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EAD 330012-01-0601

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European Assessment Document for

Cast-in anchors with internal threaded socket

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

This EAD covers cast-in anchors with internal threaded socket (in the following referred to as cast-in anchors) for the assessment of such anchors embedded in concrete according to EN 206 [12][1]. The cast-in anchor is anchored by bonding and mechanical interlock.

The cast-in anchor consists of an internal threaded socket made of metal which is anchored by a ribbed reinforcement bar (Figure 1.1.1 a), a steel rod placed through a hole in the socket (Figure 1.1.1 b) or by interlock activated by a deformed section of the socket (Figure 1.1.1 c).

This EAD covers also "headed anchors" which consist of a socket and an anchor element according to Figure 1.1.2 (headed stud made of reinforcing bar or headed stud or hexagonal bolt). The socket is connected with the anchor element by pressing, welding or screwing.

The socket and the steel rod are made of carbon steel or stainless steel.

The ribbed reinforcement bar is made of reinforcing steel with the following characteristics:

• Tensile yield strength:	$R_e \geq 500$ N/mm²
• Stress ratio (maximum strength/ tensile yield strength):	$R_m/R_e \geq 1{,}08$
• Elongation at maximum load:	$A_{gt} \geq 0{,}05$
• Bonding strength (relative rib area):	$f_R \geq 0{,}045$ (for d = 6,5 – 8,5 mm) $f_R \geq 0{,}052$ (for d = 9,0 – 10,5 mm) $f_R \geq 0{,}045$ (for d =11,0 – 28,0 mm)
• Bendability:	according to EN ISO 15630-1 [13] with mandrel diameter d_m = 5d (for d = 8 – 12 mm) d_m = 6d (for d = 14 – 16 mm) d_m = 8d (for d = 16 – 25 mm) d_m = 10d (for d = 28 mm)
• Weldability:	according to EN ISO 17660-1 [14], Table 2
• Sections and tolerances on sizes:	A_s=0,28-6,16 cm² and sectional area ≥ 0,96 A_s

The socket is made of steel tubes according to EN 10305-1/-2/-3 [6], EN 10088-3 [3], or EN 10216-5 [7], EN 10217-7 [8].

The anchor can be provided with a plastic clip to fix supplementary reinforcement (see component 3 in Figure 1.1.3).

Configurations of components and corresponding material are as follows:

(1) The anchor parts are made of carbon steel with an optional zinc coating of at minimum 5 μm (e.g., electroplated).
(2) The anchor parts are made of hot dip galvanised carbon steel according EN ISO 1461 [17] or EN ISO 10684 [18] with a minimum thickness of 50 μm.
(3) The anchor parts are made of stainless steel according EN 1993-1-4 [11], Annex A.
(4) Socket made of stainless steel according EN 1993-1-4 [11], Annex A, and the anchor element made of carbon steel is pressed on the anchor made of ribbed reinforcement bar (see Figure 1.1.1 a) or Figure 1.1.2 with coating inside of the socket on top of the bar. The coating is non-aging in the sense of A.3.

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

This EAD covers anchors with a minimum embedment depth in the concrete member h_{nom} = 50 mm.

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

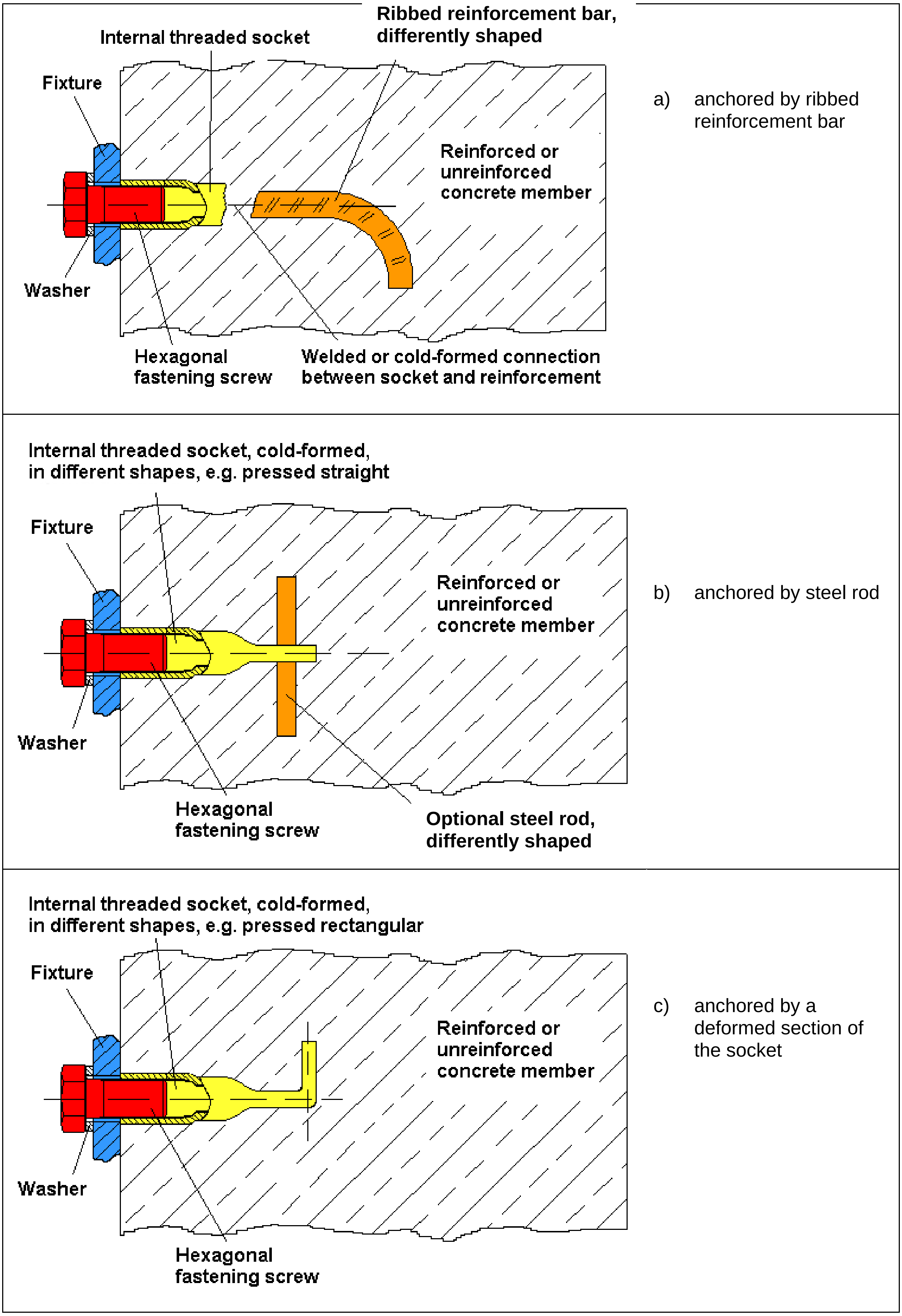
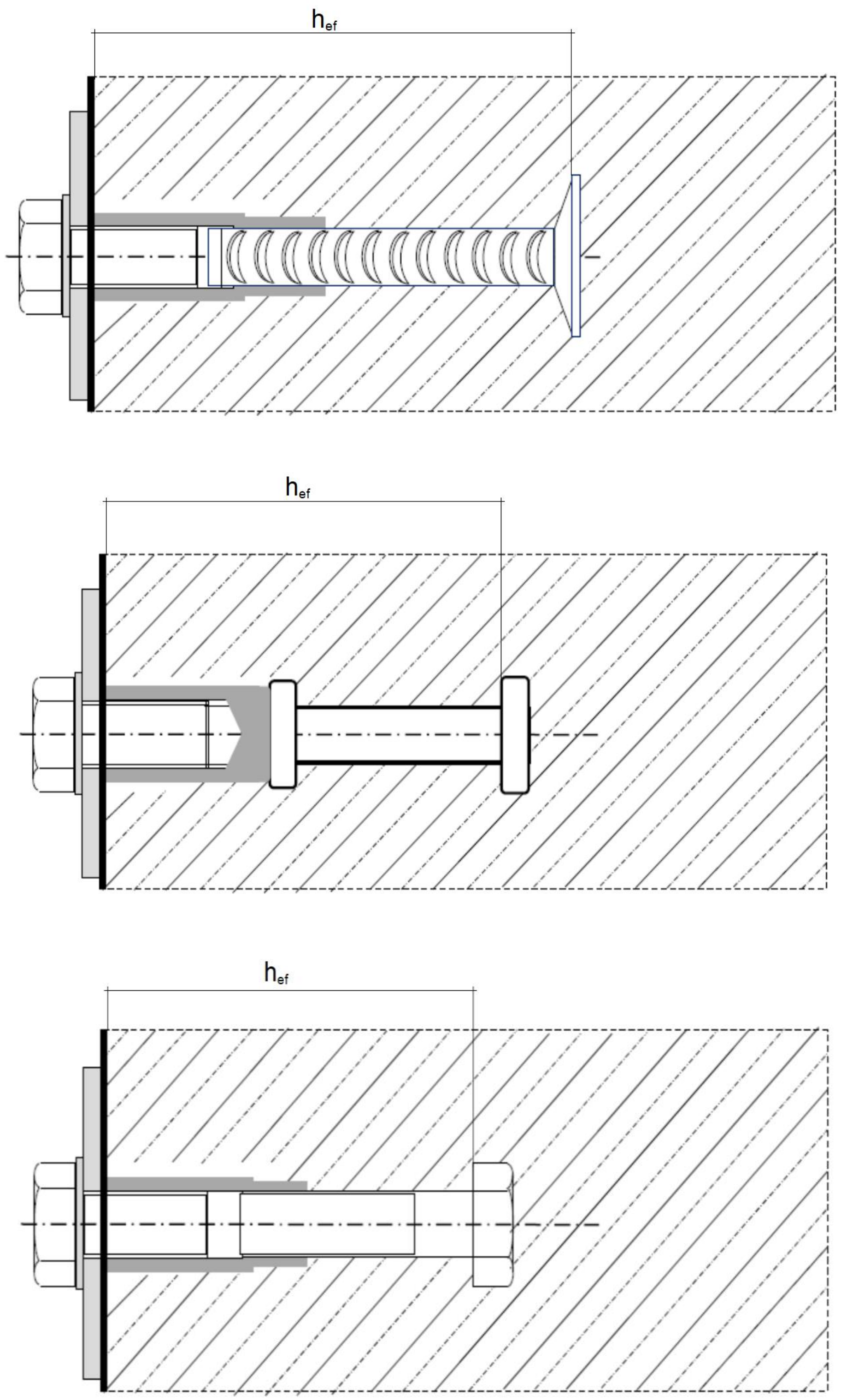


Figure 1.1.1 Examples for internal threaded socket differently anchored in assembled state

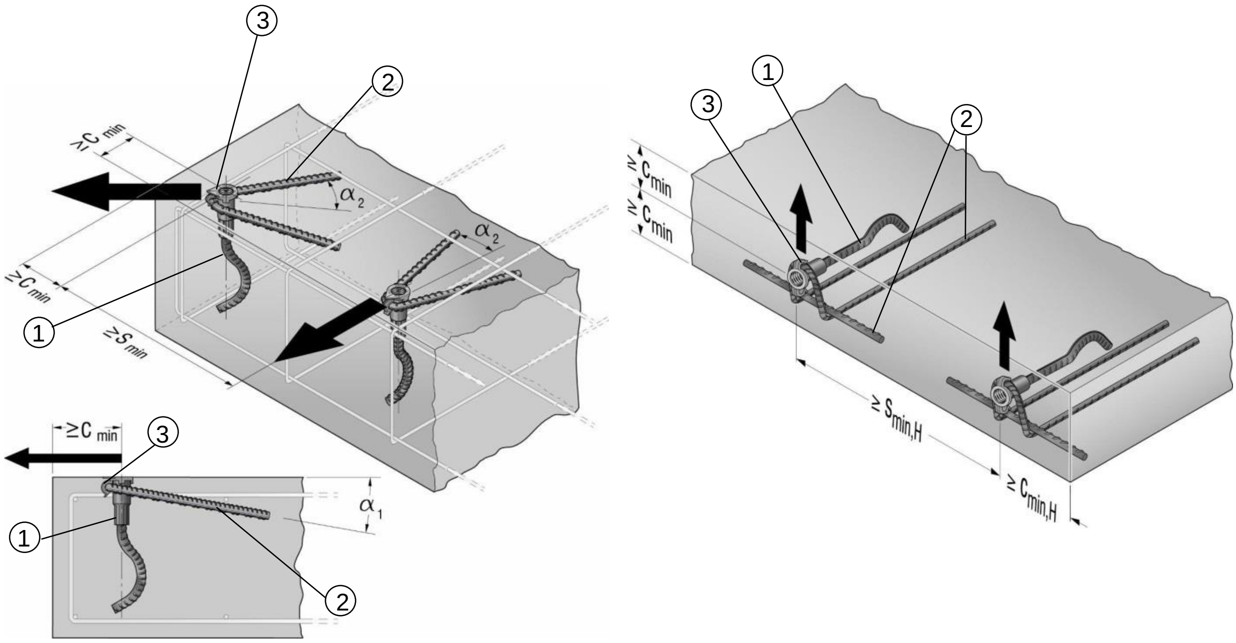


Example with pressed-on headed bolt made of reinforcing bar

Example with welded headed stud

Example with screwed-in hexagon bolt

Figure 1.1.2 Example for headed anchor



a) Plane installation b) Front-side installation

1 Anchor with socket

2 Supplementary reinforcement

3 Plastic clip to fix supplementary reinforcement

Figure 1.1.3 Example for supplementary reinforcement

The product is not fully covered by EAD 330012-00-0601.

