabricated reinforced components (Slabs) of autoclaved aerated concrete according to EN 12602:2016 [1] represent the intended use of cracked concrete and autoclaved aerated concrete masonry units (Masonry) according to EN 771-4:2011+A1:2015 [2] represent the intended use of non-cracked concrete.

At the time of testing the autoclaved aerated concrete (AAC) test specimens shall meet the following conditions: Low strength AAC: mean dry density $\rho_m \geq 350$ kg/m³
mean compressive strength $f_{c,m} = 1,8$ to $2,8$ N/mm²

High strength AAC: mean dry density $\rho_m \geq 650$ kg/m³
mean compressive strength $f_{c,m} = 6,5$ to $8,0$ N/mm²

Testing of fasteners is carried out on single units (slabs or bricks) or walls with units mortared or glued together.

Samples are taken from the test specimen for determination of the material characteristics (see Figure A.3). Dimensions of samples: 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 fastener relating to the direction of rise of the aerated concrete specimen, because the strength differs depending on the height of the direction of rise.
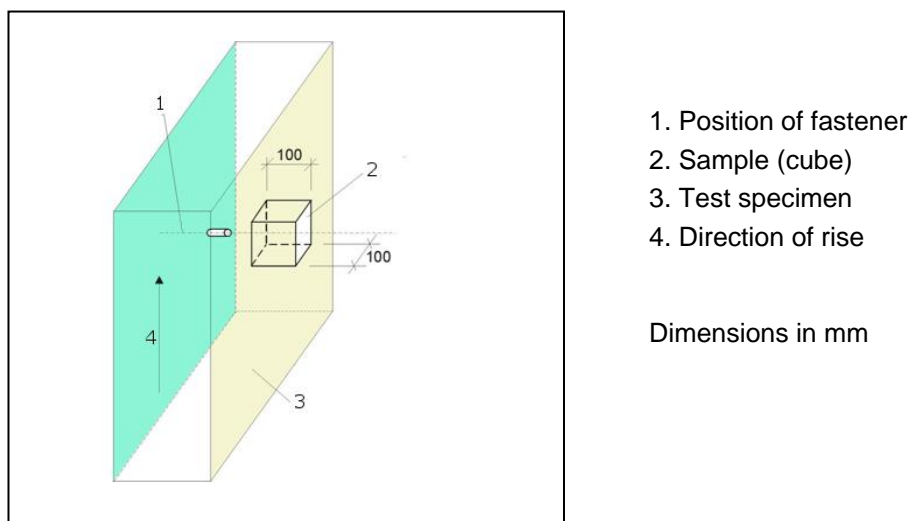

1. Position of fastener
2. Sample (cube)
3. Test specimen
4. Direction of rise

Dimensions in mm

Figure A.3   Taking of samples for autoclaved aerated concrete (AAC)

For determination of the material characteristics the following conditions apply:

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

At the beginning of testing the test specimens shall be at least 4 weeks old. The mass-related moisture content of the concrete during the time of testing shall be ≤ 30 % 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 fastener setting (see Figure A.3).

A.3   Assessment of test results

A.3.1   Conversion of failure loads to nominal strength

In case of AAC failure the failure load shall be converted as follows:

For prefabricated reinforced AAC members the characteristic compressive strength f_{ck} of strength classes AAC 2 and AAC 7 given in EN 12602:2016 [1] shall be used for conversion of test results.

For AAC blocks the characteristic compressive strength (used for conversion of ultimate loads) shall be determined from the declared characteristic value of compressive strength according to EN 771-4:2011+A1:2015 [2] using the factor of 0,9.

$$f_{ck} = 0,9\ f_{ck,decl} \tag{A.1}$$

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

$$F_u = F_{u,t} \cdot (\rho_{min}^{\,0,75} \cdot f_{ck}) / (\rho_t^{\,0,75} \cdot f_{c,test}) \tag{A.2}$$

with:
$F_{u,t}$ = failure load in the test
f_{ck} = characteristic compressive strength of AAC member
$f_{u,t}$ = compressive strength of the AAC member at the time of testing (mean value)
ρ_{min} = dry density of AAC members: low strength AAC: ρ_{min} = 350 kg/m^3
high strength AAC: ρ_{min} = 650 kg/m^3
ρ_t = dry density of AAC member at the time of testing

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

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

$$F_u = F_{u,t} \cdot f_u / f_{u,t} \tag{A.3}$$

with:
$F_{u,t}$ = failure load in the test
f_u = nominal steel strength
$f_{u,t}$ = steel strength of the fastener in the test

A.3.2   Criteria regarding scatter of failure loads

In each test series exceptional for maximum torque moment, the coefficient of variation of the ultimate load shall be calculated.

