EUROPEAN ASSESSMENT DOCUMENT

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PLASTIC ANCHORS FOR REDUNDANT NON-STRUCTURAL SYSTEMS IN CONCRETE AND MASONRY

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This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation 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 EAD covers the assessment of post-installed plastic anchors to be used in base materials made of concrete and masonry.

Types and operating principles:

Plastic anchors consisting of an expansion element and a polymeric sleeve which passes through the fixture.

Also plastic anchors consisting of an expansion element and a polymeric sleeve which is mounted prior to positioning of the fixing are possible. Polymeric sleeve and expansion element build a unit. For one sleeve expansion elements with different lengths can be provided.

The polymeric sleeve is expanded by hammering or screwing in the expansion element which presses the sleeve against the wall of the drilled hole.

The polymeric sleeve is fixed in the hole in the correct position at the position intended by the manufacturer. An uncontrolled setting of the sleeve in the drilled hole during setting is avoided; this can be done e.g. with a collar on the upper end of the sleeve.

Two types of plastic anchors are covered

- Plastic anchors with a screw as an expansion element (setting: screwed in) – see Figure 1.1.
- Plastic anchors with a nail as an expansion element (setting: hammered in) – see Figure 1.2.

Materials:

Following materials are covered:

- Metal (steel): Expansion element
- Polymeric material: Sleeve and expansion element
  - Polyamide PA 6 and PA 6.6
  - polyethylene PE or polypropylene PP
  - other polymeric materials

This EAD covers plastic anchors which are only made of virgin polymeric material (not recycled material). However, reworked material received as own waste material from the manufacturing process may be added to the manufacturing process.

Dimensions:

This EAD applies to plastic anchors with an external diameter d of the polymeric sleeve and an anchorage depth h_{nom} as follows:

$d \geq 6$ mm; $h_{nom} \geq 30$ mm for use in base material group a according to Table 1.1

$d \geq 8$ mm; $h_{nom} \geq 50$ mm for use in base material group b to d according to Table 1.1

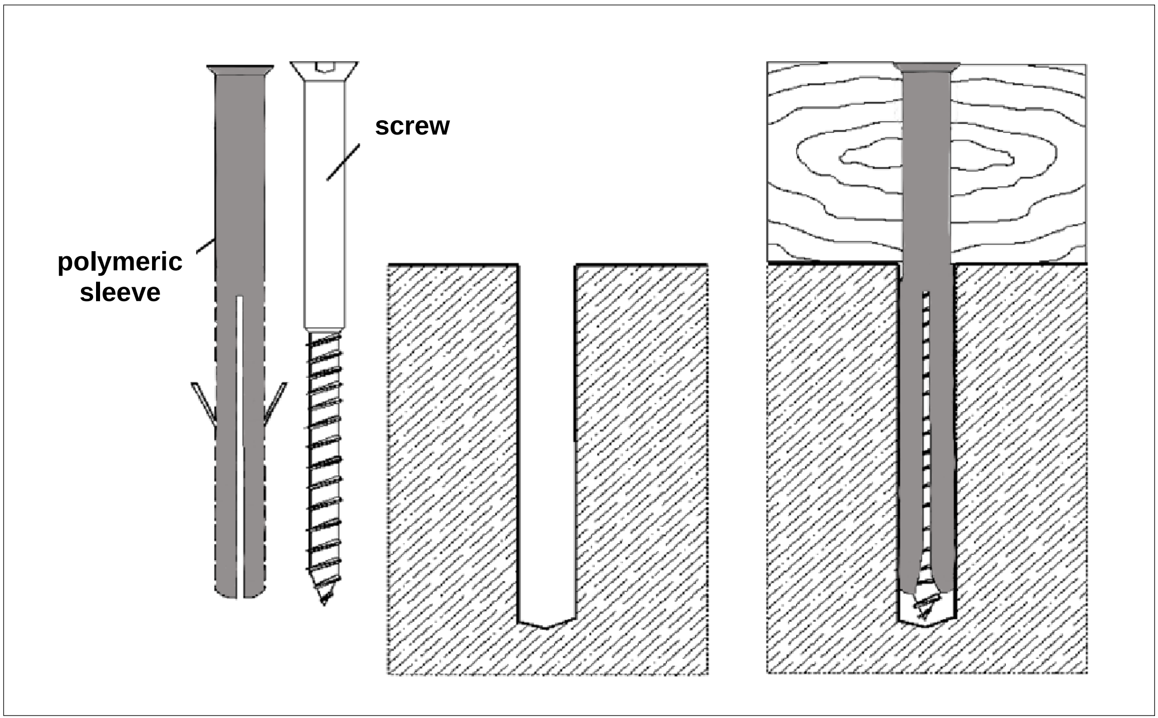


Figure 1.1 Example of plastic anchor (screwed in)

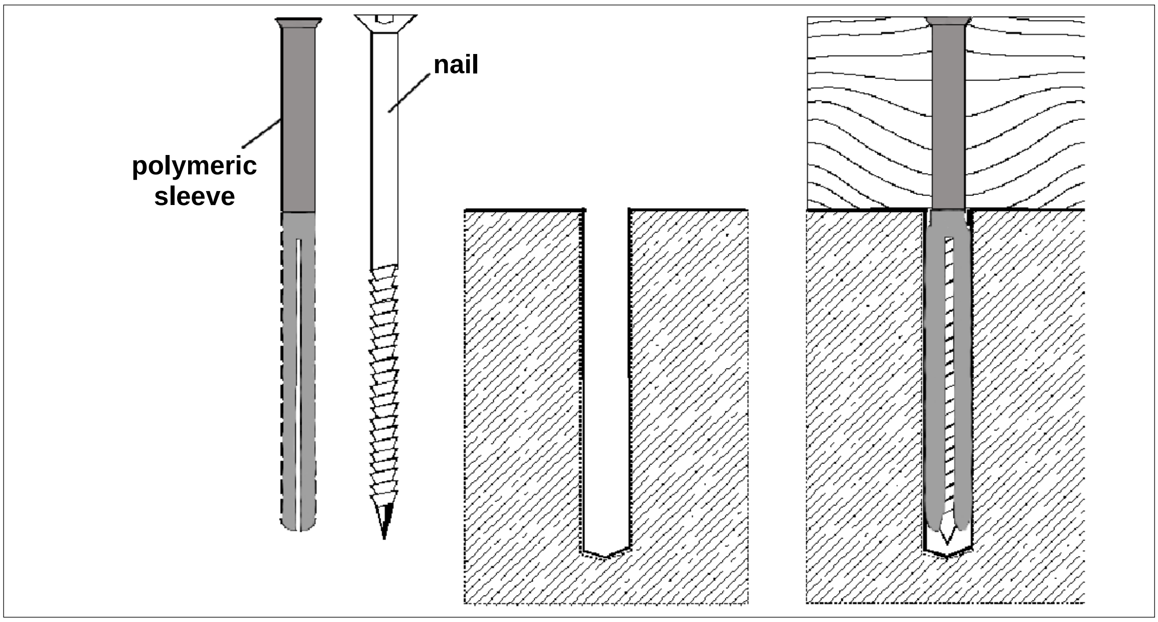


Figure 1.2 Example of plastic anchors (hammered in)

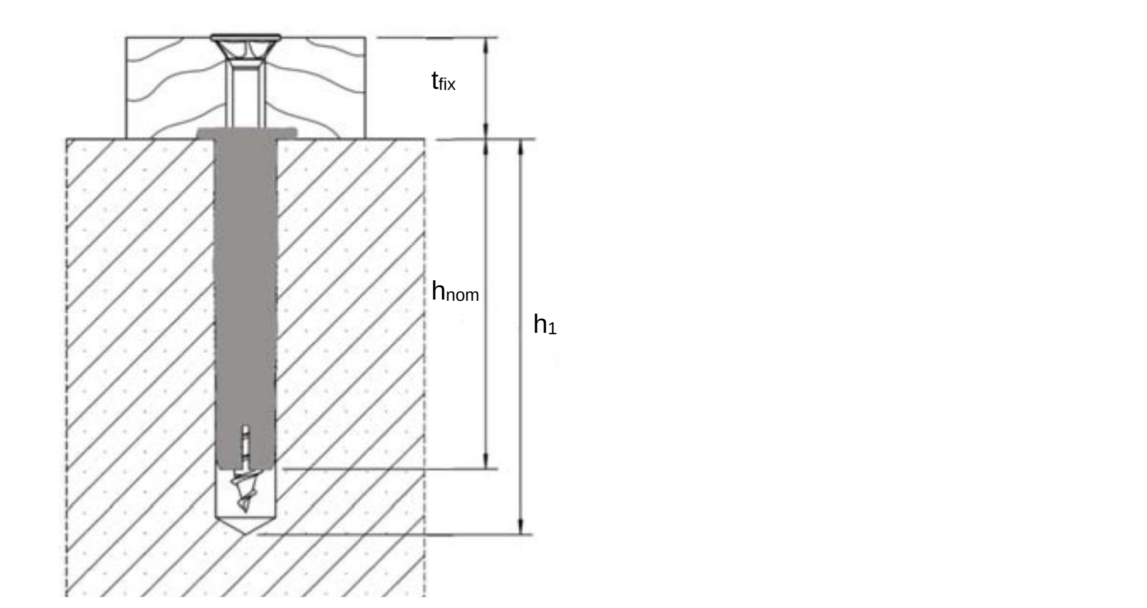


Figure 1.3 Example of plastic anchors (prepositioned installation)

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 plastic anchors are intended for redundant non-structural systems (definition see 1.3) in concrete and/or masonry.

Attention is drawn to the fact that the standards for masonry structures are not very restrictive with regard to details of units (e.g. type, dimensions and location of perforations, number and thickness of webs). As load resistance and load displacement behaviour, however, decisively depend on these influences, an assessment of the plastic anchor is only possible for each particular well-defined masonry unit concerned.

The plastic anchors are intended for applications where the minimum thickness of the base material in which plastic anchors are installed is at least h = 80 mm with exception given in Table 1.1.

Base material groups are defined as a function of base materials as follows:

Table 1.1 Definition of base material groups

Base material group	Base material	Remark
a	**Normal weight concrete**	The plastic anchors are intended for use in compacted normal weight concrete without fibres with strength classes C12/15 and higher according to EN 206 [1] [1]. The plastic anchors are not intended for use in screeds or toppings, which can be uncharacteristic of the concrete and/or excessively weak.
		Thin skins (weather resistant skin) The minimum thickness of the base material may be reduced to 40 mm, if the influence of the setting position of the plastic anchor is considered according to section A1.2.
		Precast prestressed hollow core slab The anchors are fastened in an element with a minimum thickness of 17 mm and the influence of the setting position of the plastic anchor is taken into account according to to section A1.3. The distance between the side of the drill hole and the outside of prestressed reinforcement is at least 50 mm (national regulations regarding executions apply).
b	**Solid masonry**	The plastic anchors are intended for use in masonry units consisting of solid units according to EN 771-1,-2,-3,-5 [5], which in general do not have any holes or cavities other than those inherent in the material. However, solid masonry units may have a vertical perforation of up to 15 % of the cross section. The determined characteristic resistances are valid only for the brick sizes which are used in the tests or larger brick sizes and higher compressive strengths; therefore, the information about the brick sizes shall be given in the ETA.
c	**Hollow or perforated masonry**	The plastic anchors are intended for use in masonry units consisting of hollow or perforated units according to EN 771-1,-2,-3,-5 [5], which have a certain volume percentage of voids which pass through the masonry unit. The determined characteristic resistances are valid for the bricks and blocks only which are used in the tests regarding base material, size of units, compressive strength and configuration of the voids. Therefore, the following information has to be given in the test report and in the ETA: *Base material, size of units, normalised compressive strength; volume of all holes (% of the gross volume); volume of any hole (% of the gross volume); minimum thickness in and around holes (web and shell); combined thickness of webs and shells (% of the overall width); appropriation to a group of Table 3.1 of EN 1996-1-1 [4].*
d	**Autoclaved aerated concrete (AAC)**	The plastic anchors are intended for use in autoclaved aerated concrete masonry units (blocks) according to EN 771-4 [5] (blocks) with a corresponding compressive strength in the range 1,8 ≤ $f_{c,m}$ ≤ 8,0 [N/mm²] and reinforced components of autoclaved aerated concrete (prefabricated reinforced members) according to EN 12602 [6] (slabs) with compressive strength classes AAC 2 to AAC 6.

The plastic anchors are intended for uses in masonry according to the structural rules for masonry given in, EN 1996-1-1, Clause 3 and 8 [4] and the relevant national regulations.

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

The plastic anchors are intended for uses effected by UV radiation up to 6 weeks.

Notes: According to current experience UV-radiation up to 6 weeks does not effect the durability. During working life the plastic anchors are covered by the fixture.

The plastic anchors are intended for service temperature ranges of the base material near the surface are as follow:

Range a): min ϑ to +40 °C
(max short-term temperature +40 °C and max long-term temperature +24 °C)

Range b): min ϑ to +80 °C
(max short-term temperature +80 °C and max long-term temperature +50 °C)

Range c): on manufacturer's request with min ϑ to ϑ_1
(maximum short-term temperature ϑ_1: $\vartheta_1 >$ +40 °C in steps of 10 K, maximum long-term temperature: 0,6 ϑ_1 to 1,0 ϑ_1 in steps of 5 K)

The lowest service temperature min ϑ and lowest installation temperature min. inst. ϑ are specified by the manufacturer. If no lowest service temperature and no lowest installation temperature are given by the manufacturer min ϑ = 0°C.

The plastic anchors are intended for uses at temperatures below 0 °C only if water ingress into the hole is avoided.

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

The plastic anchors are intended for anchorages subject to static or quasi-static actions in tension, shear or combined tension and shear or bending. The plastic anchors are intended for use in applications where the concrete and masonry members in which the anchors are embedded are subject to static or quasi-static actions only.

The plastic anchor in concrete of strength classes C20/25 to C50/60 according to EN 206 [1] is also intended to be used with requirements related to resistance to fire.

In this EAD the assessment is made to determine performances of essential characteristic of the plastic anchors which can be used for design according to TR 064 [18].

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 plastic anchors for the intended use of 50 years when installed in the works provided that the plastic anchors is subject to appropriate installation (see 1.1). These provisions are based upon the current state of the art and the available knowledge and experience.

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

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

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

1.3 Specific terms used in this EAD

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

1.3.1 Definitions

Anchor = a manufactured, assembled component for achieving anchorage between the base material and the fixture.

Anchorage = an assembly comprising base material, anchor or anchor group and fixture.

Anchor group = several anchors (working together)

Fixture = component to be fixed to the base material

Redundant non-structural system = Redundant non-structural systems mean applications in which multiple fastener support elements that are capable to redistribute the load to neighbouring anchors without significantly violating the requirements on the fixture in the serviceability and ultimate limit state in the case of excessive slip or failure of one anchor.

The definition of redundant non-structural systems is given in terms of the number n_1 of fixing points to fasten the fixture and the number n_2 of anchors per fixing point. Furthermore n_3 (kN) specifies the upper limit of the design value of actions on a fixing point 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 anchor need not to be taken into account in the design of the fixture.

The redistribution of loads in case of excessive slip or failure of one fastener is considered in the static verification of the fastening.

$n_1 \geq 4$; $n_2 \geq 1$ and $n_3 \leq 4{,}5$ kN or (1.1)

$n_1 \geq 3$; $n_2 \geq 1$ and $n_3 \leq 3{,}0$ kN (1.2)

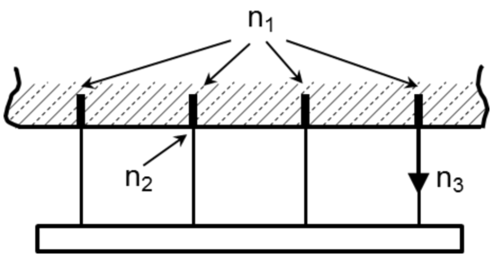


Figure 1.3 Example of a redundant non-structural system

ϑ = temperature in Celsius [°]

Normal ambient temperature = temperature of the base material 21 °C ± 3 °C (for test conditions only)

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

min. ϑ = minimum temperature, lowest service temperature as specified by the manufacturer

Installation ambient temperature = The environmental temperature range of the base material specified by the manufacturer for installation.

min. inst. ϑ = minimum installation temperature, lowest installation temperature normally 0° C to +5° C

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

max. long-term ϑ = maximum long-term temperature, specified by the manufacturer within the range according to section 1.2.1.