In comparison to EAD 330012-00-0601, new essential characteristics and assessments methods are added related to:

- Characteristic resistances for steel and concrete failure for seismic performance categories C1 and C2 wherein performance category C1 includes tests with anchors in concrete with crack width of 0,5 mm and both pulsating tension and alternating shear. Performance category C2 includes tests with crack width of mostly 0,8 mm and both pulsating tension and alternating shear as well as tension load under varying crack width.

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(s) of the construction product

1.2.1 Intended use(s)

The cast-in anchor with internal threaded socket is intended to be used:

- in reinforced and unreinforced normal weight concrete according to EN 206 [12] with strength classes of C20/25 to C90/105,
- in cracked or uncracked concrete,
- for static and quasi-static actions,
- for seismic performance categories C1 and C2,
- for transmission of tensile loads, shear loads or a combination of both,
- surface-flush or sunk in the concrete member,
- in the temperature range -40°C to +80°C.

Depending on the materials used for the cast-in anchor the anchor is used in structures subjected to the following categories:

(1) Material and components comply with clause 1.1, (1):
Cast-in anchors intended for use in structures subject to dry, internal conditions

(2) Material and components comply with clause 1.1, (2):
Cast-in anchors for use in structures subject to internal conditions with usual humidity (e.g., kitchen, bath and laundry in residential buildings, exceptional permanently damp conditions and application under water)

(3) Material and components comply with clause 1.1, (3, 4):
Cast-in anchors made of stainless steel according EN 1993-1-4 [11], Annex A, Tables A.3 and A.4, are considered to have sufficient durability for the corresponding Corrosion Resistance Class (CRC).

The fixture is assembled to the cast-in anchor with a fastening screw and washer or a threaded rod, a washer and a nut. In this EAD the assessment is made to determine performance of cast-in anchor with threaded socket which can be used for design according to EN 1992-4 [5].

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the product for the intended use of 50 years when installed in the works (provided that the product 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

1.3.1 Abbreviations

C1	=	seismic performance category C1 (use in design according to EN 1992-4 [5])
C2	=	seismic performance category C2 (use in design according to EN 1992-4 [5])

1.3.2 Notation

A_{gt}	=	Elongation at maximum load
A_s	=	stressed cross-section of the anchor used for determining the tensile capacity
$A_{s,s}$	=	Cross-section of reinforcement bar (socket)
A_5	=	fracture elongation
a_w	=	Thickness of the welding
c_1	=	edge distance in direction 1
c_2	=	edge distance in direction 2
$c_{cr,N}$	=	edge distance for ensuring the transmission of the characteristic resistance in tension of a single anchor without edge and spacing effects in case of concrete cone failure
$c_{cr,sp}$	=	edge distance for ensuring the transmission of the characteristic resistance in tension of a single anchor without edge and spacing effects in case of splitting failure
c_{min}	=	minimum edge distance
$c_{min,t}$	=	minimum edge distance in a test series
cv_F	=	coefficient of variation [%] related to loads
cv_δ	=	coefficient of variation [%] related to displacements
d	=	anchor bolt / thread diameter
d_0	=	drill hole diameter
d_m	=	Mandrel diameter
d_{nom}	=	outside diameter of anchor
$F_{u,m,t}$	=	mean failure load in a test series
$F_{u,m,r}$	=	mean failure (ultimate) load in a reference test series
$F_{u,m}$	=	mean failure(ultimate) load of a test series
f_{bd}	=	design bond strength of rebar
f_c	=	concrete compressive strength measured on cylinders
$f_{c,t}$	=	compressive strength of concrete at the time of testing
f_{ck}	=	nominal characteristic concrete compressive strength (based on cylinder)
f_R	=	relative rib area of reinforcing bar for bonding strength
$f_{u,t}$	=	ultimate tensile steel strength of the batch for the tested anchor
f_{uk}	=	nominal characteristic steel ultimate strength as specified in the technical specification of the manufacturer for the anchor
f_{yk}	=	nominal characteristic steel yield strength as specified in the technical specification of the manufacturer for the anchor
h_{ef}	=	effective embedment depth
h_{min}	=	minimum thickness of concrete member

h_{nom}	=	overall anchor embedment depth in the concrete
k_s	=	Owen factor for determination of the fractile value
k_7	=	Ductility factor
k_8	=	factor for resistance to pry-out failure
L	=	largest size of the complete product range of each anchor type as supplied to the market
l_f	=	effective length of the anchor for transfer of shear load
m	=	medium size of the complete product range of each anchor type as supplied to the market
$M^0_{Rk,s}$	=	characteristic bending moment
$M^0_{Rk,s,fi}$	=	characteristic bending moment under fire exposure
N	=	normal force (+N = tension force)
N_p	=	Permanent tensile load in a test
$N_{p0,2}$	=	yield strength
$N_{Rd,s}$	=	design steel resistance
$N_{Rk,c}$	=	characteristic resistance to concrete cone failure
$N_{Rk,p}$	=	characteristic resistance to pull-out failure
$N_{Rk,p,C1}$	=	characteristic resistance to pull-out failure for seismic performance category C1
$N_{Rk,p,C2}$	=	characteristic resistance to pull-out failure for seismic performance category C2
$N_{Rk,p,fi}$	=	characteristic resistance to pull-out failure under fire exposure
$N_{Rk,s}$	=	characteristic resistance to steel failure
$N_{Rk,s,C1}$	=	characteristic resistance to steel failure for seismic performance category C1
$N_{Rk,s,C2}$	=	characteristic resistance to steel failure for seismic performance category C2
$N_{Rk,s,fi}$	=	characteristic resistance to steel failure under fire exposure
$N_{Rk,0}$	=	5% fractile of the failure loads from the test series according to Table A.1.1.1, lines 1 to 2, for uncracked concrete or according to Table A.1.1.1, lines 3 and 4, for cracked concrete
N_{sl}	=	load at which uncontrolled slip of the anchor occurs
$N_{u,m}$	=	mean ultimate tensile load of the tests in concrete
$N_{u,5\%}$	=	5% fractile of the failure loads in a test series
$N_{1,3Tinst,m}$	=	mean value of tension force generated by torque of 1,3 T_{inst}
$N_{1,3Tinst,95\%}$	=	95% fractile of tension force generated by torque of 1,3 T_{inst}
$N^0_{Rk,sp}$	=	characteristic resistance to concrete splitting failure under tension load (initial values)
n	=	number of tests of a test series
R_e	=	tensile yield strength
R_m	=	maximum tensile strength
rqd. α	=	required value of α according to Table A.1.2.1.1
$s_{cr,N}$	=	spacing for ensuring the transmission of the characteristic resistance in tension of a single anchor without edge and spacing effects in case of concrete cone failure
$s_{cr,sp}$	=	spacing for ensuring the transmission of the characteristic resistance in tension of a single anchor without edge and spacing effects in case of splitting failure
s_{min}	=	minimum allowable spacing

$s_{min,t}$ = minimum spacing in a test series

T = torque

T_{inst} = required or maximum recommended setting torque specified by the manufacturer for expansion, installation or pre-stressing of anchor

V = shear force

V_{Rk} = characteristic resistance to shear failure

$V_{Rk,c}$ = characteristic resistance in case of concrete pry-out failure under shear load

$V_{Rk,c,re}$ = characteristic resistance in case of concrete pry-out failure with supplementary reinforcement under shear load

$V_{Rk,re}$ = characteristic resistance of reinforcement under shear load

$V_{Rk,s}$ = characteristic resistance to steel failure under shear load

$V_{Rk,s,C1}$ = characteristic resistance to steel failure for seismic performance category C1

$V_{Rk,s,C2}$ = characteristic resistance to steel failure for seismic performance category C2

$V_{Rk,s,fi}$ = characteristic resistance to steel failure under fire exposure

$V_{Rk,c,re}$ = resistance to concrete edge failure with supplementary reinforcement

W_{el} = elastic section modulus

α = reduction factor according to B.4

α_{gap} = reduction factor for annular gap of the fixture

α_p = factor for reduced load in functioning tests with crack cycling or repeated load

α_1 = reduction factor for uncontrolled slip according to B.5

$ß_{cv}$ = reduction factor for large scatter according to B.2

γ_F = partial factor for actions

γ_M = recommended material partial safety factor according to EN 1992-4

γ_{Ms} = Partial factor for steel according to EN 1992-4

$\delta_{0,5Nu,m}$ = displacement of the anchor at 50% of the mean failure load in a test series

$\delta_{N,C2}$ = displacement under tension load for seismic performance category C2

δ_{N0} = short term displacement under tension load

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

$\delta_{V,C2}$ = displacement under shear load for seismic performance category C2

δ_{V0} = short term displacement under shear load

$\delta_{V\infty}$ = long term displacement under shear load

Δw = required crack width, in addition to the initial hairline crack width as measured continuously during the test

$\Delta\sigma_s$ = working stroke of action in repeated load tests

1.3.3 Indices

cr = cracked concrete

fi = fire

r = reference tests

t = tested result

u = ultimate – situation when failure occurs

ucr	=	uncracked concrete
20	=	related to concrete strength class C20/25
50	=	related to concrete strength class C50/60

1.3.4 Definitions

fixture	=	component fixed to the concrete with the use of anchors
test member	=	concrete member in which the anchor is tested

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of the cast-in anchors is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of cast-in anchors with internal threaded socket and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
Characteristic values for tension loading under static and quasi-static actions and displacements			
1	Resistance to steel failure for tension loading	2.2.1	Level $N_{Rk,s}$ [kN]
2	Resistance to pull-out failure	2.2.2	Level $N_{Rk,p}$ [kN]
3	Resistance to concrete cone failure	2.2.3	Level h_{ef} [mm]
4	Resistance to splitting and edge distance to prevent splitting and blow-out failure	2.2.4	Level $N^0_{Rk,sp}$ [kN], $c_{cr,sp}$, [mm]
5	Minimum edge distance and spacing	2.2.5	Level c_{min}, s_{min}, h_{min} [mm]
6	Maximum torque moment	2.2.6	Level T_{inst} [Nm]
7	Displacements for tension loading	2.2.7	Level δ_{N0}, $\delta_{N\infty}$ [mm]
Characteristic values for shear loading under static and quasi-static actions and displacements			
8	Resistance to steel failure for shear loading	2.2.8	Level $V_{Rk,s}$ [kN], $M^0_{Rk,s}$ [Nm], k_7 [-]
9	Resistance to concrete edge failure without supplementary reinforcement	2.2.9	Level l_f, d_{nom} [mm]
10	Resistance to concrete edge failure with supplementary reinforcement	2.2.10	Level $V_{Rk,c,re}$ [kN]
11	Resistance to pry-out failure	2.2.11	Level k_8 [-]
12	Displacements for shear loading	2.2.12	Level δ_{V0}, $\delta_{V\infty}$ [mm]
Characteristic values for seismic performance categories C1 and C2 and displacements			
13	Resistance to tension load for seismic performance category C1	2.2.13	Level $N_{Rk,s,C1}$, $N_{Rk,p,C1}$ [kN]
14	Resistance to tension load for seismic performance category C2	2.2.14	Level $N_{Rk,s,C2}$, $N_{Rk,p,C2}$ [kN], $\delta_{N,C2}$ [mm]
15	Resistance to shear load for seismic performance category C1	2.2.15	Level $V_{Rk,s,C1}$ [kN],
16	Resistance to shear load for seismic performance category C1	2.2.16	Level $V_{Rk,s,C2}$ [kN], $\delta_{V,C2}$ [mm]
Basic Works Requirement 2: Safety in case of fire			
17	Reaction to fire	2.2.17	Class
18	Resistance to fire	2.2.18	Level $N_{Rk,s,fi}$, $N_{Rk,p,fi}$, $V_{Rk,s,fi}$ [kN], $M^0_{Rk,s,fi}$ [Nm]

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.