For a coefficient of variation cv > 20% in the tests F1 to F6, a reduction factor α_{CV} for each test series shall be calculated according to:

$$\alpha_{CV} = 1 / (1 + 0,03 \cdot (cv[\%] - 20)) \leq 1,0 \tag{A.4a}$$

with: cv = coefficient of variation of ultimate load of tests

For a coefficient of variation cv > 15% in the tests A1 to A8, a reduction factor α_{CV} for each test series shall be calculated according to:

$$\alpha_{CV} = 1 / (1 + 0,03 \cdot (cv[\%] - 15)) \leq 1,0 \tag{A.4b}$$

with: cv = coefficient of variation of ultimate load of tests

A.3.3   Establishing 5 % fractile

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.

$$F_{u,ln5\%} = F_{u,m,ln(x)} - k_s \cdot s_{ln(x)} \tag{A.5}$$

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

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

k_s =   statistical factor (e.g. 5 tests: k_s = 3,40; n = 10 tests: k_s = 2,57)

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

A.3.4   Determination of reduction factors α

For each test series F1 to F6 according to Table A.1 the factor α shall be calculated as follows:

$$\alpha = min ((F_{u,m,t} / F_{u,m,r});(F_{u,ln5\%,t} / F_{u,ln5\%,r})) \tag{A.6}$$

with: $F_{u,m,t}$ = mean value of the ultimate load in the test series F1 to F6

$F_{u,ln5\%,t}$ = 5%-logarithmic fractile of the ultimate load in the test series F1 to F6

$F_{u,m,r}$ = mean value of the ultimate load in the reference test series A1

$F_{u,ln5\%,r}$ = 5%-logarithmic fractile of the ultimate load in the reference test series A1

If the number of tests in both series is n ≥ 10, the comparison of the 5% - fractile of failure loads may be done under assumption of a k-value of 1,645 for the determination of the factor α only.

The comparison of the 5%-fractile may be omitted for any number of tests in a test series 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 both test series is smaller than 15 %.

The factor α shall be larger than the values given in Table A.1. If the requirements are not fulfilled, then the reduction factor α_u shall be calculated according to:

$$\alpha_u = \alpha / req. \alpha \leq 1,0 \tag{A.7}$$

with: α = value according Equation (A.6) for test series F1 to F6

req. α = required value of α according to Table A.1

A.3.5   Criteria for uncontrolled slip under tension loading

The load/displacement curves shall show a steady increase (see Figure). A reduction in load and/or a horizontal part in the curve caused by uncontrolled slip of the fastener is not acceptable up to a load of:

$$N_{sl} = 0,6 N_{Ru} \tag{A.8}$$

with: N_{Ru} = ultimate load in the test (see also Figure A.4)

Where the requirement given in Equation (A.8) is not met in a test, the reduction factor α_1 shall be determined according to Equation (A.9).

$$\alpha_1 = N_{sl,t} / N_{Ru,t} \tag{A.9}$$

with: $N_{sl,t}$ = load level where uncontrolled slip occurs in the test

$N_{Ru,t}$ = ultimate load in the test

This reduction may be omitted if, within an individual series of tests, not more than one test shows a load/displacement curve with a short plateau below the value determined by Equation (A.8), provided all of the following conditions are met:

- the deviation is not substantial
- the deviation can be justified as uncharacteristic of the fastener behaviour and is due to a defect in the fastener tested, test procedure, etc.
- the fastener behaviour meets the criterion in an additional series of 10 tests.
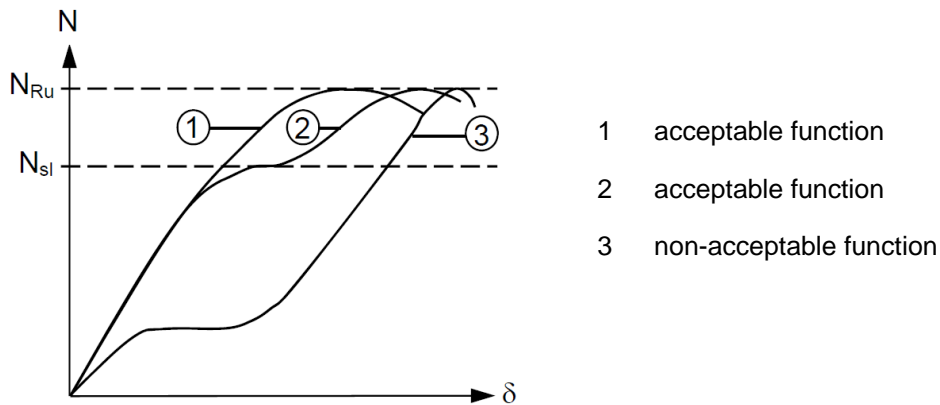
Figure A.4   Requirements for the load/displacement curve

A.3.6   Limitation of the scatter of displacements

In order to properly activate all fasteners of a fastener group, the displacement behaviour (stiffness) of individual fasteners shall be similar.

The coefficient of variation of the mean displacement at the load level of 0,5 $N_{u,m}$ in basic tension tests shall fulfil the limit given in Equation (A.10) and for any other tests the limit given in Equation (A.11) shall be kept.

$$cv_\delta \leq 0,25 \text{ (basic tension tests)} \qquad\qquad\qquad\qquad (A.10)$$

$$cv_\delta \leq 0,40 \text{ (any other tests)} \qquad\qquad\qquad\qquad (A.11)$$

The load displacement curves may be shifted according to Figure A.5 for determination of the displacement at 0,5 $N_{u,m}$.

It is not necessary to observe limitation of the scatter of the load/displacement curves in a test series if in this test series all displacements at a load of 0,5 $N_{u,m}$ are smaller than or equal to 0,4 mm.

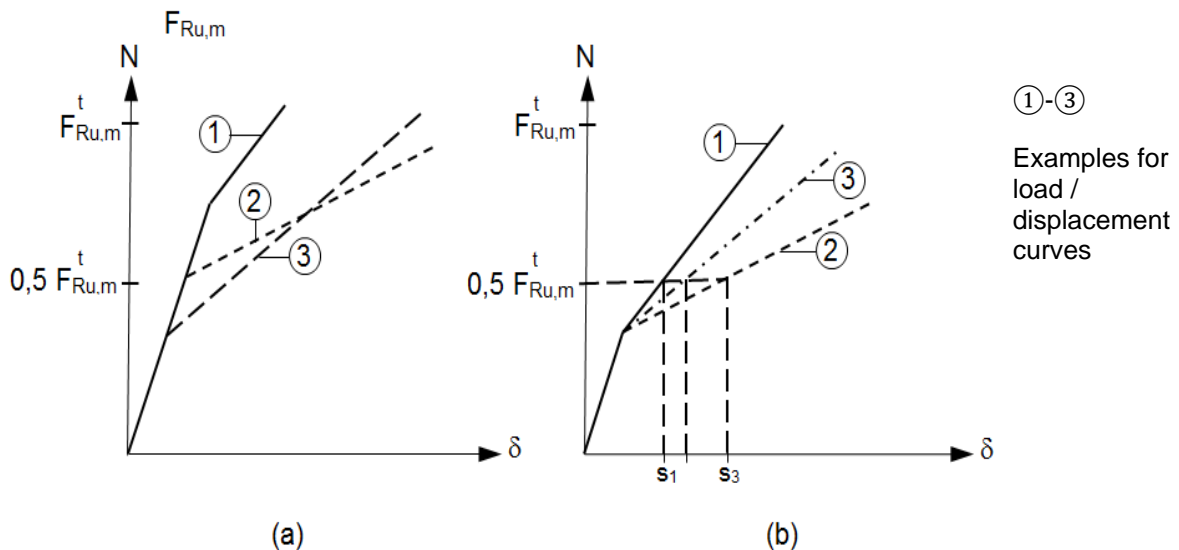**Figure A.5   Influence of pre-stressing on load/displacement curves**
            (a) original curves
            (b) shifted curves for evaluation of scatter at N = 0,5 $N_{u,m}$