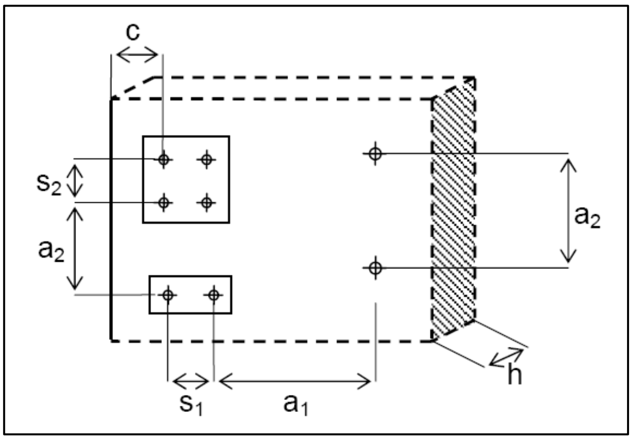
Short-term temperature = Temperatures within the service temperature range which vary over short intervals, e.g. day/night cycles and freeze/thaw cycles.

max. short-term ϑ = upper limit of the service temperature range according to section 1.2.1

1.3.2 Notation for anchors

a	=	spacing between outer anchors of adjoining groups or between single anchors
a_1	=	spacing between outer anchors in adjoining groups or between single anchors in direction 1
a_2	=	spacing between outer anchors in adjoining groups or between single anchors in direction 2
b	=	width of the member of the base material
c_1	=	edge distance in direction 1
c_2	=	edge distance in direction 2
c_{cr}	=	edge distance for ensuring the transmission of the characteristic resistance of a single anchor
c_{min}	=	minimum edge distance determined by manufacturer
d	=	nominal diameter of the anchor
d_s	=	nominal diameter of the spread element
d_o	=	drill hole diameter
d_{cut}	=	cutting diameter of drill bit
$d_{cut,max}$	=	cutting diameter at the upper tolerance limit (maximum diameter bit)
$d_{cut,min}$	=	cutting diameter at the lower tolerance limit (minimum diameter bit)
$d_{cut,m}$	=	medium cutting diameter of drill bit
d_f	=	diameter of clearance hole in the fixture
d_{nom}	=	outside diameter of anchor
h	=	thickness of member (wall)
h_{min}	=	minimum thickness of member determined by manufacturer
h_o	=	depth of cylindrical drill hole at shoulder
h_1	=	depth of drilled hole to deepest point
h_{ef}	=	effective anchorage depth
h_{nom}	=	overall anchor embedment depth in the base material

l_s	=	length of spreading element
s_1	=	spacing of anchors in an anchor group in direction 1
s_2	=	spacing of anchors in an anchor group in direction 2
s_{cr}	=	spacing for ensuring the transmission of the characteristic resistance of a single anchor
s_{min}	=	minimum spacing determined of manufacturer
T	=	torque moment
T_{inst}	=	torque moment during installation when the screw of the plastic anchor is fully attached to the anchor collar
T_u	=	maximum torque moment that can be applied to the plastic anchor
t_{fix}	=	thickness of fixture



Note for the edge distance:

For base material masonry only c (distance to the vertical edge) is assessed.

For base material concrete c_1 and c_2 (distances at the corner) are assessed.

Figure 1.4 Member thickness, anchor spacing and edge distance

1.3.3 Notation for base materials

f_c	=	concrete compressive strength measured on cylinders
$f_{c,cube}$	=	concrete compressive strength measured on cubes
$f_{c,test}$	=	compressive strength of concrete at the time of testing
f_{cm}	=	mean concrete compressive strength
f_{ck}	=	nominal characteristic concrete compressive strength (based on cylinder)
$f_{ck,cube}$	=	nominal characteristic concrete compressive strength (based on cubes)
ρ	=	bulk density of unit
f_b	=	normalised mean compressive strength of masonry unit
$f_{b,test}$	=	mean compressive strength of the test masonry unit at the time of testing
$f_{y,test}$	=	steel tensile yield strength in the test
f_{yk}	=	nominal characteristic steel yield strength
$f_{u,test}$	=	steel ultimate tensile strength in the test
f_{uk}	=	nominal characteristic steel ultimate strength

1.3.4 Notation for assessment of tests

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

N_{Rk} , V_{Rk}	=	characteristic anchor resistance (5 %-fractile of results) under tension or shear force respectively
F^t_u	=	ultimate load in a test
$F^t_{u,m}$	=	mean ultimate load in a test series
F^t_{Rk}	=	5 %-fractile of the ultimate load in a test series
n	=	number of tests of a test series
v	=	coefficient of variation
α	=	reduction factor, see equation (A.15)
α_1	=	criteria for loss adhesion, see equation (A.18)
α_2	=	ratio according to equation (A.16)
α_V	=	reduction factor for large scatter of failure loads, see equation (A.12) and (A.13)
$\delta(\delta_N, \delta_V)$	=	displacement (movement) of the anchor at the surface of the base material relative to the surface of the base material in direction of the load (tension, shear) outside the failure area The displacement includes the steel and base material deformations and a possible anchor slip.
γ_F	=	partial safety factor for action
γ_M	=	material partial safety factor

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1 shows how the performance of the plastic anchors for redundant non-structural systems in concrete and masonry 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 2: Safety in case of fire			
1	Reaction to fire	2.2.1	Class A1
2	Resistance to fire	2.2.2	Level: $N_{Rk,s,fi}$, $N_{Rk,p,fi,}$ $F_{Rk,fi,90}$ [kN]
Basic Works Requirement 4: Mechanical resistance and stability			
3	Resistance to steel failure under tension loading	2.2.3	Level: $N_{Rk,s}$ [kN]
4	Resistance to steel or polymer failure under shear loading	2.2.4	Level: $V_{Rk,s}$ [kN], $M_{Rk,s}$ [Nm], $V_{Rk,pol}$ [kN]
5	Resistance to pull-out or concrete failure or polymer failure under tension loading (base material group a)	2.2.5	Level: $N_{Rk,p}$ [kN] or $N_{Rk,pol}$ [kN]
6	Resistance in any load direction without lever arm (base material group b, c and d)	2.2.6	Level: F_{Rk} [kN]
7	Edge distance and spacing (base material group a)	2.2.7	Level: c_{cr}, s_{cr}, c_{min}, s_{min}, a, h_{min} [mm]
8	Edge distance and spacing (base material group b, c and d)	2.2.8	Level: c_{min}, s_{min}, h_{min} [mm]
9	Displacements under short-term and long-term loading	2.2.9	Level: δ_0, δ_∞ [mm]
Aspects of durability			
10	Durability	2.2.10	Description

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

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

Testing will be limited only to the essential characteristics which the manufacturer intends to declare. If for any components covered by harmonised standards or European Technical Assessments the manufacturer of the component has included the performance regarding the relevant characteristic in the Declaration of Performance, retesting of that component for issuing the ETA under the current EAD is not required.

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

Provisions valid for all tests, description of the tests as well as general aspects of the assessment (determination of 5% fractile values, determination of reduction factors, etc.) are also given in Annex A.”

2.2.1 Reaction to fire

The metal parts of plastic anchors are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the Commission Decision 96/603/EC, as amended by Commission Decisions 2000/605/EC and 2003/424/EC, without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

In the context of the end use application of the anchorages the plastic material of the anchor embedded in concrete/masonry can be considered to satisfy any reaction to fire requirements. Where the plastic parts of the anchor are embedded in the cladding/component which is not class A1 the plastic parts can be considered not to influence the reaction to fire class of the cladding/component.

2.2.2 Resistance to fire

Fire resistance to steel failure ($N_{Rk,s,fi}$) of the plastic anchor in concrete under tension loading shall be tested and assessed according to EAD 330232-00-0601 [22], 2.2.13. Fire resistance to pull-out failure ($N_{Rk,p,fi}$) of the plastic anchor is calculated as follows: $N_{Rk,p,fi} = N_{Rk,s,fi}$.

For fastening of facade systems the load bearing behaviour of the specific screwed in plastic anchor with a diameter ≥ 10 mm and a metal screw with a diameter ≥ 7 mm and a h_{ef} of ≥ 50 mm and a plastic sleeve made of polyamide PA6 $F_{Rk,fi,90}$ [kN] = 0,8 kN (no permanent centric tension load, shear load without lever arm) can be assumed.

2.2.3 Resistance to steel failure under tension loading

$$N_{Rk,s} = A_s \cdot f_{uk} \quad (2.1)$$

with:

$N_{Rk,s}$ = characteristic anchor resistance under tension load

A_s = stressed cross section of steel element

f_{uk} = nominal characteristic steel ultimate strength

2.2.4 Resistance to steel or polymer failure under shear loading

The characteristic resistance to steel failure may be calculated for steel elements with constant strength over the length of the element as given in equation (2.2) and (2.4). The smallest cross section of the fastener in the area of load transfer applies.

2.2.4.1 Characteristic resistance under shear loading without lever arm (test series A4)

The tests shall be performed according to Annex A, Table A.1. Details of tests are given in A2.5.8.

The assessment shall be made for each anchor size.

The characteristic resistances of the metal expansion element for single anchors in concrete (base material group a) under shear loading shall be calculated as follows. For base material group b,c and d $V_{Rk,s}$ is determined as given in 2.2.6.12.

$$V_{Rk,s} = V_{u,5\%} \leq 0{,}5 \cdot A_s \cdot f_{uk} \qquad (2.2)$$

with: $V_{u,5\%}$ = 5% fractile of the failure load V_u [kN] according to A3.3 resulting from Table A.1, line A4, converted to nominal characteristic steel ultimate strength according to A3.1

For thin skins the minimum results from the tests according to A1.2 have to be considered (from tests according to Table A.1, line A4 with c = c_{min}).

$V_{Rk,s}$ = characteristic anchor resistance under shear load

A_s = stressed cross section of steel element

f_{uk} = nominal characteristic steel ultimate strength

Note:

The factor 0,5 is recommended for carbon steel with an ultimate steel tensile strength up to 1000 N/mm². *For ultimate steel strength smaller than 500 N/mm² this value is considered conservative. The design provisions EN 1992-4 are valid for embedded metal parts with a nominal steel tensile strength of* $f_{uk} \leq 1000$ *N/mm².*

In case of an expansion element made of polymeric material and if rupture of polymeric element is observed in tests according to Table A.1 then:

$$V_{Rk,pol} = V_{u,5\%} \qquad (2.3)$$

with: $V_{u,5\%}$ = 5% fractile of the failure load V_u [kN] according to A3.3 resulting from Table A.1, line A4,

2.2.4.2 Characteristic resistance under shear loading with lever arm

$$M_{Rk,s} = 1{,}2 \cdot W_{el} \cdot f_{uk} \qquad (2.4)$$

with:

$M_{Rk,s}$ = characteristic value of the resistance to bending moment

W_{el} = elastic section modulus of steel element (cross section at 0,5 x d underneath the surface of the base material group)

f_{uk} = nominal characteristic steel ultimate strength

2.2.5 Resistance to pull-out or concrete failure or polymer failure under tension loading (base material group a)

2.2.5.1 Assessment of all test results

Tests are performed according to Table A.1 and Table A.2. Test details are given in Annex A. Each test series is assessed as follows:

- Conversion of failure loads to nominal strength according to A3.1

- Determine the mean value of converted failure loads $N_{u,m}$ [kN]
- Determine the 5% fractile of the converted failure loads $N_{u,5\%}$ [kN] according to A3.3
- Determine α_v to account the scatter of the failure loads (coefficient of variation) and calculate the reduction factor α_v according to A3.2
- Determine α_1 according to A3.5

2.2.5.2 Basic tension tests (A1 and A2)

These tests are performed to determine the tension capacity of the anchor and thereby establishing the baseline values for the assessment of the performance under tension load. The tests shall be performed according to Annex A, Table A.1.

The baseline values $N_{Rk,0} = N_{u,5\%}$ are determined resulting from test series A1 (as reference) and A2

2.2.5.3 Setting capacity for nailed-in anchors (F1)

These tests are performed to evaluate the sensitivity of nailed-in anchors to an additional hammer blow. The tests shall be performed according to Annex A, Table A.2. The anchor is installed and tested according to A2.5.3.

The reduction factor $\alpha_{2,line\ F1}$ is determined according to A3.4 by using reference test A1.

2.2.5.4 Diameter of drill hole (F2)

These tests are performed to evaluate the sensitivity of drill hole diameters in the range of $d_{cut,min}$ to $d_{cut,max}$. The tests shall be performed according to Annex A, Table A.2.

The reduction factor $\alpha_{2,line\ F2}$ is determined according to A3.4 by using reference test A1.

2.2.5.5 Maximum crack width (F3)

These tests are performed to evaluate the sensitivity to maximum crack width Δw = 0,35 mm. The tests shall be performed according to Annex A, Table A.2.

The reduction factor $\alpha_{2,line\ F3}$ is determined according to A3.4 by using reference tests A2 (Δw = 0,2 mm).

2.2.5.6 Conditioning of polymeric sleeve (F4)

These tests are performed to evaluate the sensitivity to conditioning of the polymeric sleeve in the range from dry to wet conditions. The tests shall be performed according to Annex A, Table A.2.

The reduction factor $\alpha_{2,line\ F4}$ is determined according to A3.4 by using the reference test A1.

2.2.5.7 Effect of temperature (F5)

These tests are performed to evaluate the sensitivity to the effect of temperature within the temperature range given by the manufacturer. The tests shall be performed according to Annex A, Table A.2. and A2.5.4.

If $\alpha_{line\ F5.1} < 1,0$, then the lowest service temperature shall be increased and the tests at lowest service temperature shall be repeated until $\alpha_{line\ F5.1} \geq 1,0$.

If $\alpha_{line\ F5.2} < 1,0$, then the minimum installation temperature shall be increased and the tests at minimum installation temperature shall be repeated until $\alpha_{line\ F5.2} \geq 1,0$.

For the various F5-tests the corresponding reference tests and resulting reduction factors (if applicable) are listed in Table 2.2:

Table 2.2

Test		Reference test	Reduction factor
min. ϑ	$F_{5.1}$	A1	–
min. inst. ϑ	$F_{5.2}$	A1	–
max. short. term ϑ	$F_{5.3}$	A1	$\alpha_{2,line\ F5.3}$

max. long. term ϑ	$F_{5.4}$	$F_{5.3}$	$\alpha_{2,line\ F5.4}$

The reduction factor $\alpha_{2,line\ F5}$ is determined according to A3.4. The reduction factor $\alpha_{2,line\ F5}$ is calculated as given in equation (2.5).

$$\alpha_{2,line\ F5} = \min(\alpha_{2,line\ F5.3} ; \alpha_{2,line\ F5.4}) \quad (2.5)$$

2.2.5.8 Sustained load (F6)

The tests are performed to check the creep behaviour of the loaded anchor at normal ambient temperature and at maximum long-term temperature. The tests shall be performed according to Annex A, Table A.2. and A2.5.5

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

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

$$s(t) = s_o + a \cdot t^b \quad (2.6)$$

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

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

The extrapolated displacements shall be less than the mean value of the displacements at the load at overcoming the friction resistance in the reference tests A1 in non-cracked concrete. The load at overcoming the friction resistance may be evaluated as described in A3.6 for the load at loss of adhesion (overcoming friction).
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 $\alpha_p = N_{p,red}/N_p$ with $N_{p,red}$ as the minimum of the reduced applied load in tests at mormal ambient temperature and in tests at maximum long-term temperature.

The reduction factor $\alpha_{2,\ line\ F6}$ is determined (based on the tension test-residual capacity) according to A3.4 by using following reference tests:

Sustained load test at normal temperature:	Reference test A1,
Sustained load test at maximum long-term temperature:	Reference test F5.3, max. long-term temperature.

2.2.5.9 Relaxation (F7)

The tests are performed to check the relaxation of the plastic anchor. The tests shall be performed according to Annex A, Table A.2 and A2.5.6. The assessment of the relaxation aspect is performed after duration of 24 hours and after 500 hours. The reduction factor $\alpha_{2,line\ F7}$ is determined according to A3.4 by using the reference test A1. The smaller value resulting from the assessments at 24 hours and 500 hours is decisive.

This test is not required for screwed-in plastic anchors with polyamide PA 6 polymeric sleeve, if failure is predominantly caused by pulling out the sleeve and the screw together. If anchors with two embedment depths of one size shall be assessed, the tests shall be carried out either with both embedment depths or only with the minimum embedment depth in which case the results from those tests apply to both embedment depths.

The reduction factor $\alpha_{2,line\ F7}$ is determined according to A3.4 by using the reference test A1.

2.2.5.10 Maximum torque moment (test series F8)

The tests are performed according to Table A.2 and A2.5.7.

The installation of the plastic anchor shall be practicable without steel failure or turn-through in the hole. This condition is fulfilled if the following conditions are met.

The ratio ξ of the maximum torque moment T_u to the torque moment during installation T_{inst} shall be determined for each test:

$$\xi_i = \frac{T_{u,i}}{T_{inst,i}} \qquad (2.7)$$

If the 5%-fractile of the ratio for all tests smaller than 1,3, then the tension tests according to Annex A, Table A.1 and Table A.2 have to be carried out with anchors which are installed with $1{,}3 \cdot T_{inst}$ see A2.3.

2.2.5.11 Characteristic resistance of plastic anchors in base material group a

The characteristic resistances for single anchors under tension loading without edge and spacing influence shall be calculated as follows. The values are valid for all concrete strengths ≥ C16/20, neglecting the effects of concrete strength.

$$N_{Rk,p} = N_{Rk,0} \cdot \min(\min \alpha_1 ; \min \alpha_{2,\text{ line F1,F2,F3,F6,F7}}) \cdot \min \alpha_{2,\text{ line F4,F5}} \cdot \min \alpha_V \cdot \alpha_p \qquad (2.8)$$

$N_{Rk,p}$ = characteristic resistance as given in the ETA.

$N_{Rk,0}$ = minimum baseline value from test series Table A.1, line A2 for base material group a

For thin skins and precast prestressed hollow core slabs the minimum results from the tests according to A1.2 and A1.3 have to be considered (from tests according to Table A.1, line A1).