2.2.1 Resistance to steel failure for tension load

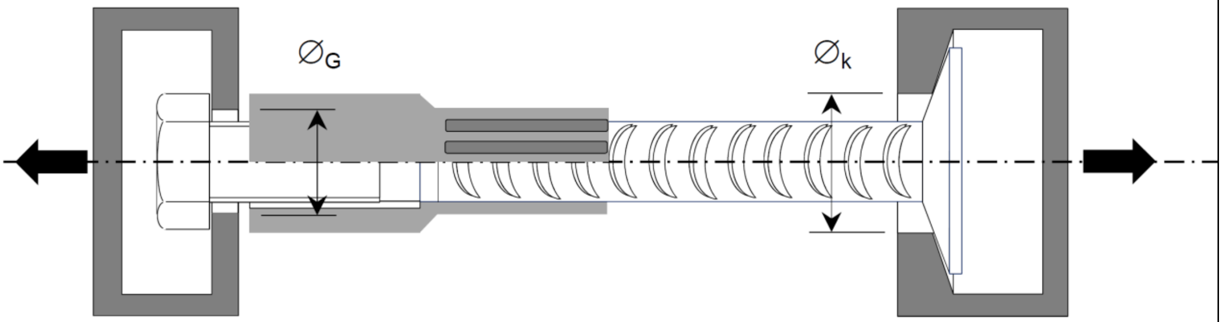
Purpose of the test

The intention of the tests is the determination of the characteristic resistance to steel failure for headed anchors with a pressed-on, welded or screwed-in socket according to Figure 1.1.2. For other types of anchors the resistance to steel failure shall be calculated.

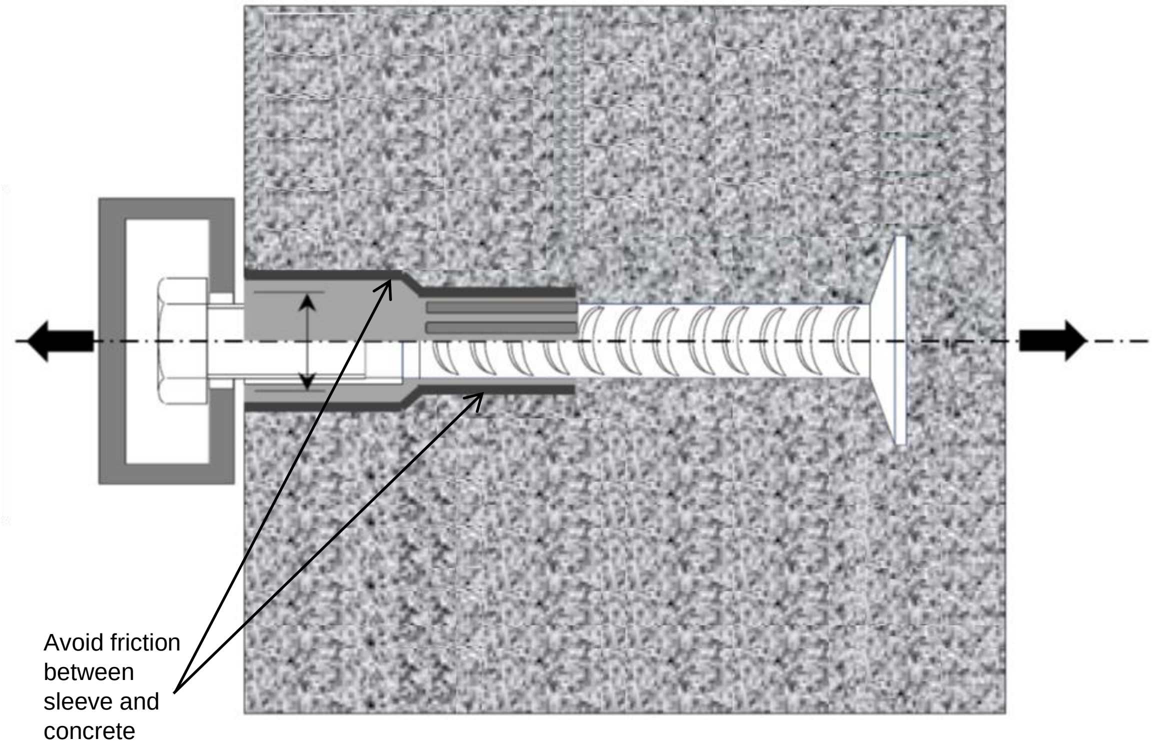
Test conditions

Test series according to Table A.1.1.1, line 8

Perform at least 3 steel tension tests with the finished product. Tests shall be performed with all sizes and each material combination. The tests may be performed with higher steel strength of the screw to avoid steel failure of the screw.



a) Clamped situation (no concrete necessary): Avoid any eccentricity of the clamp



b) Cast-in situation (easier for centred load transfer)

M ≤ 24: $\varnothing_G$ = M + 2 mm	**$\varnothing_k$ = 1,7 ϕ**
M > 24: $\varnothing_G$ = M + 3 mm	**ϕ = nominal diameter of rebar**

Figure 2.2.1.1 Examples for test setup in tests for steel failure

Perform 10^5 load cycles with a maximum frequency of approximately 6 Hz. During each cycle the load shall change as a sine curve between maximum and minimum value, i.e., max N and min N.

The maximum and minimum load during the load cycles are given as:

$$\max N = 0{,}8 \cdot A_s \cdot f_{yk} \text{ [N]} \qquad (2.2.1.1)$$

$$\min N = \max N - A_s \cdot \Delta\sigma_s \text{ [N]} \qquad (2.2.1.2)$$

with

$$A_s \cdot f_{yk} = \min \begin{cases} A_{s,socket} \cdot f_{yk,socket} \\ A_{s,rebar} \cdot f_{yk,rebar} \\ A_{s,screw} \cdot f_{yk,screw} \end{cases}$$

$\Delta\sigma_s$ = 120 N/mm²

After completion of the load cycles a tension test to failure shall be performed. For cast-in test setup concrete breakout may be avoided by confined support. Record the maximum tension load (failure load = residual tension capacity), the corresponding displacement, and plot the load-displacement response.

If failure during cycling occur these tests have to be repeated with a reduced load max N_{red} until no failure during cycling occurs.

Assessment

Determine the minimum of the products cross section A_s multiplied with the corresponding minimum of the material properties for each part of the anchor (fastening screw; socket; anchor element) according to equation (2.2.1.3) and compare the results. The smallest result is decisive for the determination of characteristic resistance to steel failure according to equation (2.2.1.4).

The strength class(es) of the fastening screw shall be given in the ETA.

$$\min [A_{s,i} \cdot \min(f_{yk,i} / 1,2 \; ; f_{uk,i} /1,4)] \quad [N] \quad (2.2.1.3)$$

$A_{s,i}$ = cross section of one steel part (fastening screw, socket, anchor element)

$f_{yk,i}$ = corresponding yield strength of that part

$f_{uk,i}$ = corresponding tensile strength of that part

$$N_{calc} = A_s \cdot f_{uk} /1000 \quad [kN] \quad (2.2.1.4)$$

A_s = cross section of the decisive steel part

f_{uk} = tensile strength of the decisive steel part

<u>For tested anchors according to Figure 1.1.2</u>

For each test series determine the 5% fractile of failure loads $N_{u,5\%t}$ and compare with N_{calc} as defined in equation (2.2.1.4). Specify the characteristic resistance to steel failure: the minimum of tested and calculated result for each size and material combination is decisive.

If failure during cycling occurred $N_{Rk,s}$ has to be reduced by factor max Nred/ max N.

$$N_{Rk,s} = \min [N_{calc} \; ; N_{u5\%t}] \cdot \max N_{red} / \max N \quad [kN] \quad (2.2.1.5)$$

N_{calc} = calculated characteristic resistance of the decisive steel part

$N_{u5\%t}$ = 5% fractile of residual tension capacity after cycling test

max N = maximum load for cycling

max N_{red} = reduced maximum load where cycling without failure occurs

If at max N no cycling failure occurs, max N_{red} = max N

(no reduction of $N_{Rk,s}$ necessary)

The characteristic resistance to steel failure under tension $N_{Rk,s}$ with the corresponding decisive steel part used in equation (2.2.1.4) shall be stated for each anchor size, each material and each corresponding fastening screw.

<u>Durability</u>

Anchors with a material combination according to clause 1.1, (4), and geometry according to Figure 1.1.1 a) or Figure 1.1.2 are tested to assess the durability of the coating on the top of the bar inside of the socket according to A.3. These anchors may be used for CRC III according EN 1993-1-4 [11].

2.2.2 Resistance to pull-out failure

Purpose of the test

The tests shall be performed to determine the resistance to pull-out failure taking into account effects of functioning with increased crack width (Table A.1.2.1.1, lines 1 and 2), crack cycling under load (Table A.1.2.1.1, line 3) and repeated load cycles (Table A.1.2.1.1, line 4).

The tests for pull-out failure may be omitted for anchors with headed anchors in accordance with Figure 1.1.2 and resistance to pull-out failure may be calculated according to EN 1992-4 [5], clause 7.2.1.5.

Test conditions

All tests shall be performed with unconfined test setup in accordance with C.1.3.

For pull-out failure reference tests according to Table A.1.1.1, lines 1 to 4, are required.

Functioning tests shall be performed according to A.1.2. Rotationally not symmetrical products according to Figure 1.1.1 shall be installed parallel to the edge.

Assessment

Determine for each test series the results $N_{Rk,0}$, α_1, α_2, α_p and $ß_{cv}$ following Annex A and Annex B.

The characteristic resistances of single anchors in C20/25 without edge and spacing effects under tension load shall be calculated as follows:

$$N_{Rk,p} = N_{Rk,0} \cdot \min \beta_{cv} \cdot \min(\min \alpha_1 ; \min \alpha_2 ; \min \alpha_p) \leq N_{Rk,c}^0 \qquad (2.2.2.1)$$

with:

$N_{Rk,0}$ = 5% fractile of the failure loads from the test series according to Table A.1.1.1, lines 1 to 2, for uncracked concrete or according to Table A.1.1.1, lines 3 and 4, for cracked concrete

If the concrete strength in tests is larger than the nominal concrete strength: Convert the results to nominal concrete strength according to Annex B.1.

min α_1 = minimum of reduction factors according to Annex B.5 to consider uncontrolled slip

min α_2 = minimum of reduction factors according to equation (A.1.2.1.1) resulting from the functioning tests according to Table A.1.2.1.1, lines 1, 2, 3 and 4 ($\leq$ 1,0),

min β_{cv} = minimum of reduction factors according to Annex B.2 to consider the scatter of the failure loads

min $\alpha_p \leq$ 1,0: minimum of factors for reduced load in functioning tests with crack cycling or repeated loads (see A.1.2.3 and A.1.2.4).

The value of the characteristic resistance $N_{Rk,p}$ for pull-out failure shall be rounded down to the following numbers and given in the ETA:

3/ 4/ 5/ 6/ 7,5/ 9/ 12/ 16/ 20/ 25/ 30/ 35/ 40/ 50/ 60/ 75/ 95/ 115/ 140/ 170/ 200 kN

The pull-out capacity of headed anchors $N_{Rk,p}$ according to Figure 1.1.2 shall be calculated according to EN 1992-4 [5], clause 7.2.1.5.

2.2.3 Resistance to concrete cone failure

Purpose of the test

Tests for concrete cone failure may be omitted for headed anchors according to Figure 1.1.2 and resistance to concrete cone failure shall be calculated according to EN 1992-4, clause 7.2.1.4 [5], if the anchor head is symmetrical and stiff enough to avoid bending failure of the head (headed anchors with a ratio between head- and shaft diameter $\geq$ 1,5). In this case h_{ef} is measured according to Figure 1.1.2.