$\min \alpha_1$ = minimum value α_1 according to equation (A.18) of all tests in base material group a

$\min \alpha_{2,\text{line F1,F2,F3,F6,F7}}$ = minimum value α_2 according to equation (A.16) of all tests according to Table A.2 line F1, F2, F3, F6 and F7 in base material group a

$\min \alpha_{2,\text{ line F4,F5}}$ = minimum value α_2 according to equation (A.16) of all tests according to Table A.2, line F4 and F5 in base material group a

$\min \alpha_V$ = minimum value α_V according to equation (A.12) and (A.13) of all tests in base material group a to consider a coefficient of variation of the ultimate loads

α_p = reduction factor to consider the sustained load in the sustained load tests according to 2.2.5.8

The value of $N_{Rk,p}$ shall be rounded to the following numbers:
Table 2.3

Range of $N_{Rk,p}$ [kN]	Increment [kN]	example
≤ 0,6	0,10	0,3 / 0,4 / 0,5 / 0,6
≤ 0,9	0,15	0,6 / 0,75 / 0,9
≤ 1,5	0,30	0,9 / 1,2 / 1,5
> 1,5	0,50	2 / 2,5 / 3 / … / 9,5 / 10 / 10,5 / 11 / 11,5

For concrete strength C12/15 equation (2.9) is valid.

$$N_{Rk,p\,(C12/15)} = 0{,}7 \cdot N_{Rk,p} \qquad (2.9)$$

with:

$N_{Rk,p}$ = characteristic resistance according to (2.8)

Note:

To account for job site specific base materials the characteristic resistance of the plastic anchor with an ETA for use in the relevant base material based on this EAD may be determined by "job site tests" according to TR051 [11].

In case of an expansion element made of polymeric material and if rupture of polymeric element is observed in tests according to Table A.1and Table A.2, $N_{RK,pol}$ is calculated according to the following equation and shall be given in the ETA:

$$N_{Rk,pol} = N_{Rk,p} \tag{2.10}$$

with:

$N_{Rk,p}$ according to equation (2.8)

2.2.6 Resistance in any load direction (base material group b, c and d)

2.2.6.1 Assessment of all test results

Tests are performed according to Table A.1 and Table A.2. Test details are given in Annex A. Each test series is assessed as follows:

- Conversion of failure loads to nominal strength according to A3.1
- Determine the mean value of converted failure loads $N_{u,m}$ [kN]
- Determine the 5% fractile of the converted failure loads $N_{u,5\%}$ [kN] according to A3.3
- Determine α_v to account the scatter of the failure loads (coefficient of variation) and calculate the reduction factor α_v according to A3.2
- Determine α_1 according to A3.5

2.2.6.2 Basic tension tests (A2 and A3)

These tests are performed to determine the tension capacity of the anchor with an edge distance larger than minimum edge distance (A2), with minimum edge distance (A3) and with minimum edge distance and minimum spacing (A3). s_{min}, c_{min} and h_{min} is given by the manufacturer for which the characteristic resistance is to be determined. For (A2) the edge distance may be selected by the manufacturer.
With theses tests the baseline values for the assessment of the performance under tension load are established. The tests shall be performed according to Annex A, A2.5.

Following baseline values are determined:

$N_{Rk1,0} = N_{u,5\%}$ resulting from test series A2,

$N_{Rk2,0} = N_{u,5\%}$ resulting from test series A3 with single anchors,

$N_{Rk3,0} = N_{u,5\%}$ resulting from test series A3 with anchor groups.

The A2 tests are also used as reference tests for functioning tests. In this case, for base material d (AAC) the tests are performed with the worst expansion direction.

2.2.6.3 Setting capacity for nailed-in anchors (F1)

These tests are performed to evaluate the sensitivity of nailed-in anchors to an additional hammer blow. The tests shall be performed according to Annex A, Table A.2. The anchor is installed and tested according to A2.5.3.

The reduction factor $\alpha_{2,line\ F1}$ is determined according to A3.4 by using reference test A2 for base material group b and d. For base material group d the worst expansion is decisive.

2.2.6.4 Diameter of drill hole (F2)

These tests are performed to evaluate the sensitivity of drill hole diameters in the range of $d_{cut,min}$ to $d_{cut,max}$. The tests shall be performed according to Annex A, Table A.2.

The reduction factor $\alpha_{2,line\ F2}$ is determined according to A3.4 by using reference tests A2 for base material group b.

2.2.6.5 Maximum crack width (F3)

These tests are performed to evaluate the sensitivity to maximum crack width Δw = 0,35 mm. The tests shall be performed according to Annex A, Table A.2 for reinforced components of AAC only.

The reduction factor $\alpha_{2,line\ F3}$ is determined according to A3.4. by using reference tests A2 (Δw = 0,2 mm) for base material group d.

2.2.6.6 Conditioning of polymeric sleeve (F4)

These tests are performed to evaluate the sensitivity to conditioning of the polymeric sleeve in the range from dry to wet conditions. The tests shall be performed according to Annex A, Table A.2.

The reduction factor $\alpha_{2,line\ F4}$ is determined according to A3.4 by using the reference test A2 for each base material group.

2.2.6.7 Effect of temperature (F5)

These tests are performed to evaluate the sensitivity to the effect of temperature within the temperature range given by the manufacturer. The tests shall be performed according to Annex A, Table A.2. and A2.5.4.

If $\alpha_{line\ F5.1} < 1,0$, then the lowest service temperature shall be increased and the tests at lowest service temperature shall be repeated until $\alpha_{line\ F5.1} \geq 1,0$.

If $\alpha_{line\ F5.2} < 1,0$, then the minimum installation temperature shall be increased and the tests at minimum installation temperature shall be repeated until $\alpha_{line\ F5.2} \geq 1,0$.

For the various F5-tests the corresponding reference tests and resulting reduction factors (if applicable) are listed in following Table.:

Table 2.4

Test		Reference test	Reduction factor
min. ϑ	$F_{5.1}$	A1	–
min. inst. ϑ	$F_{5.2}$	A1	–
max. short. term ϑ	$F_{5.3}$	A1	$\alpha_{2,line\ F5.3}$
max. long. term ϑ	$F_{5.4}$	$F_{5.3}$	$\alpha_{2,line\ F5.4}$

The reduction factor $\alpha_{2,line\ F5}$ is determined according to A3.4. The reduction factor $\alpha_{2,line\ F5}$ is calculated as given in equation (2.11).

$$\alpha_{2,line\ F5} = \min(\alpha_{2,line\ F5.3} ; \alpha_{2,line\ F5.4}) \quad (2.11)$$

2.2.6.8 Sustained load (F6)

The tests are performed to check the creep behaviour of the loaded anchor at normal ambient temperature and at maximum long-term temperature. The tests shall be performed according to Annex A, Table A.2. and A2.5.5.

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

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

$$s(t) = s_o + a \cdot t^b \tag{2.12}$$

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

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

The extrapolated displacements shall be less than the mean value of the displacements at the load at overcoming the friction resistance in the reference tests A1 in non-cracked concrete. The load at overcoming the friction resistance may be evaluated as described in A3.6 for the load at loss of adhesion (overcoming friction).

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 $\alpha_p = N_{p,red}/N_p$ with $N_{p,red}$ as the minimum of the reduced applied load in tests at mormal ambient temperature and in tests at maximum long-term temperature.

The reduction factor $\alpha_{2,\text{ line F6}}$ is determined (based on the tension test-residual capacity) according to A3.4 by using following reference tests:

Sustained load test at normal temperature:	Reference test A1,
Sustained load test at maximum long-term temperature:	Reference test F5.3, max. long-term temperature.

2.2.6.9 Relaxation (F7)

The tests are performed to check the relaxation of the plastic anchor. The tests shall be performed according to Annex A, Table A.2. The assessment of the relaxation aspect is performed after duration of 24 hours and after 500 hours. The reduction factor $\alpha_{2,\text{line F7}}$ is determined according to A3.4 by using the reference test A12 for base material group b. The smaller value resulting from the assessments at 24 hours and 500 hours is decisive.

The reduction factor $\alpha_{2,\text{line F7}}$ is determined according to A3.4 by using the reference test A2 for base material group b.

2.2.6.10 Maximum torque moment (test series F8)

The tests are performed according to Table A.2 and A2.5.7.

The installation of the plastic anchor shall be practicable without steel failure or turn-through in the hole. This condition is fulfilled if the following conditions are met.

The ratio ξ of the maximum torque moment T_u to the torque moment during installation T_{inst} shall be determined for each test:

$$\xi_i = \frac{\tau_{u,i}}{\tau_{inst,i}} \tag{2.13}$$

If the 5%-fractile of the ratio for all tests smaller than 1,3, then the tension tests according to Annex A, Table A.1 and Table A.2 have to be carried out with anchors which are installed with $1{,}3 \cdot T_{inst}$ see A2.3.

2.2.6.11 Characteristic resistance of plastic anchors in base material group b, c and d under tension loading

The characteristic resistances for single anchors corresponding to an edge distance larger than c_{min} under tension loading shall be calculated as follows:

Base material group b and c:

$$N_{Rk1} = N_{Rk1,0} \cdot \min(\min \alpha_1 ; \min \alpha_{2,\text{ line F1,F2,F6,F7}}) \cdot \min \alpha_{2,\text{ line F4,F5}} \cdot \min \alpha_V \cdot \alpha_p \tag{2.14}$$

Base material group d:

$$N_{Rk1} = N_{Rk1,0} \cdot \min(\min \alpha_1 ; \min \alpha_{2,\text{ line F1,F3,F6}}) \cdot \min \alpha_{2,\text{ line F4,F5}} \cdot \min \alpha_V \cdot \alpha_p \qquad (2.15)$$

with: $N_{Rk1,0}$ = baseline value from test series A2 according to Table A.1, line 2

$\min \alpha_1$ = minimum value α_1 according to equation (A.18) of all tests in the same base material group.

$\min \alpha_{2,\text{line F1,F2,F6,F7}}$ = minimum value α_2 according to equation (A.16) of all tests according to Table A.2, line F1, F2, F6 and F7

$\min \alpha_{2,\text{line F1,F3,F6}}$ = minimum value α_2 according to equation (A.16) of all tests according to Table A.2, line F1, F3 and F6 for reinforced AAC and all tests according to Table A.2, line F1 and F6 for non-cracked AAC

$\min \alpha_{2,\text{ line F4,F5}}$ = minimum value α_2 according to equation (A.16) of all tests according to Table A.2, line F4 and F5

$\min \alpha_V$ = minimum value α_V according to equation (A.12) and (A.13) of all tests to consider a coefficient of variation of the ultimate loads in the same base material group.

α_p = reduction factor to consider the sustained load in the sustained load tests according to 2.2.6.8

The characteristic resistances for <u>single anchors</u> influenced by minimum edge effects under tension loading shall be calculated for each base material group (b, c and d) as follows:

$$N_{Rk2} = N_{Rk2,0} \cdot \min \alpha_1 \cdot \min \alpha_V \qquad (2.16)$$

with: $N_{Rk2,0}$ = baseline value from test series A3 with single anchors according to Table A.1, line 3

$\min \alpha_1$ = minimum value α_1 according to equation (A.18) of all tests with single anchors in the same base material group.

$\min \alpha_V$ = minimum value α_V according to equation (A.12) of all tests with single anchors to consider a coefficient of variation of the ultimate loads in the same base material group.

If pull-out failure is observed in tests A3 with single anchors, then the evaluation shall be done according to equation (2.14) or (2.15) with $N_{Rk2,0}$.

The characteristic resistances for <u>anchor groups</u> influenced by minimum edge effects and minimum spacing under tension loading shall be calculated for each base material group (b, c and d) as follows:

$$N_{Rk3} = N_{Rk3,0} \cdot \min \alpha_1 \cdot \min \alpha_V \qquad (2.17)$$

with: $N_{Rk3,0}$ = baseline value from test series A3 with anchor groups according to Table A.1, line 3

$\min \alpha_1$ = minimum value α_1 according to equation (A.18) of all tests with anchor groups in the same base material group.

$\min \alpha_V$ = minimum value α_V according to equation (A.12) of all tests with anchor groups to consider a coefficient of variation of the ultimate loads in the same base material group.

If pull-out failure is observed in tests A3 with anchor groups, then the evaluation shall be done according to equation (2.14) or (2.15) with $N_{Rk3,0}$.

For solid masonry units with low compressive strength, i.e. 10 N/mm² $\leq f_b <$ 20 N/mm², the characteristic resistances may be determined without additional testing as follows:

$$N_{Rk1,low} = 0{,}7 \cdot N_{Rk1} \quad (2.18)$$

$$N_{Rk2,low} = 0{,}7 \cdot N_{Rk2} \quad (2.19)$$

$$N_{Rk3,low} = 0{,}7 \cdot N_{Rk3} \quad (2.20)$$

In case of an expansion element made of polymeric material and if rupture of polymeric element is observed in tests according to Table A.1and Table A.2 then:

$$N_{Rk,pol,1} = N_{Rk1} \quad (2.21)$$

$$N_{Rk,pol,2} = N_{Rk2} \quad (2.22)$$

$$N_{Rk,pol,3} = N_{Rk3} \quad (2.23)$$

with:
N_{Rk1} according to equations (2.14) or (2.15)
N_{Rk2} according to equation (2.16)
N_{Rk3} according to equation (2.17)

2.2.6.12 Characteristic resistance of plastic anchors in base material group b, c and d under shear loading

Steel element

The characteristic shear resistances $V_{Rk,s}$ of the metal expansion element for single anchors is calculated for all base material groups as follows:

$$V_{Rk,s} = 0{,}5 \cdot A_s \cdot f_{uk} \quad (2.24)$$

with: A_s = stressed cross section of steel element

f_{uk} = characteristic steel ultimate tensile strength (nominal value)

The assessment shall be made for each anchor size.

Polymeric element

In case of an expansion element made of polymeric material and if rupture of polymeric element is observed in tests according to Table A.1 then:

$$V_{Rk,pol} = V_{u,5\%} \cdot \alpha_V \quad (2.25)$$

with: $V_{u,5\%}$ = 5% fractile of the failure loads V_u, [kN] according to A3.3 resulting from Table A.1, test series A5, converted to normalised mean compressive strength of the masonry unit (given in the ETA) according to A3.1.

min α_V = minimum value α_V according to equation (A.12) of all tests A5 to consider a coefficient of variation of the ultimate loads

Base material group b

If no shear tests are performed, $V_{Rk,solid}$ for brick failure shall be calculated as follows:

$$V_{Rk,solid} = k \cdot \sqrt{d_{nom}} \cdot \left(\frac{h_{nom}}{d_{nom}}\right)^{0,2} \cdot \sqrt{f_b} \cdot c_1^{1,5} \cdot \left(\frac{c_2}{1{,}5 \cdot c_1}\right)^{0,5} \cdot \left(\frac{h}{1{,}5 \cdot c_1}\right)^{0,5} \quad (2.26)$$

with:

$$\left(\frac{c_2}{1{,}5 \cdot c_1}\right)^{0,5} \leq 1{,}0 \quad (2.27)$$

$$\left(\frac{h}{1{,}5 \cdot c_1}\right)^{0,5} \leq 1{,}0 \quad (2.28)$$

$$h = h_{min} \quad (2.29)$$

with: $V_{Rk,solid}$ = characteristic shear resistance for brick edge failure in base material group b [N]

k = factor for load direction [-]

= 0,225 for shear loading in direction to the free edge

= 0,45 for shear loading in other directions

d_{nom} = outside diameter of anchor [mm]

h = thickness of member (wall) [mm]

h_{min} = minimum thickness of member determined by manufacturer

h_{nom} = overall anchor embedment depth in the base material [mm]

c_1 = edge distance closest to the edge in loading direction [mm] given by the manufacturer

c_2 = edge distance perpendicular to direction 1 [mm] given by the manufacturer

f_b = normalised mean compressive strength of the bricks of base material group b [N/mm²]

f_{ck} = normalised mean compressive strength of the bricks of base material group d [N/mm²]

If tests are performed shear tests towards the free edge shall be performed according to Annex A, Table A.1, line A5. Details of tests are given in Annex A. If brick edge failure occurs the characteristic shear resistance shall be calculated as follows.

$$V_{Rk,solid} = V_{u,5\%} \cdot \min \alpha_V \tag{2.30}$$

with: $V_{u,5\%}$ = 5% fractile of the failure loads V_u, [kN] according to A3.3 resulting from Table A.1, test series A5, converted to normalised mean compressive strength of the masonry unit (given in the ETA) according to A3.1.

$\min \alpha_V$ = minimum value α_V according to equation (A.12) of all tests A5 to consider a coefficient of variation of the ultimate loads

Base material group c

If $c_{min} \geq 100$ mm or $F_{Rk} \leq 2,5$ kN the characteristic shear resistances $V_{Rk,hollow}$ for brick failure shall be calculated as follows:

$$V_{Rk,hollow} = V_{Rk,s} = 0,5 \cdot A_s \cdot f_{uk} \tag{2.31}$$

with: A_s = stressed cross section of steel element

f_{uk} = characteristic steel ultimate tensile strength (nominal value)

Tests are required if: $c_{min} < 100$ mm or $F_{Rk} > 2,5$ kN or expansion element made of polymeric material or the anchor is only bedded in the outer shell of the hollow/ perforated brick or the anchors are used under shear loads with lever arm (without bearing on the base material)

For base material group c shear tests towards the free edge shall be performed according to Annex A, Table A.1, line A5. Details of tests are given in Annex A. If brick edge failure occurs the characteristic shear resistance shall be calculated as follows.

$$V_{Rk,hollow} = V_{u,5\%} \cdot \min \alpha_V \tag{2.32}$$

with: $V_{u,5\%}$ = 5% fractile of the failure loads V_u, [kN] according to A3.3 resulting from Table A.1, test series A5, converted to normalised mean compressive strength of the masonry unit (given in the ETA) according to A3.1.

$\min \alpha_V$ = minimum value α_V according to equation (A.12) of all tests A5 to consider a coefficient of variation of the ultimate loads

<u>Base material group d</u>

If no shear tests are performed, $V_{Rk,AAC}$ for brick failure shall be calculated as follows:

$$V_{Rk,AAC} = k \cdot \sqrt{d_{nom}} \cdot \left(\frac{h_{nom}}{d_{nom}}\right)^{0,2} \cdot \sqrt{f_{ck}} \cdot c_1^{1,5} \cdot \left(\frac{c_2}{1,5 \cdot c_1}\right)^{0,5} \cdot \left(\frac{h}{1,5 \cdot c_1}\right)^{0,5} \quad (2.33)$$

with:

$$\left(\frac{c_2}{1,5 \cdot c_1}\right)^{0,5} \leq 1,0 \quad (2.34)$$

$$\left(\frac{h}{1,5 \cdot c_1}\right)^{0,5} \leq 1,0 \quad (2.35)$$

$$h = h_{min} \quad (2.36)$$

with:

$V_{Rk,AAC}$	=	characteristic shear resistance for brick edge failure in base material group d [N]
k	=	factor for load direction [-]
	=	0,225 for shear loading in direction to the free edge
	=	0,45 for shear loading in other directions
d_{nom}	=	outside diameter of anchor [mm]
h	=	thickness of member (wall) [mm]
h_{min}	=	minimum thickness of member determined by manufacturer
h_{nom}	=	overall anchor embedment depth in the base material [mm]
c_1	=	edge distance closest to the edge in loading direction [mm] given by the manufacturer
c_2	=	edge distance perpendicular to direction 1 [mm] given by the manufacturer
f_b	=	normalised mean compressive strength of the bricks of base material group b [N/mm²]
f_{ck}	=	normalised mean compressive strength of the bricks of base material group d [N/mm²]

If tests are performed shear tests towards the free edge shall be performed according to Annex A, Table A.1. Details of tests are given in Annex A. If brick edge failure occurs the characteristic shear resistance shall be calculated as follows.

$$V_{Rk,AAC} = V_{u,5\%} \cdot \min \alpha_V \quad (2.37)$$

with:

$V_{u,5\%}$	=	5% fractile of the failure loads $V_{u,}$ [kN] according to A3.3 resulting from Table A.1, test series A5, converted to normalised mean compressive strength of the masonry unit (given in the ETA) according to A3.1.
$\min \alpha_V$	=	minimum value α_V according to equation (A.12) of all tests A5 to consider a coefficient of variation of the ultimate loads

2.2.6.13 Characteristic resistance of plastic anchors in base material group b, c and d in any load direction

For the determination of the characteristic resistance F_{Rk} the <u>design</u> values for N_{Rk1}, N_{Rk2}, N_{Rk3}, $N_{RK,pol}$, $V_{Rk,solid}$, $V_{Rk,hollow}$, $V_{Rk,AAC}$, $V_{RK,pol}$ and $V_{Rk,s}$ have to be calculated under consideration of the recommended partial safety factors. The decisive failure mode shall be given in the ETA. The corresponding partial safety factors are given in TR 064 [18]

The minimum <u>design</u> value is decisive for the characteristic resistance F_{Rk} given in the ETA.

The value of the characteristic resistance F_{Rk} shall be rounded (nearest) to the following numbers:

Table 2.5

Range of F_{Rk} [kN]	Increment [kN]	example
≤ 0,6	0,10	0,3 / 0,4 / 0,5 / 0,6
> 0,6 to ≤ 0,9	0,15	0,6 / 0,75 / 0,9
> 0,9 to ≤ 1,5	0,30	0,9 / 1,2 / 1,5
> 1,5	0,50	2 / 2,5 / 3 / … / 9,5 / 10 / 10,5 / 11 / 11,5

The characteristic resistances given in the ETAs for use in solid masonry are valid for the base material and the bricks which have been used in the tests or larger brick sizes and higher compressive strengths of the masonry unit.

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

Note: To account for job site specific base materials the characteristic resistance of the plastic anchor with an ETA for use in the relevant base material based on this EAD may be determined by "job site tests" according to TR051 [11].

2.2.7 Edge distance and minimum spacing (base material group a)

2.2.7.1 Characteristic spacing and edge distances

The edge distance c_{cr} for maximum pull-out capacity of the plastic anchor is evaluated from the results of tension tests on single anchors at the corner ($c_1 = c_2 = c_{cr}$) according to Table A.1, line A3. For thin skins the minimum results from the tests according to A1.2 have to be considered. The mean failure load in the tests with plastic anchors at the corner shall be approximately equal (± 5%) with the values valid for anchors without edge and spacing effects. If this condition is not fulfilled, the tests have to be repeated with a larger edge distance. For plastic anchors in concrete strength C12/15 the evaluated values for the edge distance shall be increased by the factor 1,4.

The spacing s_{cr} ensuring the transmission of the characteristic resistance $N_{Rk,p}$ of a single anchor shall be derived as follows:

$$s_{cr} = 3 \cdot h_{ef} \qquad (2.38)$$

with:

$$h_{ef} = \left[\frac{N_{Rk,p}}{7{,}2 \cdot \sqrt{f_{ck,cube}}}\right]^{\frac{2}{3}} \qquad (2.39)$$

and $N_{Rk,p}$ as given in the ETA (h_{ef} [mm], $N_{Rk,p}$ [N], $f_{ck,cube}$ [N/mm²])

2.2.7.2 Minimum spacing and edge distances and member thickness

The minimum spacing s_{min} and minimum edge distance c_{min} shall be evaluated from the results of installation tests with double anchor groups ($c = c_{min}$, $s = s_{min}$) according to Table A.1, line A6. The 5 %-fractile of the torque moments, $T_{5\%}$ at which a hairline crack has been observed in the concrete at one anchor of the double anchor group, shall fulfil equation (2.40).

$$T_{5\%} \geq 1{,}7 \cdot \text{req. } T_{inst,m} \cdot \left(\frac{f_{c,test}}{f_{ck}}\right)^{0,5} \qquad (2.40)$$

with:

req.$T_{inst,m}$ = mean value of torque moment during installation according to Table A.2, line F8.

If no concrete failure occurs in any of the tests, equation (2.40) is considered as fulfilled.

For plastic anchors in concrete strength C12/15 the evaluated values for minimum spacing and minimum edge distance in C20/25 shall be increased by the factor 1,4 ($s_{min,C12/15} = 1,4 \cdot s_{min,C20/25}$, $c_{min,C12/15} = 1,4 \cdot c_{min,C20/25}$).

The minimum member thickness h_{min} shall be given according to h_{min} of tests A3.

2.2.8 Minimum edge distance and spacing (base material group b, c and d)

The minimum edge distance $c_{min,}$ minimum spacing s_{min} and minimum member thickness h_{min} are based on the manufacturer's instructions. These values are confirmed by tests series Table A.1, line A3.

2.2.9 Displacement

As a minimum, the displacements under short and long-term tension and shear loading shall be given in the ETA for a load F which corresponds approximately to the value according to equation (2.41)

$$F = \frac{F_{Rk}}{\gamma_F \cdot \gamma_M} \qquad (2.41)$$

with:

F_{Rk} = characteristic resistance of specific base material

γ_F = 1,4

γ_M = material partial safety factor according to TR 064 [18]

Under shear loading the displacements might increase due to a gap between fixture and anchor. The influence of this gap is taken into account in design (TR 064 [18]).

For base material group a:
The displacements under short-term tension and shear loading (δ_{NO} and δ_{VO}) are evaluated from the tests on single anchors without edge or spacing effects according to Table A.1, lines A2 and A4. The value derived shall correspond approximately to the 95 %-fractile for a confidence level of 90 %.

The long-term displacements under tension loading, $\delta_{N\infty}$, shall be calculated from the results of the sustained load tests (Table A.2, line F6) according to equation (2.42).

$$\delta_{N\infty} = \frac{\delta_{m2}}{2,0} \qquad (2.42)$$

with:

δ_{m2} = mean extrapolated displacement in the sustained load tests for every temperature range (see Annex A)

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

For base material group b, c and d:
The displacements under short-term tension and shear loading (δ_{NO} and δ_{VO}) are evaluated from the tests on single anchors without edge or spacing effects according to Table A.1, lines A2 and A5. The value derived shall correspond approximately to the 95 %-fractile for a confidence level of 90 %.

If no shear tests are performed the displacements under short-term shear loading (δ_{VO}) for a plastic anchors with metal expansion element may be determined for the loading according to equation (2.41) with a shear stiffness of 1200 N/mm for base material group b and c and 500 N/mm for base material group d.

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

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

2.2.10 Durability

2.2.10.1 Corrosion of metal parts

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

(1) Plastic anchor for redundant non-structural systems 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) Plastic anchor for redundant non-structural systems 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 [e.g. permanent, alternating immersion in seawater or the splash zone of seawater, chloride atmosphere of indoor swimming pools or atmosphere with extreme chemical pollution (e.g. in desulphurization plants or road tunnels where de-icing materials are used)] exist :

Metal parts of the anchor made of stainless steel material 1.4401, 1.4404, 1.4578, 1.4571, 1.4362, 1.4062, 1.4162, 1.4662, 1.4439, 14462 or 1.4539 according to EN 10088-4 and 5:2014 [12] can be used.

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

If an anchor involves the use of different metals, these shall be electrolytically compatible with each other. In dry internal conditions, carbon steel is compatible with malleable cast iron according to ISO 5922 [7].

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

2.2.10.2 High alkalinity of plastic sleeve

The durability of the plastic sleeve material shall be tested against high alkalinity (pH = 13,2).

The durability with respect to high alkalinity is proven, if for all specimen tested according to section A2.5.10 no cracks are visible with a microscope using a magnification of at least 100.

Furthermore it shall be verified that any coating of the steel parts do not negatively influence the durability of the polymeric sleeve.

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 97/463/EC. The system is 2+.

Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the plastic anchors for redundant non-structural systems in concrete and masonry in the procedure of assessment and verification of constancy of performance are laid down in Table 3.1.

Table 3.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC)					
Expansion element made of metal					
1	Dimensions (outer diameter, inner diameter, thread length, etc.)	Caliper and/ or gauge	Laid down in control plan	3	Every manufacturing batch or 100000 expansion elements or when raw material batch has been changed 1)
2	Tensile Load (N_p) or tensile strength (f_{uk})	According to ISO 898-1 [13]		3	
3	Zinc plating (where relevant)	x-ray measurement		3	
Expansion element, anchor sleeve and plate made of plastic					
4	Material	DSC according to ISO 11357 [14]	Tolerance: ± 5 K	2	twice yearly or each batch 1)
5	Density	according to EN ISO 1183 [15] 2)	-	2	
6	Only for polyamide (PA) / Molecular weight	VZ according to ISO 307 [16] 3)	Tolerance: ± 10%	2	
7	Only for polyethylene (PE) and polypropylene (PP)/ Molecular weight	MFI according to ISO 1133 [17] 2)	Tolerance: MFI ≤ 10: ±1 MFI > 10: ±10%	2	
8	Extrusion of anchor sleeve	visual inspection	Laid down in control plan	one shot of each production lot or shift	twice/coat

1) The lower control interval is decisive
2) Tests or inspection certificate 3.1 analogous to EN 10204 [21] or test report type 2.2 acc. EN 10204 [21] with internal document of the manufacturing plant
3) Tests or test report type 2.2 analogous to EN 10204 [21] and additional recommendation of random incoming goods inspection

3.2 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body of the plastic anchors for redundant non-structural systems in concrete and masonry in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.

Table 3.2 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	Ascertain that the manufacturing plant, personnel, equipment and factory production control are suitable to ensure a continuous and orderly manufacturing of the anchor. In particular it shall be checked if all tasks given in Table 3.1 were performed	see control plan	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. In particular it shall be checked if all tasks given in Table 3.1 were performed	-	Laid down in control plan	-	1/year

4 REFERENCE DOCUMENTS

[1] EN 206:2013+A1:2016: Concrete - Specification, performance, production and conformity

[2] EN 197-1:2011: Cement Part 1: Composition, specifications and conformity criteria for common cements

[3] ISO 6783:1982: Coarse aggregates for concrete - determination of particle density and water absorption - hydrostatic balance method

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

[5] EN 771-1 to 5:2011-07+A1:2015: Specification for masonry units

[6] EN 12602:2016: Prefabricated reinforced components of autoclaved aerated concrete

[7] ISO 5922:2005: Malleable cast iron

[8] ISO 5468:2017: Rotary and rotary impact masonry drill bits with hardmetal tips - Dimensions

[9] EN ISO 1110:1995: Plastics - Polyamides - Accelerated conditioning of test specimens

[10] EN ISO 3167:2014: Plastics - Multipurpose test specimens

[11] EOTA TR 051: April 2018: Recommendations for Job-Site tests of plastic anchors and screws

[12] 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

[13] EN ISO 898-1:2013 Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread

[14] EN ISO 11357-1:2016 Plastics - Differential scanning calorimetry (DSC)

[15] EN ISO 1183-1:2012, EN ISO 1183-2:2004, EN ISO 1183-3:1999 Plastics - Methods for determining the density of non-cellular plastics

[16] EN ISO 307:2007 + Amd 1:2013: Plastics - Polyamides - Determination of viscosity number (ISO 307:2007 + Amd 1:2013)

[17] EN ISO 1133-1 to 2:2011: Plastics - Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics

[18] EOTA TR 064: April 2018: Design of plastic anchors in concrete and masonry

[19] EN 13791:2007: Assessment of in-situ compressive strength in structures and precast concrete components

[20] R. Lewandowski: Beurteilung von Bauwerksfestigkeiten an Hand von Betongütewürfeln und –bohrproben, Schriftenreihe der Institute für Konstruktiven Ingenieurbau der Technischen Universität Braunschweig, Heft3, Werner Verlag, Düsseldorf, 1971

[21] EN 10204:2004: Metallic products - Types of inspection documents

[22] EAD 330232-00-0601: Mechanical fasteners for use in concrete

A ANNEX A TEST PROGRAM AND GENERAL ASPECTS OF ASSESSMENT

A1 Test program

A1.1 Overview test programm

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 (functioning tests).

In case of more than one anchorage depth the tests shall be done with the most unfavourable anchorage depth, if no other specifications are given. The test shall be carried out at the most unfavourable setting position in the brick, which give the lowest characteristic resistance of the anchor. Details of tests are given in section A2.

Table A.1 Test program of basic tests

	Purpose of test	Base material group	Size (1)	Number of tests	Conditions / Criteria (9)	Remarks in section
A1	Tension tests in non-cracked concrete	a $\Delta w = 0$	s / m / l	5 / 5 / 5	$s > s_{cr}$ $c > c_{cr}$ $h \geq h_{min}$	2.2.5.2
A2	Tension tests	a $\Delta w = 0,2$	s / m / l	5 / 5 / 5	$s > s_{cr}$ $c > c_{cr}$ $h \geq h_{min}$	2.2.5.2
		b	s / m / l	5 / 5 / 5	$s > s_{min}$ $c > c_{min}$ $h \geq h_{min}$	2.2.6.2
		c	s / m / l	5 / 5 / 5	$s > s_{min}$ $c > c_{min}$ $h \geq h_{min}$	
		d blocks (7)	s / m / l	5 / 5 / 5	$s > s_{min}$ $c > c_{min}$ $h \geq h_{min}$	
		d slabs (7) $\Delta w = 0,2$	s / m / l	5 / 5 / 5	$s > s_{min}$ $c > c_{min}$ $h \geq h_{min}$	
A3	Tension tests of single anchor at the corner	a $\Delta w = 0$	s / m / l	4 / 4 / 4	$s > s_{cr}$ $c_1 = c_2 = c_{cr}$ $h = h_{min}$	2.2.7.1
	Tension tests of single anchor at the edge	b	s / m / l	5 / 5 / 5	$s > s_{min}$ $c = c_{min}$ $h = h_{min}$	2.2.6.2, 2.2.8
		c	s / m / l	5 / 5 / 5	$s > s_{min}$ $c = c_{min}$ $h = h_{min}$	
		d blocks (7)	s / m / l	5 / 5 / 5	$s > s_{min}$ $c = c_{min}$ $h = h_{min}$	
		d slabs (6)(7) $\Delta w = 0$	s / m / l	5 / 5 / 5	$s > s_{min}$ $c = c_{min}$ $h = h_{min}$	
	Tension tests of double anchor group at the edge (2)	b (3)	s / m / l	5 / 5 / 5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$	2.2.6.2
		c (3)	s / m / l	5 / 5 / 5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$	2.2.6.2
		d blocks (7)	s / m / l	5 / 5 / 5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$	
		d slabs (6)(7) $\Delta w = 0$	s / m / l	5 / 5 / 5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$	
A4	Shear tests	a $\Delta w = 0$	s / m / l	5 / 5 / 5	$s > s_{cr}$ $c > c_{cr}$ $h \geq h_{min}$	2.2.4.1
A5	Shear tests towards the edge	c (4), b and d (8)	s / m / l	5 / 5 / 5	$s > s_{min}$ $c = c_{min}$ $h = h_{min}$	2.2.6.12
A6	Minimum edge distance and minimum spacing (5)	a	s / m / l	5 / 5 / 5	$s = s_{min}$ $c = c_{min}$ $h = h_{min}$	2.2.7.2

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

(2) Tests may be omitted if $s_{min} > 4 \cdot c_{min}$ (spacing parallel to the free edge) and $s_{min} > 2 \cdot c_{min}$ (spacing perpendicular to the free edge)

(3) Tension tests with double anchor group have only to be performed for the most unfavourable clay brick, sand-lime brick or lightweight concrete brick.