For all other anchors according to Figure 1.1.2 and anchors in accordance with Figure 1.1.1 tests are needed to assess the correlation between h_{ef} and concrete cone failure.

Test conditions

The test series according to Table A.1.1.1, lines 1 to 4, shall be performed with unconfined test setup and in accordance with Annex C.

Assessment

Determine the mean value of the failure loads $N_{u,m}$ in test series according to Table A.1.1.1, lines 1 to 4. Convert the results to nominal concrete strength according to Annex B.1 if the concrete strength is larger than the nominal concrete strength for C20/25 or C50/60, respectively.

The effective embedment depth of anchors according to Figure 1.1.1 shall be calculated for cracked and uncracked concrete according to equation (2.2.3.1).

$$h_{ef} = \min\left\{\left(\frac{0{,}75 \cdot N_{u,m}}{k_1\sqrt{f_{ck}}}\right)^{\frac{2}{3}} ; L - m\right\} \tag{2.2.3.1}$$

with

k_1 according to EN 1992-4 [5], clause 7.2.1.4

L, m according to Figure 2.2.3.1

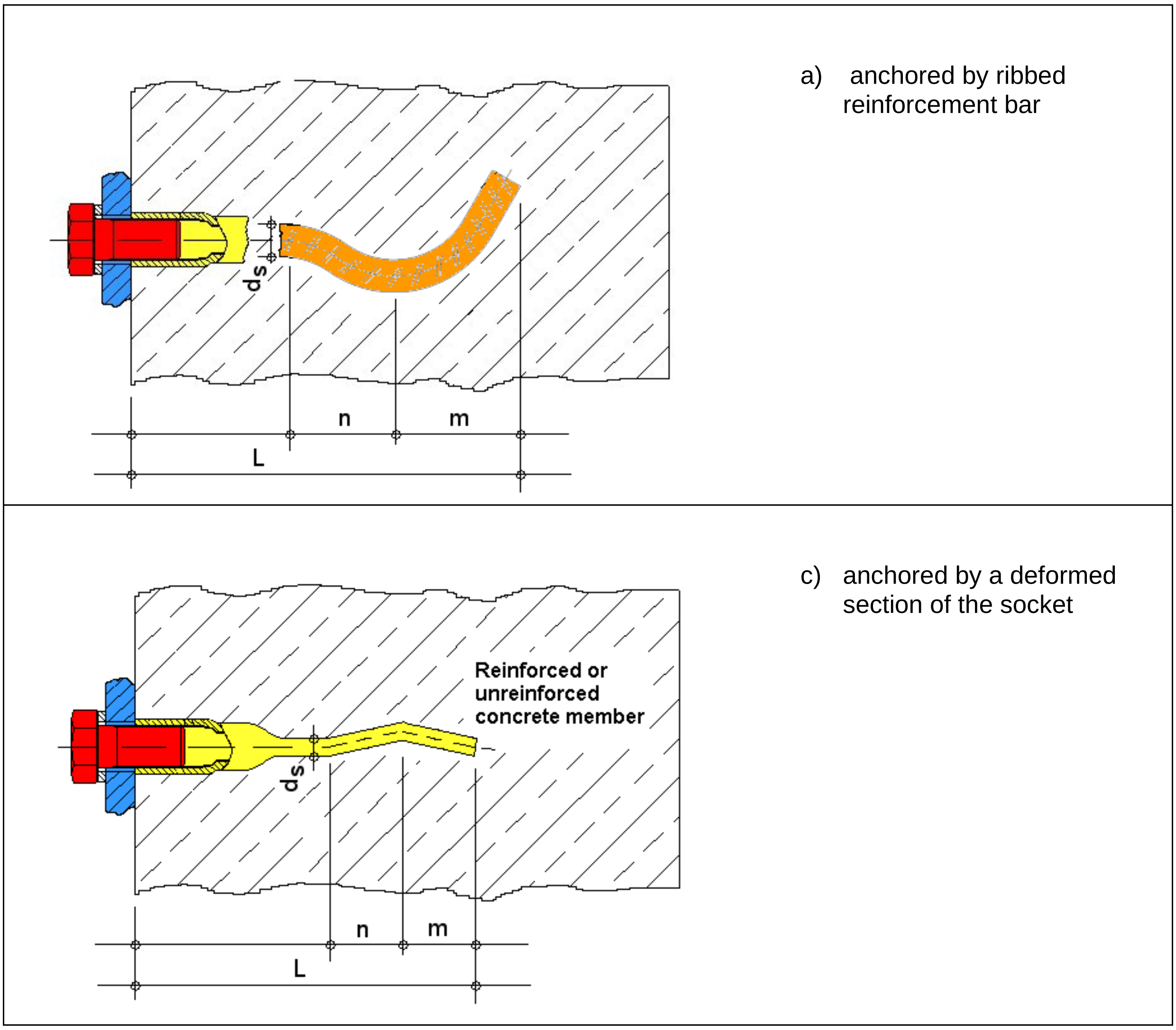


Figure 2.2.3.1 Examples for determination of L, m

The effective embedment depth of anchors according to Figure 1.1.2 shall be calculated for cracked and uncracked concrete according to equation (2.2.3.2).

$$h_{ef} = \min\left\{\left(\frac{0{,}75 \cdot N_{u,m}}{k_1\sqrt{f_{ck}}}\right)^{\frac{2}{3}} ; h_{ef,Figure\ 1.1.2}\right\} \tag{2.2.3.2}$$

with

k_1 according to EN 1992-4 [5], clause 7.2.1.4

$h_{ef,Figure\ 1.1.2}$ according to Figure 1.1.2

2.2.4 Resistance to splitting and edge distance to prevent splitting and blow-out failure

Purpose of the test

The tests are performed to check that splitting of the concrete under load does not occur. The tests may be omitted for headed anchors according to Figure 1.1.2.

Test conditions

The tests shall be performed according to C.4. Rotationally unsymmetrical anchors as shown in Figure 1.1.1 shall be installed with the smallest distance between anchorage and concrete edge. An example is given in Figure 2.2.5.1.

The tension tests are carried out at concrete members with minimum thickness and with the edge distances $c_1 = c_2 = c_{cr,sp}$. If the manufacturer does not apply for a specific edge distance, $c_{cr,sp} = 0,5\ h_{ef}$..

The tests may be omitted if the manufacturer requires reinforcement to resist the splitting forces according to EN 1992-4 [5], clause 7.2.1.7 (2) b) 2).

Assessment

The characteristic edge distance $c_{cr,sp}$ is evaluated from the results of tension tests on single anchors at the corner ($c_1 = c_2 = c_{cr,sp}$). The mean failure load in the tests with anchors at the corner shall be statistically equivalent to the result of the test series with an anchor without edge and spacing effects (Table A.1.1.1, line 1) for the same concrete strength. For headed anchors the mean failure load shall be compared with the calculated pull-out capacity according to EN 1992-4 [5], clause 7.2.1.5.

If this condition is not fulfilled, the edge distance shall be increased accordingly.

<u>Failure loads:</u>

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength.
- Determine $N_{Rk,0}$ from the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal concrete strength.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 15% (cv_F > 15%), determine the reduction factor for large scatter $ß_{cv}$ according to A.2.2.

<u>Load displacement behaviour:</u>

- Verify the criteria for uncontrolled slip and determine the load N_{sl} [kN] as well as the factor α_1 in accordance with B.5.
- Use the reduction factor α_1 together with rqd. $\alpha_1 = 0,8$ (in uncracked concrete) in equation (B.5.3).
- Determine the mean value of the failure loads $N_{u,m}$ [kN] of the test series.
- Determine the displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] in each test.
- Determine the coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%]. If the displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 25 %.

The characteristic resistance to splitting $N^0_{Rk,sp}$ shall be determined by equation (2.2.4.1). It is the lower result of either characteristic resistance to pull-out failure ($N_{Rk,p}$ according to 2.2.2) or to concrete cone failure ($N^0_{Rk,c}$ according to EN 1992-4 [5] with h_{ef} according to 2.2.3).

$c_{cr,sp}$ = edge distance in the tested situation

$$N^0_{Rk,sp} = \min \{N^0_{Rk,c}; N_{Rk,p}\} \tag{2.2.4.1}$$

For headed anchors according to Figure 1.1.2 the following values apply without testing:

$$c_{cr,sp} = 1,5\ h_{ef} \tag{2.2.4.2}$$

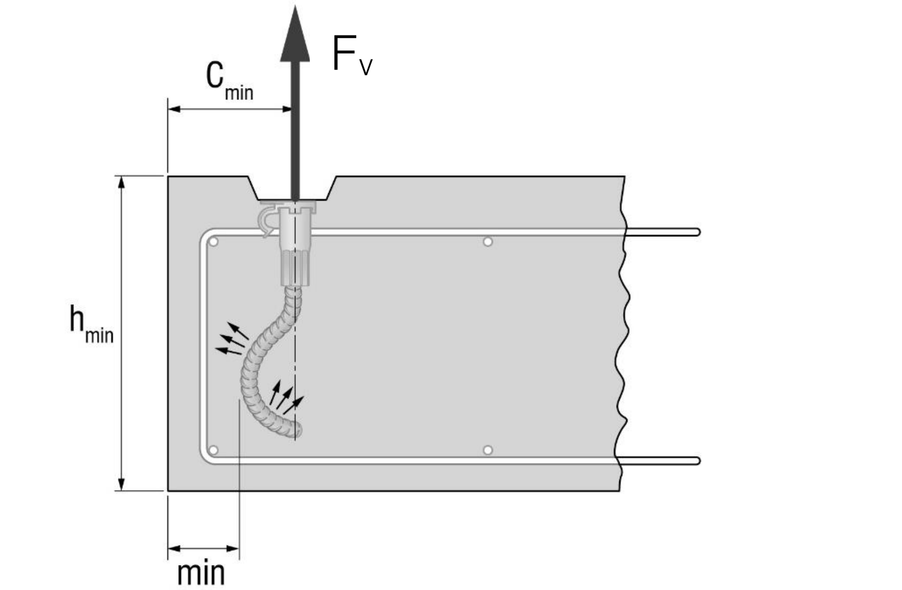
2.2.5 Minimum edge distance and spacing

Purpose of the test

The tests are performed to check that splitting of the concrete does not occur during the installation of the fixture. The tests are needed for the general application where a countersunk installation of the anchor is allowed according to the manufacturer's product installation information (MPII). Tests may be omitted if it is ensured that the fixture is always braced directly to the anchor, so that pre-stressing force does not generate reaction forces in concrete as shown in Figure 2.2.5.1. No reaction forces in concrete can be achieved if the fixture is not in contact with the concrete surface and the fixture is fastened to the anchor by suitable steel part (e.g., washer).

Test conditions

Install the anchor in the most unfavourable position (see Figure 2.2.5.1).



Example for most unfavourable installation position (the fixture is not illustrated.)

F_V: pre-stressing force caused by the installation torque

Figure 2.2.5.1 Example for installation in the test for minimum distance and spacing

The tests are carried out with double anchors with a spacing $s = s_{min}$ and an edge distance $c = c_{min}$ at a concrete member with minimum thickness $h = h_{min}$. The anchors shall be alternately torqued in steps of 0,2 T_{inst}. The test is stopped when the torque moment cannot be increased further or cracks on the concrete surface are observed. Details of the test are described in C.4.

Assessment

For all tested sizes the minimum spacing s_{min} and minimum edge distance c_{min} and minimum member thickness h_{min} shall be evaluated from the results of installation tests with double anchors ($c = c_{min,t}$, $s = s_{min,t}$). The 5 %-fractile of the torque $T_{5\%}$, calculated according to B.3, at which a hairline crack has been observed at one anchor shall fulfil equations (2.2.5.1) or (2.2.5.2).

$$T_{5\%} \geq 1{,}3 \cdot T_{inst} \cdot (f_{c,t} / f_{ck})^{0{,}5} \quad \text{(for concrete failure in cracked concrete)} \qquad (2.2.5.1)$$

$$T_{5\%} \geq 1{,}7 \cdot T_{inst} \cdot (f_{c,t} / f_{ck})^{0{,}5} \quad \text{(for concrete failure in uncracked concrete)} \qquad (2.2.5.2)$$

If steel failure occurs in this test series, increase of the edge distance and spacing will not change the failure mode and the tested edge distance c_{min} and spacing s_{min} and member thickness h_{min} apply.