(4) Tests are required if: $c_{min} < 100$ mm or $F_{Rk} > 2{,}5$ kN or expansion element made of polymeric material or the anchor is only bedded in the outer shell of the hollow/ perforated brick or the anchors are used under shear loads with lever arm (without bearing on the base material).

(5) Tests are required only for screwed-in plastic anchors.

(6) Tests may be omitted if tests in base material group d blocks exist.

(7) If characteristic resistance in low and high strength AAC are requested by the manufacturer, the tests have to be performed in low and high strength AAC elements (strength definitions are given in A2.2.3).

(8) May be performed to achieve better resistances than calculated values. (see also 2.2.6.12)

(9) c_{cr}, c_{min}, s_{min}, h_{min} given by the manufacturer, $s_{cr} = 3\ h_{ef}$

Table A.2 Test program of functioning tests

	Purpose of test	Base material group	Δw [mm] (11)	Drill bit	Temperature (see also section 1.3.1) (8)	Conditions of polymeric sleeve	Size (1)	Number of tests	req. α	Remarks in section
Tension tests										
F1	Setting capacity for nailed-in anchors only	a,b	0	$d_{cut,m}$	min. inst. ϑ	standard	s/m/l	5/5/5	≥ 0,9	2.2.5.3 and 2.2.6.3
		d blocks (10)	0	$d_{cut,max}$	min. inst. ϑ	standard	s/m/l	5/5/5	≥ 0,9	2.2.6.3
F2	Functioning, depending on the diameter of drill hole	a,b	0	$d_{cut,min}$ (4)	normal	standard	s/m/l	5/5/5	≥ 1,0	2.2.5.4 and 2.2.6.4
				$d_{cut,max}$ (5)	normal	standard	s/m/l	5/5/5	≥ 0,8	
F3	Functioning in cracks	a	0,35	$d_{cut,max}$	normal	standard	s/m/l	5/5/5	≥ 0,75	2.2.5.5
		d slabs (7)(9)	0,35	$d_{cut,m}$	normal	standard	s/m/l	5/5/5	≥ 0,75	2.2.6.5
F4	Functioning under conditioning (3)	a,b d blocks (10)	0	$d_{cut,m}$	normal	dry	s/m/l (6)	5/5/5	≥ 0,8	2.2.5.6 and 2.2.6.6
						wet	s/m/l (6)	5/5/5	≥ 0,8	
F5	Effect of temperature (3)	a ,b , d blocks (10)	0	$d_{cut,m}$	F.5.1 min. ϑ	standard	s/m/l (6)	5/5/5	≥ 1,0	2.2.5.7 and 2.2.6.7
					F.5.2 min. inst. ϑ	standard	s/m/l (6)	5/5/5	≥ 1,0	
					F.5.3 max. long-term ϑ	standard	s/m/l (6)	5/5/5	≥ 1,0	
					F.5.4 max. short-term ϑ	standard	s/m/l (6)	5/5/5	≥ 0,8	
F6	Sustained loads	a, b, d blocks (10)	0	$d_{cut,m}$	normal	standard	s/m/l	5/5/5	≥ 0,9	2.2.5.8 and 2.2.6.8
					max. long-term ϑ	standard	s/m/l	5/5/5	≥ 0,9	
F7	Relaxation (2) (3) – 24 h	a, b	0	$d_{cut,m}$	normal	standard	m	5	≥ 0,9	2.2.5.9 and 2.2.6.9
	Relaxation (2) (3) – 500 h	a, b	0	$d_{cut,m}$	normal	standard	m	5	≥ 1,0	
Torque tests and tests on material										
F8	Maximum torque moment	a, b, d (10)	0	$d_{cut,m}$	normal	standard	s/m/l (7)	5/5/5	-	2.2.5.10 and 2.2.6.10
F9	Corrosion of metal parts	See 2.2.10.1								
F10	High alkaline	See 2.2.10.2								

(1) s: smallest fastener size, m: medium fastener size, l: largest fastener size
If the tests A1 or A2 according to Table A.1 do not show regularity in failure mode and ultimate load all sizes shall be tested.
(2) This test is not required for screwed-in plastic anchors with polyamide PA 6 polymeric sleeve, if failure is predominantly caused by pulling out the sleeve and the screw together.
(3) If anchors with two embedment depths of one size shall be assessed, the tests shall be carried out either with both embedment depths or only with the minimum embedment depth in which case the results from those tests apply to both embedment depths.
(4) If more than one embedment depth of one size shall be assessed, these tests shall be carried out with the maximum embedment depth.
(5) The test series with $d_{cut,max}$ may be omitted if the test series according to Table A.1, line A2 are carried out with $d_{cut,max}$.
(6) For base material group a and b only size m is to be tested.
(7) For AAC: Tests shall be carried out with the most unfavourable direction of expansion determined in tests Table A.1, line A2
(8) Normal ambient temperature: +21 ± 3 °C (plastic anchor and base material)
(9) If characteristic resistance in low and high strength AAC are requested by the manufacturer, the tests have to be performed in low and high strength AAC elements (strength definitions are given in A2.2.3).
(10) Low strength AAC
(11) Only for base material group group a and d

The tests shall be performed in the base material group for which the anchor is intended to be used according to the following Table A.3.

Table A.3 Tests for base material groups

Base material group for the intended use	Base material group	Tests according to Table A.1, line						Table A.2, line							
		A1	A2	A3	A4	A5	A6	F1	F2	F3	F4	F5	F6	F7	F8
a	a	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
b	b	×	✓	✓	×	×	×	✓	✓	×	✓	✓	✓	✓	✓
a and b	a	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
	b	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×
a, b and c	a	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓
	b	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×
	c	×	✓	✓	×	✓(2)	×	×	×	×	×	×	×	×	×
b and c	b	×	✓	✓	×	×	×	✓	✓	×	✓	✓	✓	✓	✓
	c	×	✓	✓	×	✓(2)	×	×	×	×	×	×	×	×	×
c	b	×	✓	✓	×	×	×	✓	✓	×	✓	✓	✓	✓	✓
	c	×	✓	✓	×	✓(2)	×	×	×	×	×	×	×	×	×
d	d	×	✓	✓	×	×	×	✓	×	✓	✓(1)	✓(1)	✓	×	✓

✓ Test required
× No test required

(1) If there are existing tests for functioning carried out in base material group a or b, then the results of these functioning tests (min α_1, min α_2 and min α_V) may be taken for the determination of the characteristic values of the plastic anchors.

(2) Tests are required if: c_{min} < 100 mm or F_{Rk} > 2,5 kN or expansion element made of polymeric material or the anchor is only bedded in the outer shell of the hollow/ perforated brick or the anchors are used under shear loads with lever arm (without bearing on the base material)

A1.2 Specific detail for thin skin

If anchors are set in a range of setting depth from min t_{fix} to max t_{fix} (see Figure A.1) in a thin skin 40 mm ≤ h < 80 mm (e.g. weather resistant skin of external wall panels according to Table 1.1, thin skins), the anchor may extend beyond the thin member (see Figure A.1 b)). This may negatively affect the load carrying capacity. In these cases the most unfavourable setting position (e.g. Figure A.1 b)) shall be considered in additional tests at least according to Table A.1, line A1, A3 and line A4 (shear test with c = c_{min}).

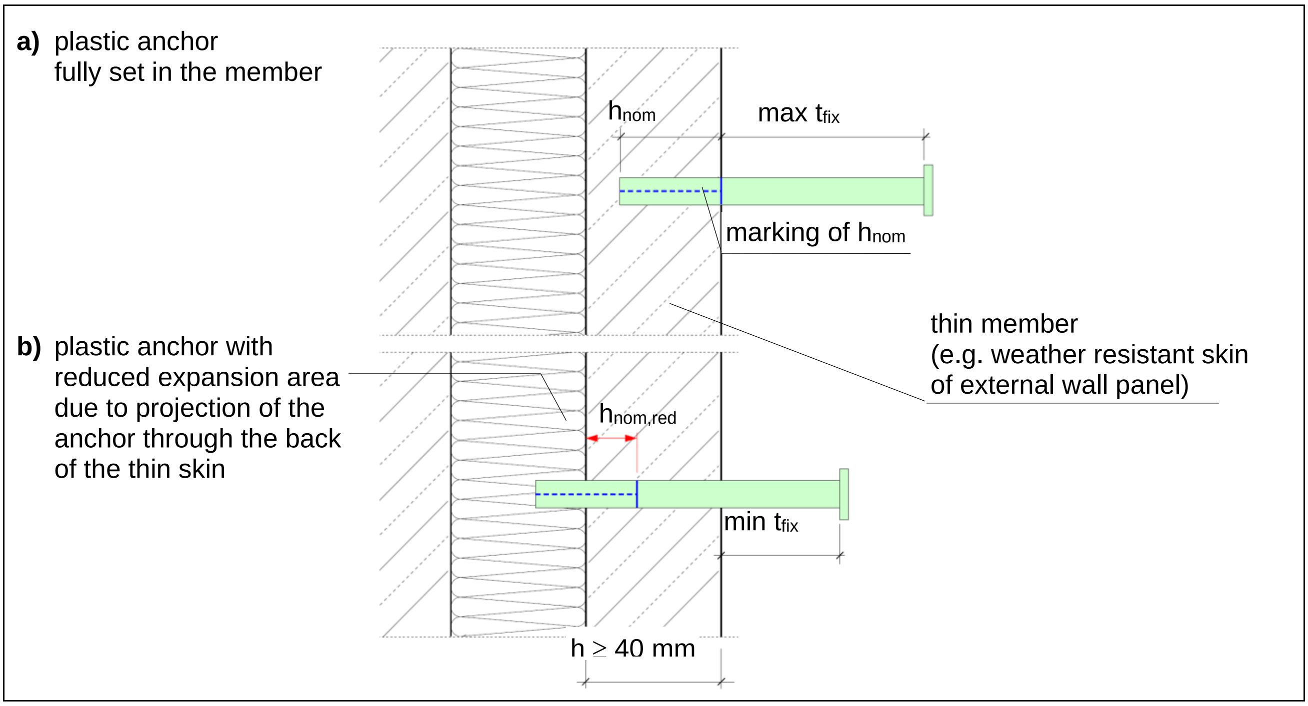


Figure A.1 Example for different setting positions of plastic anchors in thin members

A1.3 Specific detail for precast prestressed hollow core slab

If plastic anchors are set in a precast prestressed hollow core slab, in most cases the anchors extend beyond the wall with h ≥ 17 mm (see Figure A.2a). This may negatively affect the load carrying capacity. In these cases the most unfavourable setting position (Figure A.2.b) shall be considered in additional tests at least according to Table A.1, line A1.

a) plastic anchor with **max** t_{fix} and **minimum** reduced expansion area ($h_{nom,red}$ = h ≥ 17 mm)

b) plastic anchor with **min** t_{fix} and **maximum** reduced expansion area ($h_{nom,red}$ ≤ h)

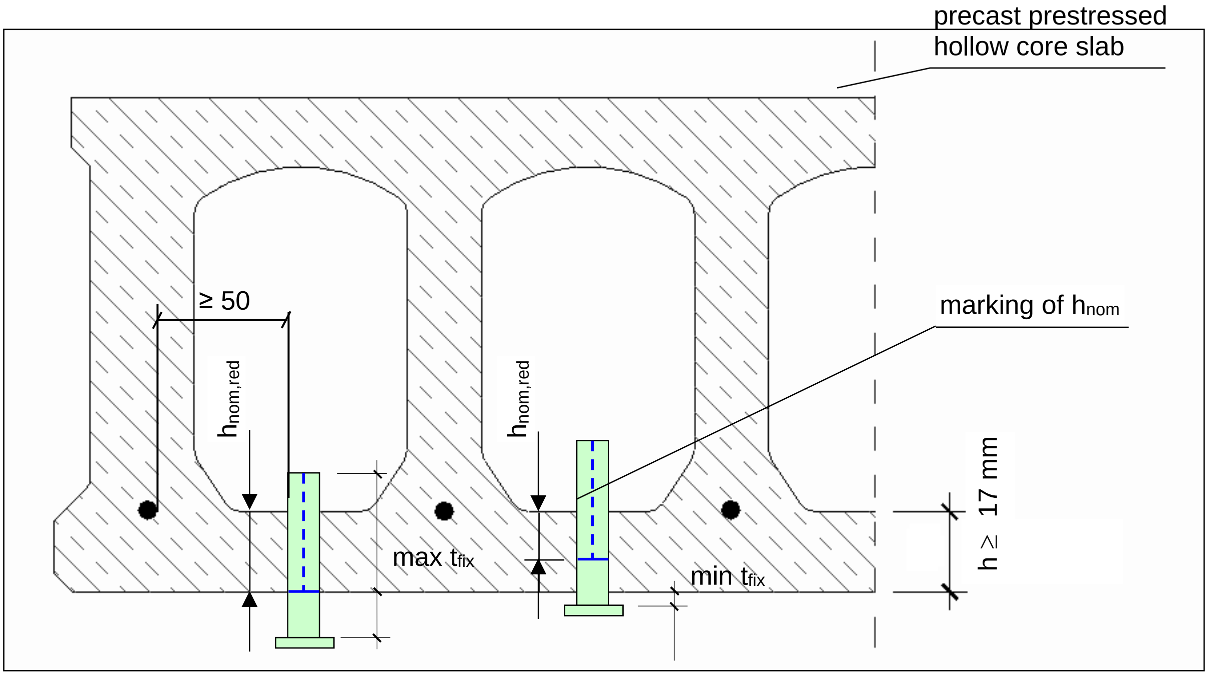


Figure A.2 **Example for different setting positions of plastic anchors in precast prestressed hollow core slabs**

A1.4 Specific detail for hollow or perforated masonry

The tests shall be carried out with the minimum overall anchor embedment depth min h_{nom} given by the manufacturer.

These test results are valid for the minimum overall anchor embedment depth min h_{nom} only because the performance of the anchor with larger overall anchor embedment depth than min h_{nom} can be reduced depending on the volume of holes (see Figure A.3).

The embedment depth h_{nom} of one plastic anchor results from the thickness of fixture t_{fix}. The thickness of fixture t_{fix} (including tolerances) for the individual anchor is given by manufacturer (intended use of the product).

If the manufacturer provides a wide usable intended range of thickness of fixture t_{fix} for individual one anchor then the largest embedment depths shall be tested (most unfavourable setting position).

Dimensions in [mm]

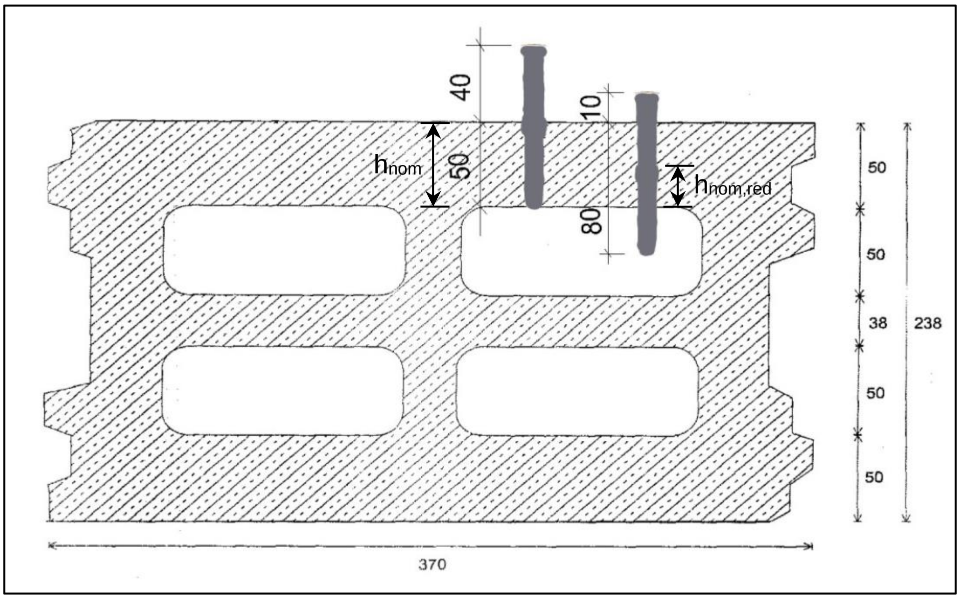


Figure A.3 Example of plastic anchor with a total length of 90 mm designed for a maximum thickness of fixture 40 mm (max t_{fix} = 40 mm) in different setting positions

A2 Details of tests

A2.1 Samples

Samples shall be chosen of normal production as supplied by the manufacturer, including screws, nails and plastic sleeves.

A2.2 Test members

A2.2.1 Base material group a

This EAD is valid for plastic anchors tested in concrete members using compacted normal weight concrete without fibres with strength classes C20/25 in accordance with EN 206[1].

Aggregates shall be of natural occurrence (i.e. non-artificial) and with a grading curve falling within the boundaries given in Figure A.4. The maximum aggregate size shall be 16 mm or 20 mm. The aggregate density shall be between 2,0 and 3,0 t/m³ (see EN 206 [1] and ISO 6783 [3]).

The boundaries reported in Figure A.4 are valid for aggregate with a maximum size of 16 mm. For different values of maximum aggregate sizes, different boundaries may be adopted, if previously agreed with the responsible TAB.