For all other sizes use the coefficient of friction k_{test} according clause 2.2.6 to calculate N_{calc} at 1,3 T_{inst} according to (2.2.6.2) for cracked concrete. For uncracked concrete calculate N_{calc} according to (2.2.6.2) by using 1,7 T_{inst} instead of 1,3 T_{inst}.

The ratio of the prestressing force N_{calc} to the Area $A_c = (2 \cdot c_{min} + s_{min}) \cdot h_{min}$ of the intermediate untested sizes exceed 1,1 times the ratio corresponding to the next largest and next smallest tested anchor size.

If the ration N_{calc} / A_c exceed this value c_{min}, s_{min} and/or h_{min} shall be increased until this condition is fulfilled.

2.2.6 Maximum torque moment

Purpose of the test

The tests are performed in order to assess that steel failure (yielding) of the bolt may not occur by application of the installation torque, accounting for corresponding tolerances. The tests are needed for the general application where a countersunk installation of the anchor is allowed according to the MPII. Tests may be omitted if it is ensured that the fixture is always braced directly to the anchor, so that pre-stressing force does not generate reaction forces in concrete as shown in Figure 2.2.5.1. No reaction forces in concrete can be achieved if the fixture is not in contact with the concrete surface and the fixture is fastened to the anchor by suitable steel part (e.g., washer).

Test conditions

The tests shall be performed according to C.5.

The cast-in anchors shall be installed sunk in the concrete member so that the internal threaded socket shall not be tensioned against the fixture. The torque moment is applied with a calibrated torque wrench until at least up to 1,3 T_{inst}. The tension force in the cast-in anchor shall be measured as a function of the applied torque moment.

Assessment

- For all tested sizes determine the mean value of the tension force $N_{1,3Tinst,m}$ [kN] and the 95% fractile of the tension force $N_{1,3Tinst,95\%}$ [kN] at 1,3 T_{inst} and the coefficient of friction k_{test} according to equation (2.2.6.1).

k_{test}	=	$k_{test,m} \cdot (1 - k_s \cdot cv_F)$	[-]	(2.2.6.1)
$k_{test,m}$	=	mean value of the values $k_{test,i}$	[-]	

with:

$k_{test,i}$	=	$\frac{1,3 \cdot T_{inst}}{N_{test,i} \cdot d}$	
$N_{test,i}$	=	pre-stressing force at T = $1,3 \cdot T_{inst}$ measured in test i	[N]
T_{inst}	=	installation torque specified by the manufacturer	[Nmm]
d	=	diameter of the screw	[mm]
k_s ,cv_F		see equation (B.3.1)	[-]

- For all other sizes use the coefficient of friction k_{test} of the tests above to determine the pretension force $N_{calc.}$ [kN] at 1,3 T_{inst} according to equation (2.2.6.2).

N_{calc}	=	$\frac{1,3 \cdot T_{inst}}{k \cdot d}$	[N]	(2.2.6.2)
T_{inst}	=	installation torque moment specified by the manufacturer	[Nmm]	
k	=	friction factor	[-]	
	=	min (0,2; k_{test}) for sizes without tests, with k_{test} according to equation (2.2.6.1) resulting from the tested sizes		
d	=	diameter of the screw	[mm]	

All following criteria shall be fulfilled for tested and not tested sizes.

- The 95 %-fractile of the tension force generated in the torque tests at a torque T = 1,3 T_{inst} and the calculated tension force N_{calc} shall be smaller than the nominal yield force ($A_s \cdot f_{yk}$) of the anchor part which is decisive to steel failure (fastening crew, socket of anchor element).
- The tension force generated in the torque test shall be smaller than the concrete cone capacity for concrete C20/25 according to EN 1992-4 [5], clause 7.2.1.4. This criterion may be neglected if the MPII does not allow countersunk installation.
- At the end of the test, the connection shall be capable of being unscrewed.

If the generated tension force is higher than mentioned above T_{inst} shall be reduced correspondingly.

2.2.7 Displacements for tension loading

The characteristic displacements for short-term and quasi-permanent loading shall be specified for the tension load N in accordance with following equation:

$$N = N_{Rk} / (1,4 \cdot 1,5) \qquad (2.2.7.1)$$

with: N_{Rk} = characteristic resistance to tension load (minimum of $N_{Rk,p}$ and $N^0_{Rk,c}$).

$N^0_{Rk,c}$ = characteristic resistance of a single anchor placed in concrete and not influenced by adjacent anchors or edges of the concrete according EN 1992-4, equation (7.2)

For anchors according to Figure 1.1.1 the displacements δ_{N0} under short-term loading shall be evaluated from test series Table A.1.1.1, lines 1 to 4. δ_{N0} is the maximum displacement obtained in the test series at the load level N.

Determine the mean value of displacements in the test series at the load N according to equation (2.2.7.1) and round up to zero or five on the first place after the decimal point.

For headed anchors according to Figure 1.1.2 tests in concrete are not required. The displacements shall be calculated according to equation (2.2.7.2) on the basis of the stiffness of the concrete under the head and the elasticity of the shaft (e.g., according to [21]).

$$\delta_{N0} = \delta_{head} + \delta_{el} \quad \text{[mm]} \qquad (2.2.7.2)$$

$$\delta_{head} = \frac{k_A \cdot k_a}{600} \cdot \left(\frac{\frac{N}{A_h}}{25} \right)^2 \quad \text{[mm]} \qquad (2.2.7.3)$$

with:

$$k_A = \frac{\sqrt{d_a{}^2 + 9 \cdot (d_h{}^2 - d_a{}^2)} - d_h}{2}$$

$$k_a = \sqrt{\frac{10}{(d_h - d_a)}}$$

d_a = diameter of the anchor [mm]

d_h = diameter of the head of the anchor [mm]

N = tension load according equation (2.2.7.1) for uncracked concrete [N]

A_h = load bearing area of the head according to EN 1992-4 [5], clause 7.2.1.5, equation (7.12)

$$\delta_{el} = \frac{N \cdot h_{ef}}{A_s \cdot E} \quad \text{[mm]} \qquad (2.2.7.4)$$

with:

h_{ef} = effective embedment depth [mm]

A_s = cross section of the anchor [mm²]

E = elastic modulus of the anchor [N/mm²]

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

2.2.8 Resistance to steel failure for shear load

(a) Without lever arm

The characteristic resistance $V_{Rk,s}$ for screw and socket shall be calculated according to EN 1992-4 [5], clause 7.2.2.3.

(b) With lever arm

The characteristic resistance $M^0_{Rk,s}$ shall be determined for the socket and the screw of appropriate strength class:

$M^0_{Rk,s} = 1.2 \cdot W_{el} \cdot f_{uk}$ (2.2.8.1)

with: W_{el} = section modulus of the socket calculated on the net tensile area

Socket: $W_{el} = ((d_o^4 - d_2^4) / d_o) \cdot \pi / 32$ (2.2.8.2)

Screw: $W_{el} = d^3 \cdot \pi / 32$ (2.2.8.3)

d_o = outer diameter of the socket

d_2 = effective pitch diameter of the socket (taking the internal thread into account)

f_{uk} = relevant characteristic tensile strength

The smaller value is decisive. $M^0_{Rk,s}$ and the required material, strength class and screwing length for the screw shall be given in the ETA.

(c) Ductility factor k_7

The fracture elongation A shall be tested and determined according to EN ISO 6892-1:2019 [20]. The ductility factor shall be determined according to equation (2.2.8.4). If the fracture elongation is not determined in tests, the ductility factor shall be taken as k_7 = 0,8.

$A \leq 8\%: k_7 = 0,8$

$A > 8\%: k_7 = 1,0$ (2.2.8.4)

2.2.9 Resistance to concrete edge failure without supplementary reinforcement

Determine d_{nom} as the nominal outer diameter of the socket at maximum 25 mm and l_f as the length of the socket at maximum 200 mm both measured at the undeformed part of the socket for example according to Figure 2.2.9.1.

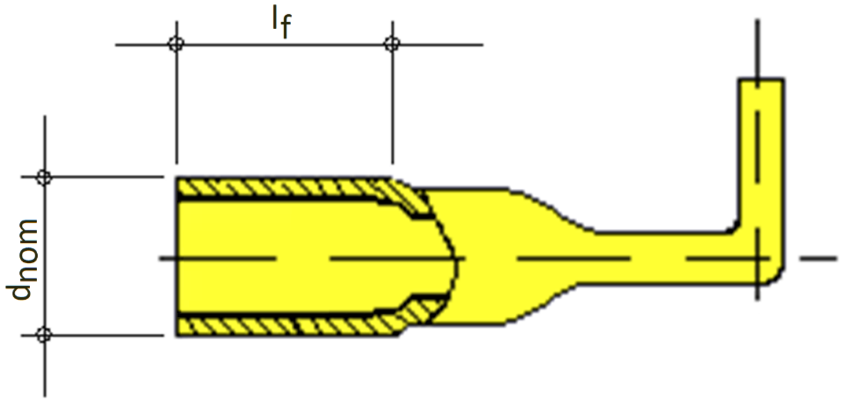


Figure 2.2.9.1 Example for measurement of d_{nom} and l_f

2.2.10 Resistance to concrete edge failure with supplementary reinforcement

Purpose of the test

Increased resistance to concrete edge failure by a supplementary reinforcement in form of loops or stirrups as shown in Figure 1.1.3 for plane installation and front-side installation shall be tested .

Test conditions

The tests shall be performed for each type of special hanger reinforcement that is requested by the manufacturer.

The tests shall be performed as shear tests according to C.6 with supplementary reinforcement if applied for by the manufacturer. Plane installation and front-side installation shall be tested separately according to the MPII.

The most adverse possible installation of the anchor shall be used in the test, e.g., see Figure 2.2.5.1 concerning the direction of the hook.

Assessment

- Determine the 5% fractile of failure loads $V_{u,5\%}$ (= $V_{Rk,c,test}$) converted to the nominal concrete strength according to Annex B.1 to B.3.
- Determine the resistance to steel failure of the supplementary reinforcement as given in equation (2.2.10.1).

$$V_{Rk,re} = k \cdot A_s \cdot f_{yk} \cdot \cos\alpha_1 \cdot \cos\alpha_2 \qquad (2.2.10.1)$$

with:

$k = 0{,}5$

A_s = Cross-section of the hanger reinforcement of both legs

α_1, α_2 = Angle between shear load and supplementary reinforcement according to Figure 1.1.3

f_{yk} = nominal characteristic steel yield strength

- Determine $V_{Rk,c,re} = \min(V_{Rk,c,test}; V_{Rk,re})$

2.2.11 Resistance to pry-out failure

Tests may be omitted if the default values for k_8 as given in Table 2.2.11.1 apply. Higher values for k_8 may be obtained in tests according to EAD 330232-01-0601 [1], clause 2.2.8, test series V2.

Table 2.2.11.1 Default values for k_8

Effective embedment depth h_{ef} [mm]	k_8 [-]
< 60 mm	1,0
≥ 60 mm	2,0

2.2.12 Displacement for shear loading

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

$$V = V_{Rk} / (1{,}4 \cdot 1{,}5) \qquad (2.2.12.1)$$

with: $V^0_{Rk,c}$ = initial value of the characteristic resistance to shear load for concrete edge failure .

The displacements δ_{V0} under short-term loading are evaluated from test series Table A.1.1.1, line 6. The value derived shall correspond to the mean value of the deformations of these test series at the load V. The displacements (in mm) shall be rounded up to zero or five on the first place after the decimal point.

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

2.2.13 Resistance to tension load for seismic performance category C1

Purpose of the test

These tests are intended to evaluate the performance of the cast-in anchor under simulated seismic tension loading, including the effects of cracks, and without edge effects for seismic performance category C1.

Test conditions (Series C.1.1)

The general test conditions are given in EAD 330232-01-0601 [1], C.3.1.

Specific test conditions are given in EAD 330232-01-0601 [1], C.3.3.2.

Modifications for cast-in anchors are given in Annex A.2.

Assessment

The assessment of tests is given in EAD 330232-01-0601 [1], C.4.1.1.

The characteristic resistance to tension load for seismic performance category C1, $N_{Rk,s,C1}$ and $N_{Rk,p,C1}$, shall be calculated according to in EAD 330232-01-0601 [1], C.4.3.1.1.

2.2.14 Resistance to tension load for seismic performance category C2

Purpose of the test

These tests are intended to evaluate the performance of the cast-in anchor under simulated seismic tension loading, including the effects of cracks, and without edge effects for seismic performance category C2.

Test conditions (Series C2.1, C2.3, C2.5)

Test series C2.1, C2.3 and C2.5 shall be performed with the same embedment depths and test set-up (confinement conditions).

The general test conditions are given in EAD 330232-01-0601 [1], C.3.1.

Specific test conditions are given in EAD 330232-01-0601 [1], C.3.4.1, for reference test series C.2.1, in EAD 330232-01-0601 [1], C.3.4.2, for tests under pulsating tension loading (test series C2.3) and in EAD 330232-01-0601 [1], C.3.4.4, for tests with tension load and varying crack width (test series C2.5).

Modifications for cast-in anchors are given in Annex A.2.

Assessment

The assessment of test series is given in EAD 330232-01-0601 [1], C.4.2.

The characteristic resistance to tension load for seismic performance category C2, $N_{Rk,s,C2}$, and $N_{Rk,p,C2}$, shall be determined according to EAD 330232-01-0601 [1], C.4.3.2.1.

The displacements $\delta_{N,C2}$ shall be assessed according to EAD 330232-01-0601 [1], C.4.3.2.3.

2.2.15 Resistance to shear load for seismic performance category C1

Purpose of the test

These tests are intended to evaluate the performance of anchors under simulated seismic shear loading, including the effects of cracks, and without edge effects for seismic performance category C1.

Test conditions (Series C1.2)

The general test conditions are given in EAD 330232-01-0601 [1], C.3.1.

Specific test conditions are given in EAD 330232-01-0601 [1], C.3.3.3.

Modifications for cast-in anchors are given in Annex A.2.

Assessment

The assessment of test series is given in EAD 330232-01-0601 [1], C.4.2.

The characteristic resistance to shear load for seismic performance category C1, $V_{Rk,s,C1}$, shall be determined according to EAD 330232-01-0601 [1], C.4.3.1.2.

2.2.16 Resistance to shear load for seismic performance category C2

Purpose of the test

These tests are intended to evaluate the performance of anchors under simulated seismic shear loading, including the effects of cracks, and without edge effects for seismic performance category C2.

Test conditions (Series C2.2, C2.4)

Test series C2.2 and C2.4 shall be performed with the same embedment depths and test set-up (confinement conditions).

The general test conditions are given in EAD 330232-01-0601 [1], C.3.1.

Specific test conditions are given in EAD 330232-01-0601 [1], C.3.4.1, for the reference test series C2.2 and in EAD 330232-01-0601 [1], C.3.4.3, for test series under alternating shear load (series C2.4).

Modifications for cast-in anchors are given in Annex A.2.

Assessment

The assessment of test series is given in EAD 330232-01-0601 [1], C.4.2.

The characteristic resistance to shear load for seismic performance category C2, $V_{Rk,s,C2,}$ shall be determined according to EAD 330232-01-0601 [1], C.4.3.2.2.

The displacements $\delta_{V,C2}$ shall be assessed according to EAD 330232-01-0601 [1], C.4.3.2.3.

2.2.17 Reaction to fire

The product is 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.

Therefore, the performance of the product is class A1.

2.2.18 Resistance to fire

The fire resistance to steel failure due to tension load $N_{Rk,s,fi}$ shall be determined according to EAD 330232-01-0601 [1], clause 2.2.17.

The fire resistance to pull-out failure due to tension load $N_{Rk,p,fi}$ shall be determined according to EAD 330232-01-0601 [1], clause 2.2.18.

The fire resistance to steel failure due to shear load $V_{Rk,s,fi}$ and $M^0_{Rk,s,fi}$ shall be determined according to EAD 330232-01-0601 [1], clause 2.2.19.

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 Commission Decision 96/582/EC.

The system is 1.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of cast-in anchors with internal threaded socket in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

Table 3.2.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
1	Metal part / dimensions and tolerances	Measuring or optical	Laid down in control plan	3 samples for each size and for each material	Each batch/ production week 10000 anchors
2	Metal part / material properties e.g., tensile strength or hardness, elastic limit, elongation on rupture	e.g., tensile test, hardness testing Brinell or Vickers	Laid down in control plan	3 samples for each size and for each material	Each batch/ production week 10000 anchors
3	Metal part / coating	Measuring of thickness	Laid down in control plan	3 samples for each size and for each material	Each batch/ production week 10000 anchors
4	Final product	Tensile test	Laid down in control plan	3 samples for each size and for each material	Each batch/ production week 10000 anchors

3.3 Tasks of the notified body

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

Table 3.3.1 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control *(for systems 1+, 1 and 2+ only)*					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the of the cast-in anchor.	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	1, When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control *(for systems 1+, 1 and 2+ only)*					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	**1**/year

4 REFERENCE DOCUMENTS

[1] EAD 330232-01-0601:2019-12: Mechanical fasteners for use in concrete

[2] EN ISO 3506-1:2020: Fasteners - Mechanical properties of corrosion-resistant stainless steel fasteners - Part 1: Bolts, screws and studs with specified grades and property classes (ISO 3506-1:2020)

[3] EN 10088-3:2014: Stainless steels - Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes

[4] 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 (ISO 898-1:2013)

[5] EN 1992-4:2018: Eurocode 2: Design of concrete structures - Part 4: Design of fastenings for use in concrete

[6] series EN 10305 Steel tubes for precision applications - Technical delivery conditions

EN 10305-1:2016 - Part 1: Seamless cold drawn tubes

EN 10305-2:2016 - Part 2: Welded cold drawn tubes

- EN 10305-3:2016 - Part 3: Welded cold sized tubes

[7] EN 10216-5:2021: Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 5: Stainless steel tubes

[8] EN 10217-7:2021: Welded steel tubes for pressure purposes - Technical delivery conditions - Part 7: Stainless steel tubes

[9] EN 1993-1-8:2005+AC:2009: Eurocode 3: Design of steel structures - Part 1-8: Design of joints

[10] EN ISO/IEC 17025:2017: General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2017)

[11] EN 1993-1-4:2006 + A1:2015+A2:2020: Eurocode 3: Design of steel structures, Part 1-4: General rules – Supplementary rules for stainless steels

[12] EN 206:2013+A2:2021: Concrete - Specification, performance, production and conformity

[13] EN ISO 15630-1:2019: Steel for the reinforcement and prestressing of concrete - Test methods - Part 1: Reinforcing bars, rods and wire (ISO 15630-1:2019)

[14] EN ISO 17660-1:2006: Welding - Welding of reinforcing steel - Part 1: Load-bearing welded joints (ISO 17660-1:2006)

[15] EN ISO 9227:2017: Corrosion tests in artificial atmospheres - Salt spray tests (ISO 9227:2017)

[16] EAD 330012-00-0601:2015-09: Cast-in anchor with internal threaded socket

[17] EN ISO 1461:2022: Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods (ISO 1461:2022)

[18] EN ISO 10684:2004+AC:2009: Fasteners – Hot dip galvanized coatings (ISO 10684:2004 + Cor. 1:2008)

[19] ISO 6783:1982: Coarse aggregates for concrete; Determination of particle density and water absorption; Hydrostatic balance method

[20] EN ISO 6892-1:2019: Metallic materials – Tensile testing – Part 1: Method of test at room temperature (ISO 6892-1:2016)

For further information:

[21] Furche, Johannes: Zum Trag- und Verschiebungsverhalten von Kopfbolzen bei zentrischem Zug, University of Stuttgart 1994, ISBN 978-3-9803044-3-6

ANNEX A TEST PROGRAM AND GENERAL ASPECTS OF ASSESSMENT

A.1 Test program – static and quasi-static actions

A.1.1 Reference tests

The purpose of the tests for evaluating characteristics is to establish the resistance subjected to the loading direction, the mode of failure and the spacing respectively edge distance.

The types of tests for evaluating characteristics, test conditions, the number of required tests and the criteria applied to the results shall be taken in accordance with Table A.1.1.1. Detailed information about special tests is given in the chapters after this Table.

Tests for intermediate size can be omitted if interpolation is geometrically explainable.

Table A.1.1.1 Tests for evaluating characteristics for cast-in anchors for use in concrete

	1	2	3	4	5	6				
	Purpose of test	Con-crete	Crack width	Load direction	Test with … see section	Number of tests (2)				
						s	i	m	i	l
1	Characteristic resistance for tension loading not influenced by edge and spacing effects (1) (6)	C20/25	0	N	Single anchors 2.2.2 2.2.3	3 (3)	3 (3)	3	3 (3)	3 (3)
2	Characteristic resistance for tension loading not influenced by edge and spacing effects (1) (6)	C50/60	0	N	Single anchors 2.2.2 2.2.3	3 (4)	3 (4)	3 (4)	3 (4)	3 (4)
3	Characteristic resistance for tension loading not influenced by edge and spacing effects (1) (6)	C20/25	0,3	N	Single anchors 2.2.2 2.2.3	3 (5)	3 (5)	3	3 (5)	3 (5)
4	Characteristic resistance for tension loading not influenced by edge and spacing effects (1) (6)	C50/60	0,3	N	Single anchors 2.2.2 2.2.3	5 (5)	-	5 (5)	-	5 (5)
5	Edge distance for characteristic tension resistance (c_1=c_2=$c_{cr,sp}$)	C20/25	0	N	Single anchors at the corner 2.2.4	3	3	3	3	3
6	Characteristic shear resistance close to an edge	C20/25	0	V	Single anchors at the edge with supplementary reinforcement 2.2.10	5 tests for each size of supplementary reinforcement				
7	Minimum edge distance for characteristic tension resistance	C20/25	0	T	Double anchor group at the edge 2.2.5	5	-	5	-	5
8	Characteristic resistance for tension loading (steel failure)	---	---	N	Single anchors 2.2.1	3	3	3	3	3
9	Maximum torque moment ($T \geq 1{,}3\ T_{inst}$)	C50/60	0	T	Single anchors 2.2.6	3	-	-	-	3

(1) Reference tension tests for determination of the results of the functioning tests. They have to be carried out at the same concrete as it is given for the corresponding functioning tests (cracked/ uncracked concrete, compressive strength). The results of reference tests may also be considered for evaluating the characteristic resistance of the anchors.

(2) Anchor size: s = smallest, i = intermediate, m = medium, l = largest

(3) Tests can be omitted if tests of line 3 (C20/25) or line 4 (C50/60) are evaluated here.

(4) Tests can be omitted if tests of line 4 are evaluated here.

(5) Tests can be omitted if tests of Table A.1.2.1.1, line 1 are evaluated here.

(6) The test series may be omitted for headed anchors according to Figure 1.1.2.

A.1.2 Functioning tests

A.1.2.1 General

The purpose of the functioning tests is the assessment of the characteristic resistance regarding various effects for the relevant application range according to the intended use.

The types of functioning tests, test conditions, the number of required tests and the criteria applied to the results shall be taken in accordance with Table A.1.2.1.1. Detailed information about special tests is given below this Table.

The test series according to Table A.1.2.1.1 may be omitted for headed anchors according to Figure 1.1.2.

Table A.1.2.1.1 Functioning tests for cast-in anchors to be used in concrete

	Purpose of test	Concrete	Crack width Δw(mm)	Minimum number of tests for anchor size (1)					Criteria
				s	i	m	i	l	rqd. α
1	Functioning - low strength concrete	C20/25	0,5	3	3	3	3	3	≥ 0,8
2	Functioning - high strength concrete	C50/60	0,5	3 (2)	-	3 (2)	-	3 (2)	≥ 0,8
3	Functioning – crack cycling under load	C20/25	0,1-0,3	3	-	3	-	3	≥ 0,9
4	Functioning - repeated loads	C20/25	0	-	-	3	-	-	≥ 1,0

(1) Anchor size: s = smallest, i = intermediate, m = medium, l = largest

(2) Tests may be omitted if in tests according to Table A.1.1.1, line 4, only steel failure is decisive.

The tests shall be performed as single anchor tests in concrete members without any influence by edge and spacing effects under tension loading.

The anchors shall be installed according to the installation instructions (including the depth of the screw in the socket) of the manufacturer.