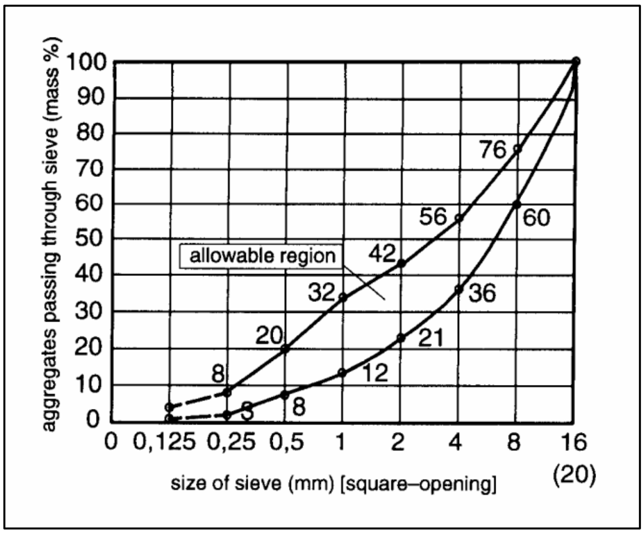


Figure A.4 Admissible region for the grading curve

The concrete shall be produced using Portland cement type CEM I or Portland-Composite CEM II/A-LL, CEM II/B-LL (see EN 197-1 [2]).

The water/cement ratio shall not exceed 0,75 and the cement content shall be at least 240 kg/m³.

No additives likely to change the concrete properties (e.g. fly ash or silica fume or other powders) shall be included in the mix.

For the tests carried out in low strength concrete (strength class C20/25) the following mean compressive strengths at the time of testing fasteners shall be obtained:

f_{cm} = 20-30 MPa (cylinder: diameter 150 mm, height 300 mm)

= 25-35 MPa (cube:150 x 150 x 150 mm)

It is recommended to measure the concrete compressive strength either on cylinders with a diameter of 150 mm and height of 300 mm, or on cubes of 150 mm.

$$f_{cyl} = \frac{1}{1{,}25} f_{cube150} \qquad (A.1)$$

For other dimensions, the concrete compressive strength may be converted as follows:

$$f_{cube100} = \frac{1}{0{,}95} f_{cube150} \qquad (A.2)$$

$$f_{cube150} = \frac{1}{0{,}95} f_{cube200} \qquad (A.3)$$

$f_{cube150}$ = $f_{core100}$ (according to EN 13791 [19], section 7.1) (A.4)

Note: Additional literature for conversion is given by R. Lewandowski, [20]

For every concreting operation, specimens (cylinder, cube) shall be prepared having the dimensions mentioned in this clause; the specimens being made and treated in the same way as the test members.

Generally, the concrete control specimens shall be tested on the same day as the plastic anchors in the corresponding concrete test member. If a test series takes a number of days, the specimens shall be tested at a time giving the best representation of the concrete strength at the time of the plastic anchor tests, e.g. in general at the beginning and at the end of the tests.

The concrete strength at a certain age shall be measured on at least 3 specimens, the mean value shall be used to check compliance with the requirement.

If, when evaluating the test results, there are doubts about whether the strength of the control specimens represents the concrete strength of the test members, then at least three cores of 100 mm or 150 mm diameter shall be taken from the test members outside the zones where the concrete has been damaged in the tests, and tested in compression. The cores shall be cut to a height equal to their diameter, and the surfaces to which the compression loads are applied shall be ground or capped. The compressive strength measured on these cores shall be converted into the strength of cubes by equation (A.4):

The specification and dimensions of the test members shall conform to the following:

(a) Tests in cracked concrete

The tests are carried out on test members with unidirectional cracks; the crack width measured close to the anchor shall be approximately constant throughout the member thickness. The thickness of the test member should be $h \geq 2h_{nom}$ but at least 80 mm. The thickness of the test member has no effect on the minimum thickness given in the ETA. To control cracking, so-called ‘crack-formers’ may be built into the member, provided they are not situated near the anchorage zone. An example for a test member is given in Figure A.5.

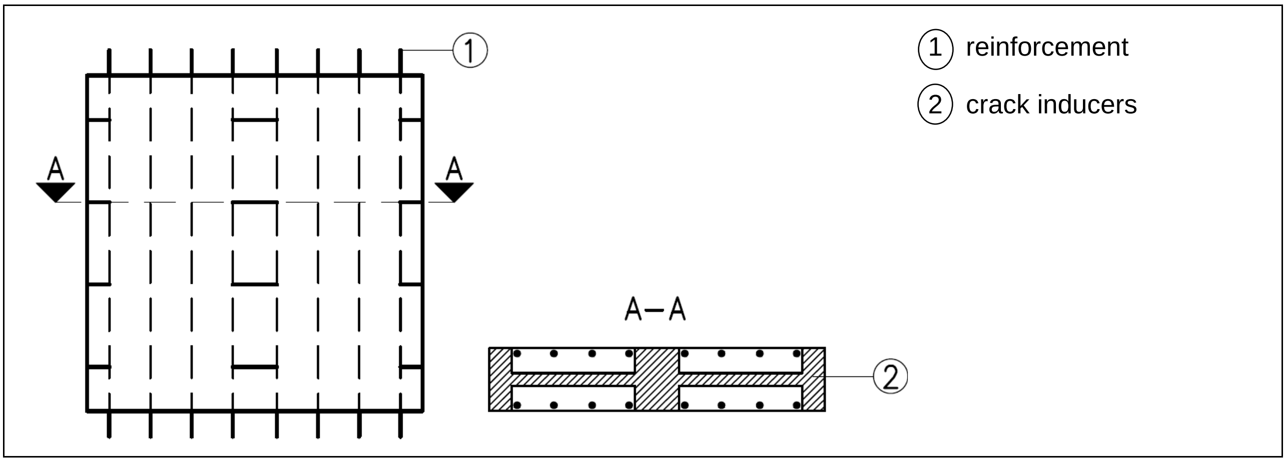


Figure A.5 Example of a test member for plastic anchors tested in cracked concrete

When using a test member according to Figure A.5, the reinforcement ratio and/or the member depth shall be sufficiently large to allow for a small increase in crack width during loading of the plastic anchor.

(b) Tests in non-cracked concrete

Generally, the tests are carried out on unreinforced test members. Only in the tests according to A2.5.9 the member may be provided with an edge reinforcement. This edge reinforcement used in the tests shall be stated in the ETA. The reinforcement bars shall be straight and have a concrete cover on both sides of 15 mm.

In cases where the test member contains reinforcement to allow handling or for the distribution of loads transmitted by the test equipment, the reinforcement shall be positioned such as to ensure that the loading capacity of the tested plastic anchors is not affected. This requirement will be met if the reinforcement is located outside the zone of concrete cones having a vertex angle of 120°.

In general, the test members shall be cast horizontally. They may also be cast vertically if the maximum height is 1,5 m and complete compaction is ensured.

Test members and concrete specimens (cylinders, cubes) shall be cured and stored indoors for seven days. Thereafter they may be stored outside provided they are protected such that frost, rain and direct sun does not cause a deterioration of the concrete compressive and tension strength. When testing the plastic anchors the concrete shall be at least 21 days old.

A2.2.2 Base material group b and c

The tests shall be performed in single units or in a wall. If test are done in a wall, the thickness of the joints should be about 10 mm and the joints shall be completely filled with mortar of strength class M2,5 with a strength ≤ 5 N/mm². If tests have been performed in walls with a mortar strength higher than M2,5 then the minimum mortar strength shall be given in the ETA. The walls may be lightly prestressed in vertical direction to allow handling and transportation of the wall.

The tests shall be carried out in the base material for which the plastic anchor is intended to be used:

- Solid clay bricks and sand-lime solid bricks with a compressive strength between 20 and 40 N/mm² shall be used in the tests.

A2.2.3 Base material group d

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

Table A.4 AAC conditions

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

(1) If the anchor manufacturer applies for autoclaved aerated concrete masonry units with f_{cm} > 8,0 N/mm² or reinforced components of autoclaved aerated concrete of strength > AAC 6 to be stated in the ETA, additional tests have to be performed for these compressive strengths.

Test member AAC blocks:
Testing of plastic anchors is carried out on single units or walls with units glued together. The walls may be lightly prestressed in vertical direction to allow handling and transportation of the wall.

Samples: Samples (cubes/cylinders) are taken from the test member for determination of the material characteristics (see Figure A.6).
(cube: 100 x 100 x 100 mm); (cylinder: diameter 100 mm, height 100 mm)

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

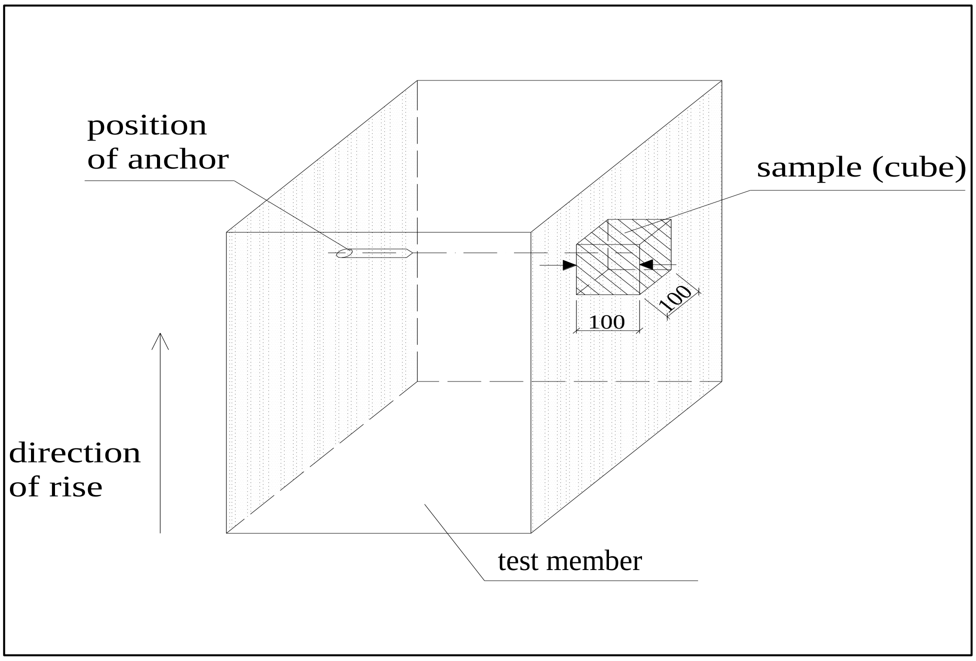


Figure A.6 Taking of samples

For determination of the material characteristics the following conditions apply:

Test member 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 member shall always be taken from series production. The direction of rise shall be discernible on the test member.

At the beginning of testing the test member shall be at least 4 weeks old. The moisture content of the concrete during the time of testing shall be ≤ 30 M% measured on the sample (cube/cylinder) or AAC block. The test member shall be stored in the testing laboratory or under comparable conditions such that air gains access on all sides. The clear distance between test member 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 plastic anchor setting (see Figure A.6).

A2.3 Anchor installation

The plastic anchors shall be installed in accordance with the installation instruction supplied by the manufacturer unless otherwise required in a specific test series.

In all tests screw-in-anchors shall be installed using a suitable screwgun. Nail-in-anchors shall be installed with a hammer having a reasonable hammer weight commonly used in the practical application.

The result of the test series “maximum torque moment (test series F8)” described in 2.2.5.10 or 2.2.6.10 may affect the installation of the anchor for other test series. Meaning, if the requirement listed in 2.2.5.10 or 2.2.6.10 is not fulfilled, the tension tests according to Annex A, Table A.1 and Table A.2 have to be carried out with anchors, that are installed with 1,3 · T_{inst}. Therefore, it is recommended that this test series is carried out at the beginning of the assessment.

If no other conditions are specified (as e.g. Table A.2), the holes are drilled with drill bits $d_{cut,m}$. The tension tests according to Annex A, Table A.1, A2-Tests can be performed with $d_{cut,m}$ or $d_{cut,max}$.

In case of concrete the tested plastic anchors shall be installed in the surface that has been cast against a form of the test member. Exception see section A2.5.9.

When testing in cracked concrete, plastic anchors are placed in the middle of hairline cracks. The anchor shall be installed with the most unfavourable expansion direction with respect to the direction of the crack opening. Details are specified in A2.5.

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

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

If hard metal hammer-drill bits are required, these bits shall meet the requirements of the standard ISO 5468 [8] with regard to dimensional accuracy, symmetry, symmetry of insert tip, height of tip and tolerance on concentricity.

The diameter of the cutting edges as a function of the nominal drill bit diameter is given in Figure A.7.

The diameter of the drill bit shall be checked every 10 drilling operations to ensure continued compliance.

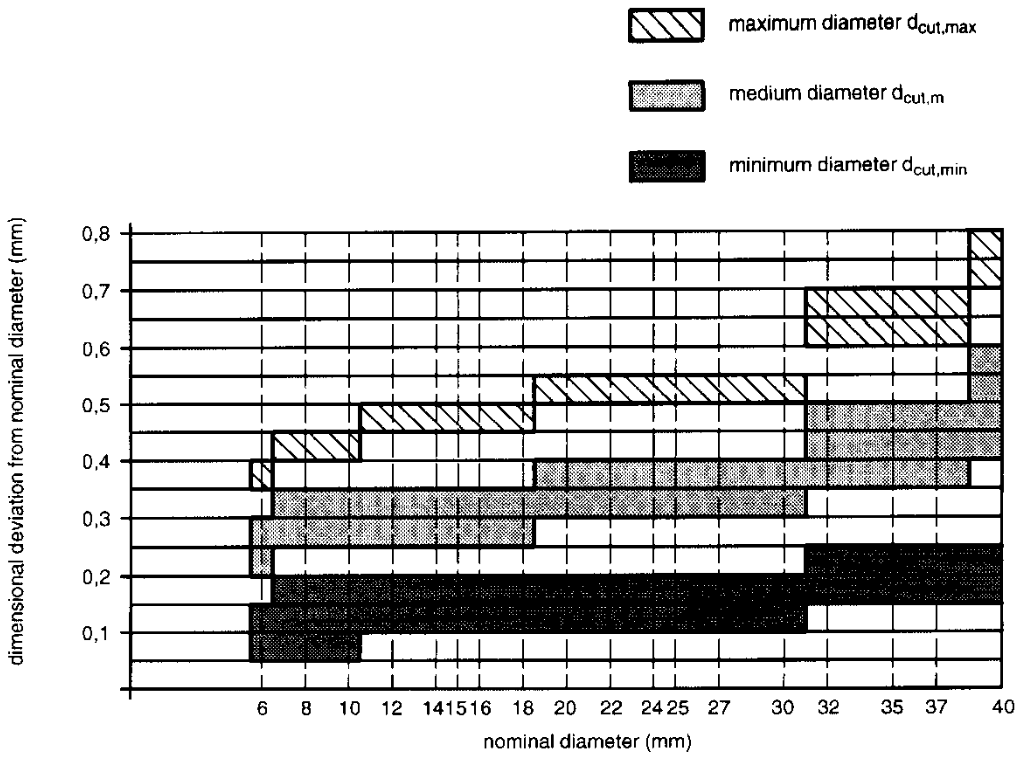


Figure A.7 Cutting diameter of hard metal hammer drill bits

A2.4 Test equipment

The plastic anchor shall be installed with a special fixture (see Figure A.8). The fixture shall guarantee the exact embedment depth of the plastic anchor. The fixture shall have the same form as the sleeve of the plastic anchor. All tests shall be performed with a diameter d_f of the clearance hole in the fixture as specified by the manufacturer e.g. external diameter of plastic anchors +0,5 mm.

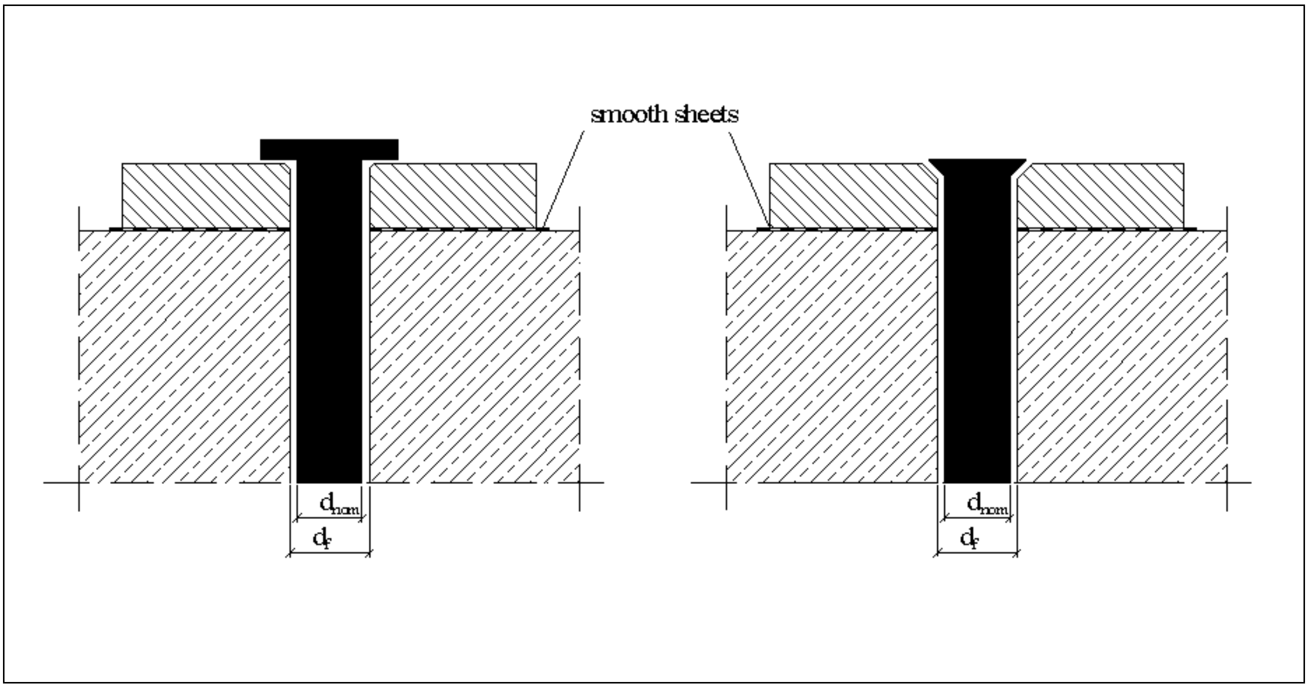


Figure A.8 Special fixture for tension tests with plastic anchors

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

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

In general, the test rigs shall allow the formation of an unrestricted rupture cone of the base material. For this reason the clear distance between the support reaction and a plastic anchor (single plastic anchor) shall be at least 2 h_{nom} (tension test) or 2 c_1 (shear tests with edge influence). In shear tests without edge influence where steel failure is expected the clear distance may be less than 2 c_1.