For each test series according to Table A.1.2.1.1, lines 1 to 4, the factor α according to Annex B shall be calculated. The factor α shall be larger than the values given in Table A.1.2.1.1. If the requirements on the ultimate load in the functioning tests are not fulfilled in one or more test series, then the reduction factor α_2 shall be calculated according to equation (A.1.2.1.1):

$$\alpha_2 = \alpha / \text{req. } \alpha \leq 1{,}0 \qquad \text{(A.1.2.1.1)}$$

with: α = value according to Annex B.4
req. α = required value of α according to Table A.1.2.1.1

For cast-in anchors as given in Figure 1.1.1 a) the reference ultimate load may be calculated according to this section, (a) and (b), if this calculation is proven by tests according to Table A.1.2.1.1, line 1, and Table A.1.1.1., lines 3 and 4.

The concrete cone failure shall be calculated not influenced by edge and spacing effects with h_{ef} according to 2.2.3.

(a) Cracked concrete

$N_u = N_{u,h} + N_{u,b} \leq N_{u,s}$ and $\leq N_{Rk,c}$ (A.1.2.1.2)

N_u = calculated reference ultimate load

with: $N_{u,h}$ = ultimate load part of the hook

$N_{u,h} = \alpha_{hook} \cdot A_s \cdot f_{yk} \cdot (f_{ck}/25,2)^{0,5}$ (A.1.2.1.3)

$\alpha_{hook} = 0,8$

$N_{u,b}$ = ultimate load part for the bonding

$N_{u,b} = \pi \cdot d_s \cdot l_v \cdot \tau_u$ (uncracked concrete) (A.1.2.1.4)

$N_{u,b} = 2/3 \cdot \pi \cdot d_s \cdot l_v \cdot \tau_u$ (cracked concrete) (A.1.2.1.5)

$N_{u,s}$ = minimum ultimate load for steel failure

$N_{u,s}$ = min. {$A_s \cdot f_u$ steel failure of the reinforcement bar

$A_{s,s} \cdot f_{u,s}$ steel failure of the socket

$N_{u,sc}$} failure of connection between socket and reinforcement bar (test according to Table A.1.1.1, line 8)

$N_{Rk,c}$ = concrete cone capacity according to EN 1992-4 [5], equation (7.2).

$A_{s,s}$ = cross-section of reinforcement bar (socket)

f_{yk} = characteristic steel yield strength

f_{ck} = nominal characteristic compressive cylinder strength (150 mm diameter by 300 mm height)

d_s = diameter of reinforcement bar

l_v = bond length of reinforcement bar without hook

τ_u = ultimate bond strength

$\tau_u = 1,5 \cdot f_{bd}/ 0,75 = 4,5$ N/mm² (C20/25)

$\tau_u = 8,7$ N/mm² (C50/60)

$f_{bd} = (2,25\ f_{ctk;0,05})/ \gamma_c$ with $\gamma_c = 1,5$

$f_{ctk;0,05}$ = 5%-fractile of the characteristic concrete central tensile strength

$f_{ctk;0,05} = 1,5$ N/mm² (C20/25)

$f_{ctk;0,05} = 2,9$ N/mm² (C50/60)

$f_{s(,s)}$ = characteristic steel ultimate tensile strength of reinforcement bar (socket)

$N_{u,sc} = l_w \cdot a_w \cdot f_s/(3^{0,5} \cdot \beta_w)$ if the connection is welded

l_w (a_w) = length and thickness of the welding

β_w = according to EN 1993-1-8 [9], clause 4.5.3.2, Table 4.1

In all other cases the connection has to be assessed by testing according to Table A.1.1.1, line 8.

(b) Uncracked concrete

The reference tension load shall be evaluated by the tests according Table A.1.1.1, lines 1, 2 and 5. The 5%-fractile is limited by concrete cone capacity according to EN 1992-4 [5], equation (7.2).

A.1.2.2 Functioning - low and high strength concrete

Purpose of the test

These tests are performed to evaluate the sensitivity to low and high strength concrete.

Test conditions

The single anchors are tested in tension and loaded to failure. The tests shall be performed according to C.2 and C.3. The anchors shall not be applied with a defined torque moment before testing.

Assessment

Failure loads

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal strength in accordance with B.1, accounting for the relevant failure mode.
- Determine the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal concrete strength in accordance with B.1, accounting for the relevant failure mode.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 20% (cv_F > 20%), determine the reduction factor for large scatter $ß_{cv}$ according to B.2.
- Determine the reduction factor α according to Annex B.4 comparing the test results with reference test series according to Table A.1.1.1, line 3 (cracked concrete), or test series 1 (uncracked concrete only, respectively)
- Determine α_2 with rqd. α = 0,8 in equation (A.1.2.1.1).

Load displacement behaviour:

- Determine the load N_{sl} [kN] according to B.5.
- Determine the reduction factor α_1 according to Annex B.5 for cracked concrete.
- Determine the mean value of the failure loads $N_{u,m}$ [kN] of the test series.
- Determine the displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] in each test
- Determine the coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%]. If the displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40 %.

A.1.2.3 Functioning - crack cycling under load

Purpose of the test

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

Test conditions

The tests shall be performed according to C.3.2.

The tests shall be performed for small, medium and large anchor size. The tests are performed in concrete C20/25.

The tensile load N_p applied to the anchor during the crack cycling test is defined in equation (A.1.2.3.1).

$$N_p = 0{,}50\ N_{Rk} \qquad \text{(A.1.2.3.1)}$$

with: N_{Rk} = characteristic tensile resistance in cracked concrete C20/25 evaluated according to test series Table A.1.1.1, line 3, converted to the nominal concrete strength f_{ck} = 20 N/mm² in accordance with B.1.

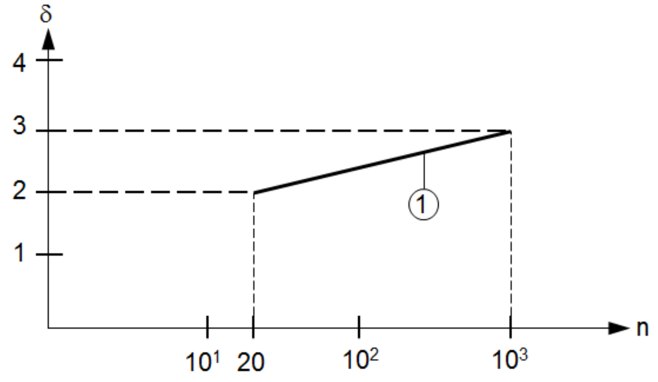
Assessment

Displacements during crack cycles

In each test the rate of increase of anchor displacements, plotted in a half-logarithmic scale (see Figure A.1.2.3.1), shall either decrease or be almost constant: the criteria of the allowable displacement after 20 (δ_{20}) and 1000 (δ_{1000}) cycles of crack opening are graduated as a function of the number of tests as follows:

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

Note 1: The displacements are considered to be stabilized if the increase of displacements during cycles 750 to 1000 is smaller than the displacement during cycles 500 to 750.



1 maximum allowable displacement

n number of crack cycles

δ displacement of the anchor in [mm]

Figure A.1.2.3.1 Criteria for results of tests with variable crack width

If in the tests the above given requirements on the displacement behaviour, i.e., rate of increase and allowable displacements, are not fulfilled, the test series shall be repeated with a reduced tension load $N_{p,red}$ until the requirements are fulfilled. The characteristic resistance shall be reduced by applying the reduction factor $\alpha_p = N_{p,red}/N_p$ in equation (2.2.2.1).

Failure loads of tension tests after completion of crack cycles (residual load tests)

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal strength in accordance with B.1, accounting for the relevant failure mode.
- Determine the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal strength in accordance with B.1, accounting for the relevant failure mode.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 20% (cv_F > 20%), determine the reduction factor for large scatter $ß_{cv}$ according to B.2.
- Determine the reduction factor α according to Annex B.4 comparing the test results with reference test series according to Table A.1.1.1, line 3.
- Determine α_2 with rqd. α = 0,9 in equation (A.1.2.1.1).

Load displacement behaviour in the residual load tests:

- Determine the load N_{sl} [kN] according to B.5.
- Determine the reduction factor α_1 according to Annex B.5 for cracked concrete.
- Determine the mean value of the failure loads $N_{u,m}$ [kN] of the test series.
- Determine the displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] in each test
- Determine the coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%]. If the displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40 %.

A.1.2.4 Functioning - repeated loads

Purpose of the test

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

Test conditions

The tests shall be performed according to C.3.3.

The maximum and minimum load during the load cycles are given as:

$$\max N = \text{smaller value of } 0{,}6\ N_{Rk,ucr} \text{ and } 0{,}8 \cdot A_s \ f_{yk}\ [N] \quad (A.1.2.4.1)$$

$$\min N = \text{higher value of } 0{,}25\ N_{Rk,ucr} \text{ and } \max N - A_s \ \Delta\sigma_s\ [N] \quad (A.1.2.4.2)$$

with:

$N_{Rk,ucr}$ = characteristic value of the failure load in tension in uncracked concrete for the concrete strength of the test member. This value is determined from the reference tension tests according to Table A.1.1.1, line 1.

$\Delta\sigma_s$ = 120 N/mm^2

Assessment

During the repeated load portion of the test no failure is allowed to occur and the increase of displacements during the cycling shall stabilize in a manner that failure is unlikely to occur after some additional cycles. If these requirements are not met, repeat the test with load values max N and min N determined based on a reduced value max N_{red} until the requirements are met. The characteristic resistance shall be reduced by applying the reduction factor α_p = max N_{red} / 0,6 $N_{Rk,ucr}$ in equation (2.2.2.1).

The assessment of the residual capacity portion of the test is carried out in terms of failure loads and load displacement behaviour as follows:

<u>Failure loads</u>

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal strength in accordance with B.1, accounting for the relevant failure mode.
- Determine the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal strength in accordance with B.1, accounting for the relevant failure mode.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 20% (cv_F > 20%), determine the reduction factor for large scatter $ß_{cv}$ according to B.2.
- Determine the reduction factor α according to B.4. The following test series are used as corresponding reference test series:
  - For tests performed in concrete C20/25 use the test results of test series according to Table A.1.1.1, line 1.
  - For tests performed in concrete C50/60 use the test results of the test series according to Table A.1.1.1, line 2.
- Determine α_2 with rqd. α = 1,0 in equation (A.1.2.1.1).

<u>Load displacement behaviour:</u>

- Determine the load N_{sl} [kN] according to B.5.
- Determine the reduction factor α_1 according to Annex B.5 for uncracked concrete.
- Determine the mean value of the failure loads $N_{u,m}$ [kN] of the test series.
- Determine the displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] in each test
- Determine the coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%]. If the displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40 %.

A.1.3 Provisions for all test series

For the test members, test setup and performance of the tests C.1 and C.2 shall be followed.

It is recommended that handling of tests and calibration items are performed in accordance with EN ISO/IEC 17025 [10].

If the anchor bolts are intended to be installed with more than one embedment depth, in general, the tests have to be carried out with all embedment depths. In special cases, e.g., when steel failure occurs, the number of tests may be reduced.

A.2 Test program – seismic performance categories C1 and C2

A.2.1 Anchors types to be tested

In general, the tests shall be performed with all anchor diameters, lengths, steel types (galvanized steel, stainless steel, high corrosion resistant steel) and grades (strength classes), production method, types of anchor elements, types of inserts (threaded rod, threaded sleeve or rebar for bonded anchors). The number of variants to be tested may be reduced as described below.

A.2.2 Steel type, steel grade and production method

A.2.2.1 Tension tests

If sufficient experience in tension tests according to static and quasi-static loading exists for all steel types only anchors of one steel type, and one production method need to be tested. The measured displacements shall be applied to all steel types, steel grades and production methods. If this condition is not fulfilled, test all anchors; however, only anchors with the minimum load bearing area of the head of a headed anchor need to be tested. The decisive reduction factors $\alpha_{N,C1}$, $\alpha_{N,C2}$, $\beta_{cv,N,C2}$, determined according EAD 330232-01-0601 [1], C.4.2, shall be applied for all anchor configurations which are not tested separately.

A.2.2.2 Shear tests

Only anchors made of galvanized steel of the highest grade and lowest rupture elongation (percentage of elongation after fracture, *A*, see EN ISO 898 [4]) need to be tested if the reduction of the characteristic steel shear resistance due to simulated seismic shear testing as compared to the characteristic steel shear resistance under static loading is accepted by the Technical Assessment Body for all steel types and steel grades, for example on the basis of concrete failure in those tests only. Otherwise, all steel types and steel grades shall be tested. The measured displacements shall be applied to the anchors made from other steel types, steel grades or by other production methods.