During tension tests (see A2.5.2) the load shall be applied concentrically to the plastic anchor. To achieve this, hinges shall be incorporated between the loading device and the plastic anchor. An example of the tension test rig is illustrated in Figure A.9.

In shear tests (see A2.5.8), the load shall be applied parallel to the surface of the base material. In general the height of the fixture shall be equal to the outside diameter of the plastic anchor. To reduce friction, smooth sheets (e.g. PTFE) with a maximum thickness of 2 mm shall be placed between the fixture and the test member.

An example of a shear test rig is illustrated in Figure A.10. As there is a lever arm between the applied load and the support reaction, this eccentricity moment shall be taken up by additional reaction forces placed sufficiently far away from the plastic anchor.

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

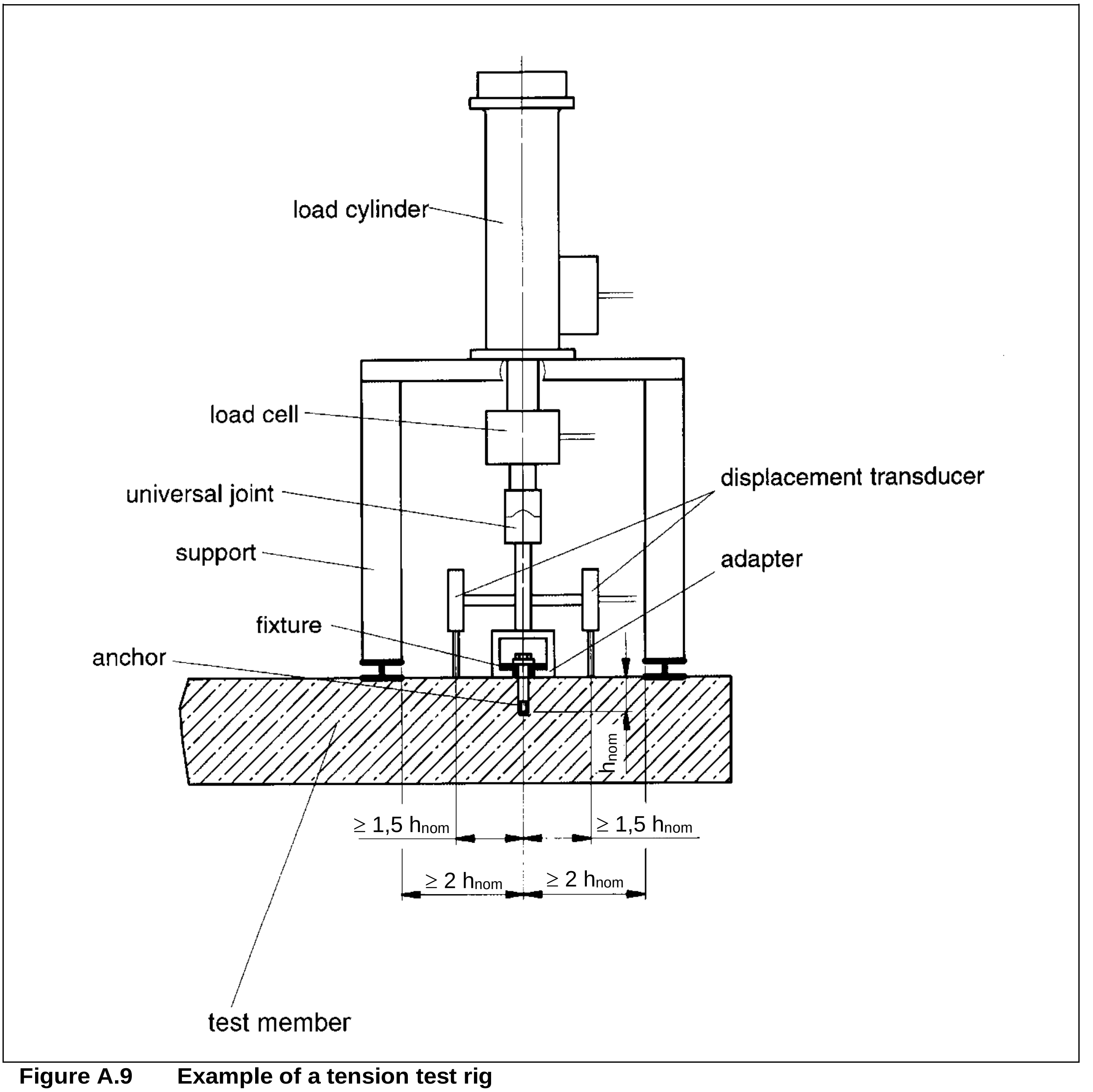


Figure A.9 Example of a tension test rig

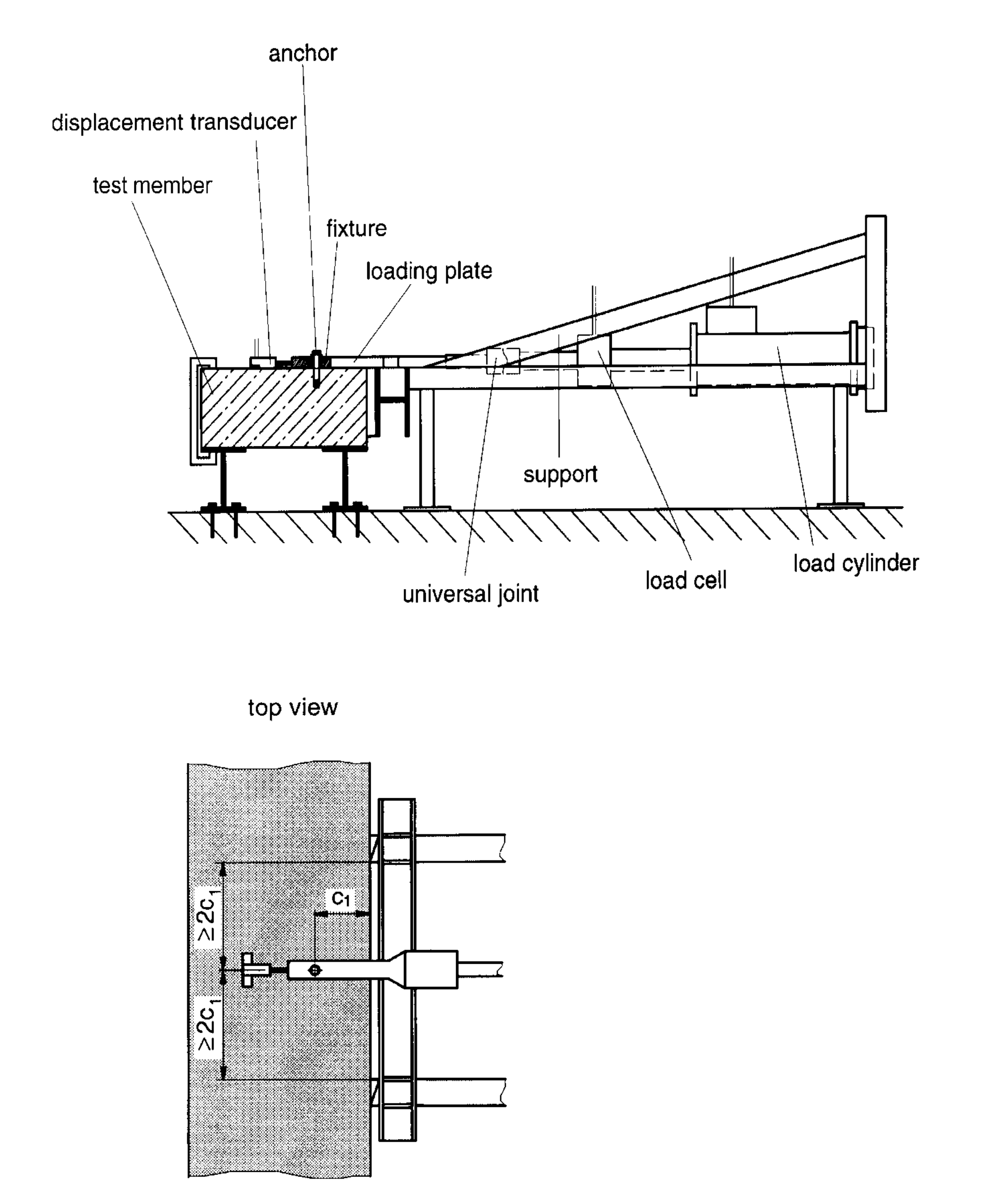


Figure A.10 Example of a shear test rig

A2.5 Test procedure

A2.5.1 General

If no other conditions are specified the tests shall be performed with anchor sleeves with a standard moisture content at normal ambient temperature (T = +21 ± 3 °C).

For the tests 3 different humidity levels are defined for the moisture condition of the polymeric material:

standard: equilibrium water content at T = +21 ± 3 °C and 50 ± 3 % relative humidity.

dry: equilibrium water content at T = +21 ± 3 °C and ≤ 10 % relative humidity.

wet: equilibrium water content after storing under water (wet condition means water saturated).

In general the tests are done with a standard conditioning of the plastic sleeve except in the functioning tests "Functioning under conditioning". For standard humidity the conditioning can be done according to ISO 1110 [9]. The dry conditioning can be reached by drying the plastic sleeve in an oven at +70 °C until the mass loss is smaller than 0,1 % in 3 consecutive measurements every 24 hours. The wet conditioning can be reached by placing the plastic sleeve under water until the mass increase is smaller than 0,1 % in 3 consecutive measurements every 24 h.

The tension tests in cracked concrete and cracked AAC shall be done with the most unfavourable expansion direction with respect to the direction of the crack opening. The worst expansion direction shall be derived either from the plastic anchor design or by tests in cracked concrete.

The tests in cracked concrete are performed in unidirectional cracks; the crack width measured close to the anchor shall be approximately constant throughout the member thickness. The plastic anchor has to be installed in closed hairline cracks. The crack width Δw is given in Table A.1 and Table A.2. Δw is the difference between the crack width when loading the plastic anchor and the crack width after installation. In general 5-10 min after the installation of the plastic anchor the crack is widened to the appropriate crack width while the plastic anchor is unloaded. The initial crack width at the start of loading the anchor shall be in a range in between ±10 % of the specified value. However, the mean value of a series shall reflect the specified value.

The time difference between crack opening and loading of anchor has to be between 10 minutes and 3 days for all tests in cracked concrete The functioning tests in cracked concrete according to Table A.2, line F3 and the corresponding reference tests in cracked concrete according to Table A.1, line A2 shall be performed approximately at the same time after crack opening, because the anchor resistance may increase with time after crack opening.

The crack width is controlled either:

(a) At a constant width, for example, by means of a servo system or
(b) Limited to a width close to the intended value by means of appropriate reinforcement and depth of the test member.

In both cases the crack width at the face opposite to that through which the plastic anchor is installed shall be maintained close to the specified value.

For tests in non-cracked concrete the anchor has to be loaded at least 10 minutes after installation except in the tests for relaxation. Suitability tests and corresponding reference tests shall be done approximately at the same time.

The load shall be increased in such a way that the peak load occurs after 1 to 3 minutes from commencement. Load and displacement shall be recorded either continuously or at least in about 100 intervals up to the peak load. The tests may be carried out with load or displacement control. In case of displacement control, then the test shall be continued up to at least 75 % of the maximum load to be measured (to allow the drop of the displacement curve) or at least up to 10 mm or 2 s_U displacement if the drop of the displacement curve is smaller than 75 %.

A2.5.2 Tension tests

After installation, the plastic anchor is connected to the test rig and loaded to failure. The displacements of the plastic anchor relative to the surface of the test member at a distance of ≥ 1,5 h_{nom} from the plastic anchor shall be measured by use of either one displacement transducer on the head of the plastic anchor or at least two displacement transducers on either side; the mean value shall be recorded in the latter case.

When testing plastic anchors at the corner of a test member, then the test rig shall be placed such that an unrestricted failure towards the corner is possible (see Figure A.11). It may be necessary to support the test rig outside the test member.

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

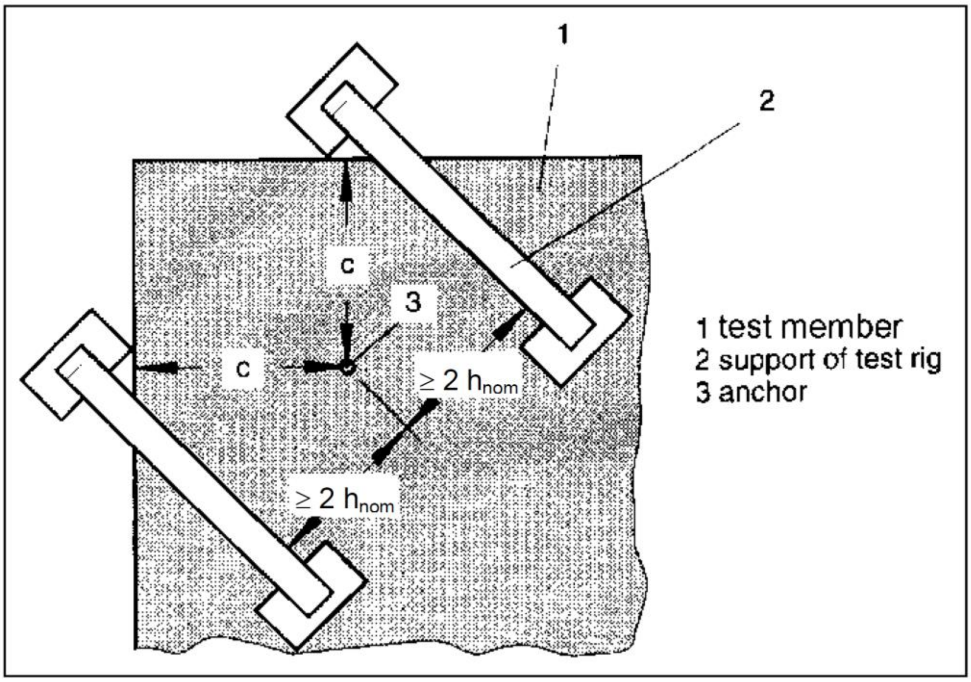


Figure A.11 Example of the test rig for tension tests on plastic anchors at a corner

A2.5.3 Setting capacity for nailed-in anchors (F1)

Nail-in-anchors shall be installed with a hammer having a reasonable hammer weight commonly used in the practical application. For Table A.2, F1-Tests: After complete setting of the anchor, an additional hammer blow (using a hammer with a reasonable weight) shall be carried out on the anchor.

A2.5.4 Temperature tests

The tests are carried out in slabs or, where space of the heating chamber is restricted, in cubes or in single masonry units. Splitting of the test member shall be prevented.

a) Tests at maximum long-term temperature or maximum short-term temperature:

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

- Temperature range a) with maximum short-term temperature up to +40 °C:

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

- Temperature range b) with maximum short-term temperature up to +80 °C:

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

- Temperature range c) on manufacturer's request:

Tests are performed with the maximum short-term temperature and the maximum long-term temperature as specified by the manufacturer according to 1.2.1 [range c)].

Install plastic anchors at normal ambient temperature according to the manufacturer's installation instructions. Raise the test member temperature to the required maximum long-term temperature or maximum short-term temperature at a rate of approximately 20 K per hour. Cure the test member at this temperature for 24 hours. While maintaining the temperature of the test member in the area of the plastic anchor at a distance of 1d from the concrete surface at ±2 K of the required value, carry out the tension test according to A2.5.2.

b) Tests at lowest service temperature min. ϑ:

After installation of the plastic anchors at normal ambient temperature raise the test member temperature to the maximum long-term temperature and keep the test member at this temperature for 4 days. After that cool the test member to the lowest service temperature min ϑ and carry out tension tests according to A2.5.2. Plastic anchors made out of polyamide have to be checked by pull-out tests only at the lowest service temperature min ϑ, if this lowest service temperature is less than -20 °C.

c) Tests at minimum installation temperature min. inst. ϑ:

The plastic anchor shall be installed at the lowest installation temperature (plastic anchor and base material) specified by the manufacturer within the range given in 1.2.1. After that cool the test member to the required minimum service temperature and carry out tension tests according to A2.5.2.

A2.5.5 Sustained load tests

The test is performed at normal temperature (ϑ = +21 ± 3 °C) for temperature range a), b) and c) and at maximum long-term temperature for temperature range b) and c) [ϑ = +50 ± 3 °C for temperature range b)].

The plastic anchor shall be installed at normal temperature.

The plastic anchor is then subjected to a load according to equation (A.5) which is kept constant (variation within ±5 %).

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

The tests will generally be carried out over at least 5000 hours for polymeric sleeves of PE, PP or other polymeric materials; however tests with at least 3000 hours are sufficient for polymeric sleeves of PA6 or PA6.6 based on current experience with this material.

$$N_P = 0{,}4 \cdot N_{Rk} \qquad \text{(A.5)}$$

with:
N_{Rk} = F_{Rk} = characteristic resistance of single anchor expected to be given in the ETA for the specific base material

The frequency of monitoring displacements shall be chosen so as to demonstrate the characteristics of the anchor. As displacements are greatest in the early stages, the frequency shall be high initially and reduced with time.

After completion of the sustained load test the plastic anchor shall be unloaded and the displacement shall be measured. Immediately after unloading a tension test shall be performed (residual capacity) at the corresponding test temperature.

A2.5.6 Relaxation tests

The plastic anchors are installed in the test member and left there unloaded for 24 hours and up to 500 hours. After that tension tests shall be carried out.

A2.5.7 Tests for determination of maximum torque moment

The plastic anchor shall be installed with a screw driver. The torque moment shall be measured with a calibrated torque moment transducer. The torque moment shall be increased until failure of the plastic anchor.
The torque moment is measured as a function of time. From the gradient of this curve two torque moments can be determined, the one if the screw is fully attached to the anchor collar (T_{inst}) and the maximum value (T_u) that can be applied to the plastic anchor.

A2.5.8 Shear tests

After installation, the plastic anchor is connected to the test rig without gap between the plastic anchor and the loading plate; it is then loaded to failure. The displacements of the plastic anchor relative to the base material shall be measured in the direction of the load application, for example by use of a displacement transducer fixed behind the plastic anchor (seen from the direction of load application) on the concrete (see Figure A.10).

A2.5.9 Test for determining minimum spacing and edge distance

Only for screwed in plastic anchors.

Base material group a:

The tests are carried out with double plastic anchors with a spacing $s = s_{min}$ and an edge distance $c = c_{min}$. The double anchors are placed on an uncast side of a concrete test member with a distance $a \geq 3\ h_{nom}$ between neighbouring groups. The dimensions of the fixture shall be width = 3 d_f, length = s_{min} + 3 d_f and thickness ≅ d_f.

The plastic anchors shall be installed according to the instructions of the manufacturer. Afterwards the anchors have to be torqued alternately in steps of about 0,2 $T_{inst,m}$ [$T_{inst,m}$ determined in the "Maximum torque moment test" (e.g. Table A.2, line F8)]. After each load step the concrete surface shall be inspected for cracks. The test is stopped when the torque moment cannot be increased further.

The number of revolutions per load step may be measured for both plastic anchors. Furthermore, the torque moment at the formation of the first hairline crack at one or both plastic anchors and the maximum torque moment that can be applied to the two anchors shall be recorded.

Other base material groups:

Tension tests shall be performed at the free edge of a unit (tests in units) or the wall (test in a wall) with an edge distance $c = c_{min}$.

A2.5.10 Test for checking durability of the polymeric sleeve

This shall be done for PA 6, PP, PE or other polymeric materials by the following tests:

Test specimen:

1. Manufactured of tension bars according to ISO 3167 [10].
2. Determination of the water content of the tension bars following ISO 3167 [10]. If the water content is higher than 0,1 percentage by weight, the slices have to be dried.
3. Drilling holes (diameter 2,8 mm) with a drill into the centre of the tension bars perpendicularly to the flat side of the specimen followed by rubbing the hole with a reamer (diameter 3,0 ± 0,05 mm).
4. Pressing a round pin (diameter according to Table A.5) quickly into tension bars.
5. Putting the tension bars into the different agents (see Table A.5 for number of necessary tension bars).
   - Water (reference tests):

     The tension bars with pins are stored under standard climate conditions in a container filled with condensed water. All specimens shall be completely covered for 2000 hours.

   - High alkalinity (pH = 13,2):

     The tension bars with pins are stored under standard climate conditions in a container filled with an alkaline fluid (pH = 13,2). All slices shall be completely covered for 2000 hours (T = +21 ℃ ± 3 ℃). The alkaline fluid is produced by mixing water with $Ca(OH)_2$ (calcium hydroxide) powder or tablets until the pH-value of 13,2 is reached. The alkalinity shall be kept as close as possible to pH 13,2 during the storage and not fall below a value of 13,0. Therefore the pH-value has to be checked and monitored at regular intervals (at least daily).
6. Visual analysis to observe cracks after storage with a microscope with a magnification ≥ 100.

The tests have to be carried out for each colour of the plastic anchor.

Table A.5 Necessary number of tests on tension bars with pins

line	Test description	Diameter of pins [mm]	water	High alkalinity
1	reference-test	3,0	5	-
2	high alkalinity test	3,5	-	5

A2.6 Test report

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

General

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

Test members

- Composition of concrete. Properties of fresh concrete (consistency, density)
- Date of manufacture
- Dimensions of control specimens, and/or cores (if applicable) measured value of compressive strength, and in case of AAC moisture content, at the time of testing (individual results and mean value)
- Dimensions of test member
- Nature and positioning of any reinforcement
- Direction of concrete pouring

Anchor installation

- Information on the positioning of the plastic anchor
- Distances of plastic anchors from edges of test member and between adjacent anchors
- Tools employed for plastic anchor installation, e.g. impact drilling tool, drilling hammer, other equipment, e.g. torque wrench, hand hammer
- Type of drill bit, manufacturer's mark and measured drill bit dimensions, particularly the effective diameter, d_{cut}, of the hard metal insert
- Information on the direction of drilling
- Information on cleaning of the hole
- Depth of drill hole
- Width of crack when installing the plastic anchor (where applicable)
- Overall anchor embedment depth in the base material (h_{nom})
- Tightening torque or other parameters for control of installation
- Number of impacts for setting the nailed–in anchor
- Displacement of plastic anchor at the applied torque moment (if measured)
- Quality and type of screws and nuts employed
- Length of thread engagement (where applicable)
- Type of attachment

Measured values

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

The above measurements shall be recorded for each test.

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

A3 General assessment methods

A3.1 Conversion of failure loads to nominal strength

Steel failure

In case of steel failure the failure load shall be converted to the nominal steel strength by equation (A.6)

$$F_{u\,(fuk)} = F^{t}_{u} \cdot \frac{f_{uk}}{f_{u,test}} \qquad (A.6)$$

with: $F_{u\,(fuk)}$ = failure load at nominal steel ultimate strength

Polymere failure

In case of steel failure the failure load shall be converted to the nominal steel strength by equation (A.6)

$$F_{u\,(fpol)} = F^{t}_{u} \cdot \frac{f_{pol}}{f_{pol,test}} \qquad (A.7)$$

with: $F_{u\,(fpol)}$ = failure load at nominal polymere strength

Base material group a

In case of pull out failure no conversion is necessary.

In case of concrete failure (concrete cone or splitting failure) equation (A.8) shall be used.

$$F_{u\,(fc)} = F^{t}_{u} \cdot \left(\frac{f_{c}}{f_{c,test}}\right)^{0,5} \qquad (A.8)$$

Base material group b and c

Solid masonry made of lightweight concrete and hollow/ perforated masonry

$$F_{u\,(fb)} = F^{t}_{u} \cdot \left(\frac{f_{b}}{f_{b,test}}\right) \qquad (A.9)$$

Base material group d

In case of AAC failure the failure load shall be converted as far as compressive strength and dry density are concerned.

For AAC blocks the characteristic compressive strength shall be determined from the declared value of compressive strength according to EN 771-4 [5] using the factor of 0,9.

$$f_{ck} = 0{,}9 \cdot f_{c,decl} \qquad (A.10)$$

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

As reference values of dry density the following minimum values of dry density shall be used for AAC for conversion of the test results:

low strength AAC: ρ_{min} = 350 kg/m^3

high strength AAC: ρ_{min} = 650 kg/m^3

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

$$F^{tk}_u = F^t_u \cdot \frac{\rho_{min}^{3/4} \cdot f_{ck}}{\rho_{test}^{3/4} \cdot f_{c,test}} \quad [kN] \qquad (A.11)$$

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

A3.2 Criteria regarding scatter of failure loads

In each test series, the coefficient of variation of the ultimate load shall be smaller than v = 15 % in the basic tests (see Table A.1) and v = 20 % in the functioning tests (see Table A.2).

If the coefficient of variation of the ultimate load in the basic tests is greater than 15 %, then the following α_V-value has to be taken into account:

$$\alpha_V = \frac{1}{1 + 0{,}03 \cdot (v[\%] - 15)} \leq 1{,}0 \qquad (A.12)$$

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

$$\alpha_V = \frac{1}{1 + 0{,}03 \cdot (v[\%] - 20)} \leq 1{,}0 \qquad (A.13)$$

A3.3 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 %. If a precise verification does not take place, a normal distribution and an unknown standard deviation of the population shall be assumed.

$$F_{5\%} = F_m \cdot (1 - k_s \cdot v) \qquad (A.14)$$

eg.:

n = 5 tests: $k_s = 3{,}40$

n = 10 tests: $k_s = 2{,}57$

A3.4 Determination of reduction factors α

The factor α shall be larger or equal than the req α given in Table A.2.

$$\alpha = \min\left(\frac{N^t_{u,m}}{N^r_{u,m}};\frac{N^t_{u,5\%}}{N^r_{u,5\%}}\right) \geq \text{req. } \alpha \qquad \text{(A.15)}$$

with:

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

$N^r_{u,m}$; $N^r_{u,5\%}$ = mean value or 5 %-fractile, respectively, of failure loads in the reference tests [e.g. for base material group a: tests for characteristic resistance / reference according to Table A.1, line A1 (basic tests in non-cracked concrete) or line A2 (basic tests in cracked concrete)].

$\frac{N^t_{u,5\%}}{N^r_{u,5\%}}$ is based on test series with a comparable number of test results in both series.

If the number of tests in the two series is very different $\frac{N^t_{u,5\%}}{N^r_{u,5\%}}$, may be omitted when the coefficient of variation of the test series is smaller than or equal to the coefficient of variation of the reference test series or if the coefficient of variation in the functioning tests is v ≤ 15 %.

If the criterion for the required value of α (see Table A.2) is not met in a test series, then the factor α_2 shall be calculated.

$$\alpha_2 = \frac{\alpha}{\text{req. } \alpha} \leq 1{,}0 \qquad \text{(A.16)}$$

with:

α = lowest value according to equation (A.15) in the test series

req.α = required value of α according to Table A.2

A3.5 Criteria for uncontrolled slip under tension loading

The load-displacement curves shall show a steady increase (see Figure A.12). A reduction in load and/or a horizontal or near-horizontal part in the curve caused by uncontrolled slip of the anchor is not acceptable up to a load of:

$$N_1 = 0{,}4 \cdot N_u \qquad \text{(A.17)}$$

If the requirements on the load-displacement behaviour are not fulfilled by the tension tests according to A2.5.2, then the factor α_1 shall be calculated.

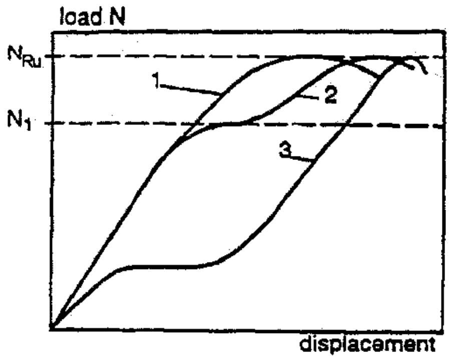
$$\alpha_1 = \frac{N_1}{0{,}4 \cdot N_u} \leq 1{,}0 \qquad \text{(A.18)}$$

with:

α = lowest ratio N_1/N_u in the test series

N_1 = load at which uncontrolled slip of the anchor occurs (see Figure A.12)

N_u = failure load in that test



Curve 1: steady increase of the load displacement curve

Curve 2 and Curve 3: uncontrolled slip at level N_1

Figure A.12 load-displacement curve

A3.6 Overcoming friction

The load at overcoming friction corresponds to the load at loss of adhesion ($N_{u,adh}$).

$N_{u,adh}$ shall be evaluated for every test from the measured load displacement curve.

The load at overcoming friction is characterised by a significant change of stiffness, see Figure A.13. If the change in stiffness at a defined load is not so obvious, e.g. the stiffness is smoothly decreasing, the load at overcoming friction shall be evaluated as follows:

1) Compute the tangent to the load-displacement curve at a load 0,3 N_u (N_u = peak load in test). The tangent stiffness can be taken as the secant stiffness between the points 0/0 and 0,3 $N_u/\delta_{0,3}$ ($\delta_{0,3}$: displacement at N = 0,3 N_u).
2) Divide the tangent stiffness with a factor of 1,5.
3) Draw a line through the point 0/0 with the stiffness as calculated in 2).
4) The point of intersection between this line and the measured load-displacement curve gives the load $N_{u,adh}$ where the friction is overcome, see Figure A.14.
5) If there is a peak in the load-displacement curve, to the left side of this line, which is higher than the load at intersection, $N_{u,adh}$ is taken as the peak load, see Figure A.15.
6) If there is a very stiff load-displacement curve at the beginning ($\delta_{0,3} \leq$ 0,05 mm) the drawing of the line for the calculation can be shifted to the point (0,3 N_u / $\delta_{0,3}$), see Figure A.16.

Examples of load-displacement curves

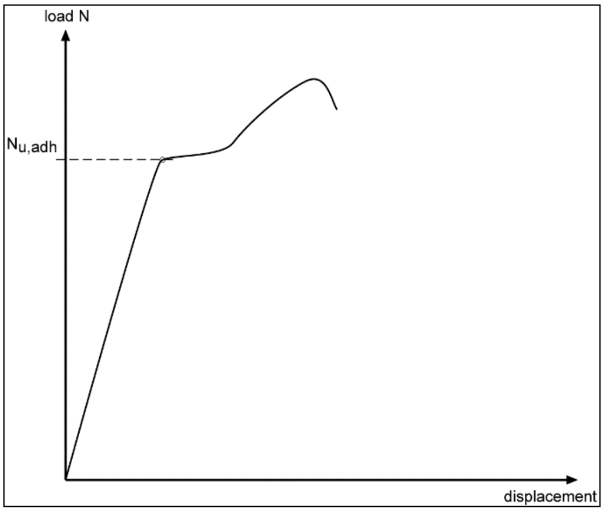


Figure A.13

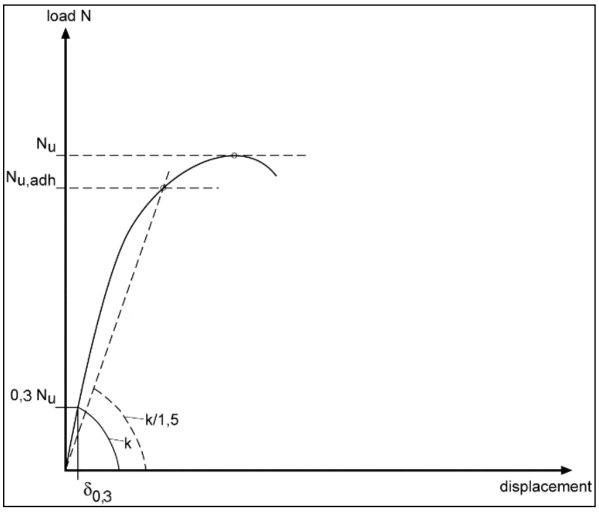


Figure A.14

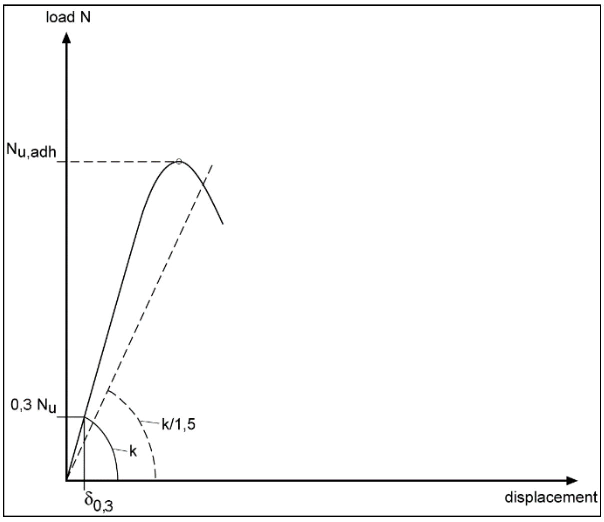


Figure A.15

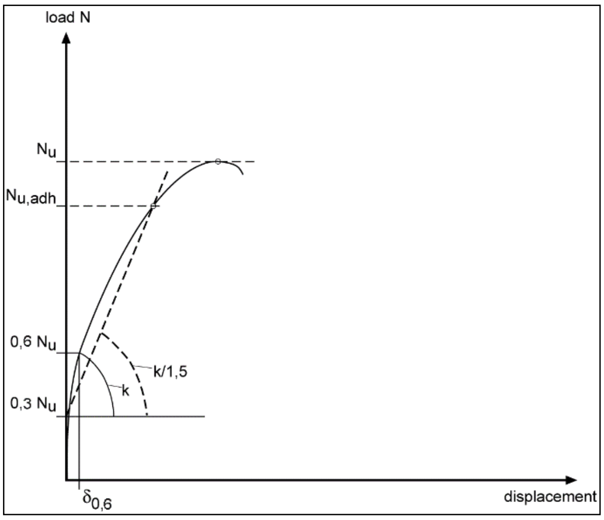


Figure A.16