A.2.2.3 Head configuration

The specific test series shall be performed with the most adverse head configuration of the product in respect to functioning and ultimate load. If the most adverse head configuration is not obvious all head configurations shall be tested. Whenever the head and the shaft of the anchor are not produced with characteristics of 360° rotational symmetry around the longitudinal screwing axis, tests shall be performed with the anchor head rotated at least in two different directions with the respect of the direction of load application (e.g., shear tests).

A.2.2.4 Anchor length

If there is more than one length specified for one anchor diameter, tests need to be performed for the minimum and maximum length.

A.2.3 Tests for category C1

The test program, test procedure and assessment criteria for category C1 are shown in Table A.2.3.1.

Table A.2.3.1 Additional tests for assessment of anchors under seismic performance category C1

Test no.	Purpose of tests	Concrete	Crack width Δw [mm]	Minimum numbers of tests 1)	Tests procedure	Assessment criteria
C1.1	Functioning under pulsating tension load	C20/25	0,5	5	EAD 330232-01-0601 [1], C.3.3.2	EAD 330232-01-0601 [1], C.4.1.1
C1.2	Functioning under alternating shear load	C20/25	0,5	5	EAD 330232-01-0601 [1], C.3.3.3	EAD 330232-01-0601 [1], C.4.1.2

1) If the load-displacement behaviour of the system has been well investigated and the product monitored and studied under the supervision of an expert third party, the anchor sizes to be tested may be reduced to the small, medium and large size of the product range.

Test series C1.1 can be performed with bare anchors not set into concrete.

A.2.4 Tests for category C2

The test program, test procedure and assessment criteria for category C2 are shown in Table A.2.4.1.

Table A.2.4.1 Additional tests for assessment of anchors under seismic performance category C2

Test no.	Purpose of tests	Con-crete	Crack width Δw [mm]	Minimum numbers of tests 1)	Tests procedure	Assessment criteria
C2.1a	Reference tension tests in low strength concrete	C20/25	0,8	5	EAD 330232-01-0601 [1], C.3.4.1	EAD 330232-01-0601 [1], C.4.2.2
C2.1b	Tension tests in high strength concrete	C50/60	0,8	5	EAD 330232-01-0601 [1], C.3.4.1	EAD 330232-01-0601 [1], C.4.2.2
C2.2 2)	Reference shear tests	C20/25	0,8	5	EAD 330232-01-0601 [1], C.3.4.1	EAD 330232-01-0601 [1], C.4.2.3
C2.3	Functioning under pulsating tension load	C20/25	0,5 ($\leq 0{,}5 \cdot N/N_{max}$) 3) 0,8 ($> 0{,}5 \cdot N/N_{max}$)	5	EAD 330232-01-0601 [1], C.3.4.2	EAD 330232-01-0601 [1], C.4.2.4
C2.4 4)	Functioning under alternating shear load	C20/25	0,8	5	EAD 330232-01-0601 [1], C.3.4.3	EAD 330232-01-0601 [1], C.4.2.5
C2.5	Functioning with tension load under varying crack width	C20/25	Δw_1 = 0,0 2) Δw_2 = 0,8	5	EAD 330232-01-0601 [1], C.3.4.4	EAD 330232-01-0601 [1], C.4.2.6

1) If sufficient experience is available for the system, only a reduced number of sizes may be tested. The tests shall be performed at least with size that presents the most adverse head configuration of the product in respect to functioning and ultimate load.

2) Δw_1 = 0,0: The hairline crack is defined in EAD 330232-01-0601 [1], C.3.4.4.

3) The tests may also be conducted in Δw = 0,8 mm at all load levels (N/N_{max}).

4) Always a minimum number of 2 sizes (e.g., smallest and largest) has to be tested.

If the results of tests for category C2 have proved that $\alpha_{N,C2}$, $\beta_{cv,N,C2}$ = 1,0 and $\alpha_{V,C2}$, $\beta_{cv,V,C2}$ =1,0, such results can be considered as valid also for category C1.

For headed anchors according to Figure 1.1.2 functioning under pulsating load according to Table A.2.4.1, C2.3 may be performed with bare anchors not set into concrete (see Figure 2.2.1.1).

The displacements are determined according to EAD 330232-01-0601 [1], C.3.4.2.3.

A.3 Coating of the connection socket - bar

Purpose of the test

The tests are needed for anchors with a material combination according to 1.1 (4) and geometry according to Figure 1.1.1 a) or Figure 1.1.2 to check the coating on the top of the reinforcement bar inside of the socket.

Test conditions

Perform salt spray tests according to EN ISO 9227 [15] with anchors of the medium size:

- 1 anchor without coating, socket arranged opening up
- 1 anchor without coating, socket arranged opening down
- 1 anchor with coating, socket arranged opening up
- 2 anchors with coating, socket arranged opening down

The anchors shall be exposed to the salt spray for at least 1000 h and until the not coated reinforcement bar shows clear indication of corrosion.

After the tests the coating of the reinforcement bar shall be removed.

Assessment

The coating inside the socket on the top of the bar is considered as non-aging if no corrosion on top of the rebar is observed.

ANNEX B GENERAL ASSESSMENT METHODS

B.1 Conversion of failure loads to nominal strength

The conversion of failure loads shall be done according to equations (B.1.1) to (B.1.6) depending on the failure mode.

Concrete failure	$F_{u,c} = F_{u,t} \cdot \left(\frac{f_c}{f_{c,t}}\right)^{0,5}$ with $\frac{f_c}{f_{c,t}} \leq 1,0$	(B.1.1)
Pull-out failure	$F_{u,c} = F_{u,t} \cdot \left(\frac{f_c}{f_{c,t}}\right)^{n}$ with $\frac{f_c}{f_{c,t}} \leq 1,0$	(B.1.2)
	$\psi_{c,50} = \min\left\{\frac{N_{u,m,A2}}{N_{u,m,A1}}; \frac{N_{u,m,A4}}{N_{u,m,A3}}\right\} \leq 1,58$	(B.1.3)
	$n = \log(\Psi_{c,50}) / \log(50/20)$	(B.1.4)
	$\psi_{c,xx} = \left(\frac{f_{ck,xx}}{f_{ck,20}}\right)^{n}$	(B.1.5)
Steel failure	$F_{u,s} = F_{u,t} \frac{f_u}{f_{u,t}}$	(B.1.6)

B.2 Criteria regarding scatter of failure loads

If the coefficient of variation of the failure load in test series according to Table A.1.1.1 exceeds 15% and is not larger than 30%, the following reduction shall be taken into account:

$$\beta_{cv} = \frac{1}{1 + 0,03(cv_F - 15)} \leq 1,0 \qquad \text{(B.2.1)}$$

If the coefficient of variation of the failure load in any test series according to Table A.1.2.1.1 exceeds 20% and is not larger than 30%, the following reduction shall be taken into account:

$$\beta_{cv} = \frac{1}{1 + 0,03(cv_F - 20)} \leq 1,0 \qquad \text{(B.2.2)}$$

If the maximum limit for the coefficient of variation of the failure loads of 30% is exceeded the number of tests shall be increased to meet this limit. This EAD does not cover anchors for which this limit cannot be achieved.

If the coefficient of variation is smaller than the criteria mentioned above, β_{cv} = 1,0.

The smallest result of β_{cv} shall be taken for assessment.

B.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.

$$F_{u,5\%} = F_{u,m}(1 - k_s \cdot cv_F) \tag{B.3.1}$$

$$F_{u,95\%} = F_{u,m}(1 + k_s \cdot cv_F) \tag{B.3.2}$$

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

Note 2: The confidence level of 90% is defined for characteristic resistance of anchors in EN 1992-4 [5] and is, therefore, used for the assessment in this EAD.

B.4 Determination of reduction factors

For test series according to Table A.1.2.1.1 the mean failure loads and 5% - fractile of failure loads shall be compared with the corresponding reference test series of basic tension tests:

$$\alpha = min\left\{\frac{F_{u,m,t}}{F_{u,m,r}};\frac{F_{u,5\%,t}}{F_{u,5\%,r}}\right\} \tag{B.4.1}$$

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

The comparison of the 5%-fractile may be omitted for any number of tests in a test series when the coefficient of variation of the test series is smaller than or equal to the coefficient of variation of the reference test series or if the coefficient of variation in both test series is smaller than 15 %.

The following references may be used for the comparison according to equation (B.4.1):

- $F_{u,m,r}$ = $N_{Rk,c}$ / 0,75
- $F_{u,5\%,r}$ = N_{Rk} (characteristic resistance given in the ETA)

B.5 Criteria for uncontrolled slip under tension loading

The load/displacement curves shall show a steady increase (see Figure B.5.1). A reduction in load and/or a horizontal part in the curve caused by uncontrolled slip of the anchor is not acceptable up to a load of:

Tests in cracked concrete: N_{sl} = 0,7 N_{Ru} (B.5.1)

Tests in uncracked concrete N_{sl} = 0,8 N_{Ru} (B.5.2)

Where the requirement given in equations (B.5.1) and (B.5.2) is not met in a test, meaning $N_{sl,t}$ < 0,7 $N_{Ru,t}$ and $N_{sl,t}$ < 0,8 $N_{Ru,t}$, respectively, the reduction factor α_1 shall be determined according to equations (B.5.3) and (B.5.4).

α_1 = ($N_{sl,t}$ / $N_{Ru,t}$) / 0,7 ≤ 1,0 for cracked concrete (B.5.3)

α_1 = ($N_{sl,t}$ / $N_{Ru,t}$) / 0,8 ≤ 1,0 for uncracked concrete (B.5.4)

with

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

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

This reduction may be omitted if, within an individual series of tests, not more than one test shows a load/displacement curve with a short plateau below the value determined by equation (B.5.1), provided all of the following conditions are met:

- the deviation is not substantial
- the deviation can be justified as uncharacteristic of the anchor behaviour and is due to a defect in the anchor tested, test procedure, etc.
- the anchor behaviour meets the criterion in an additional series of 10 tests.

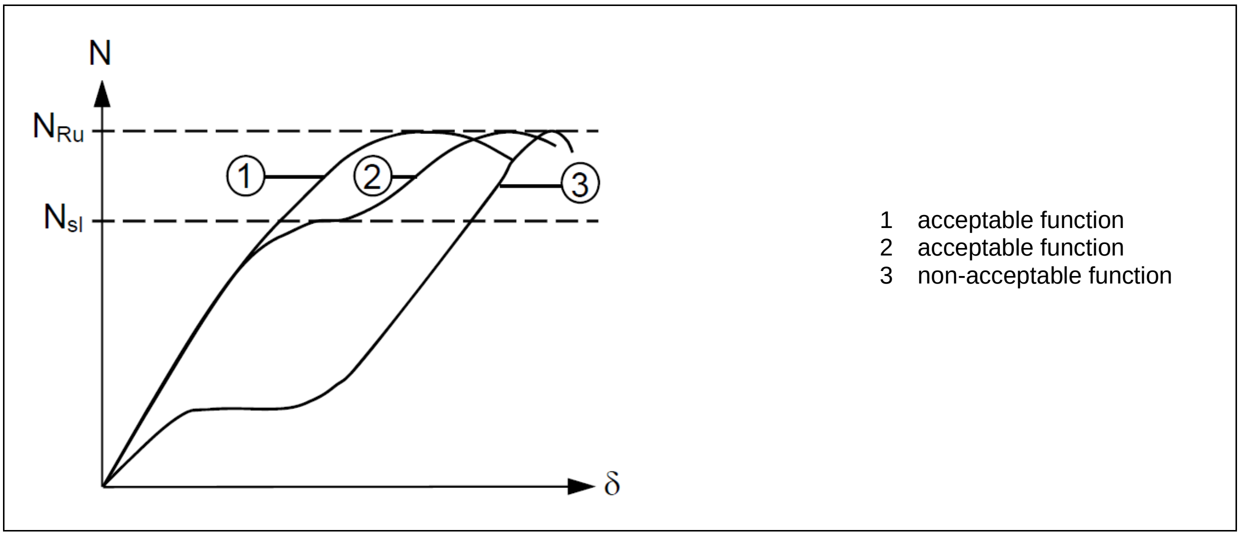
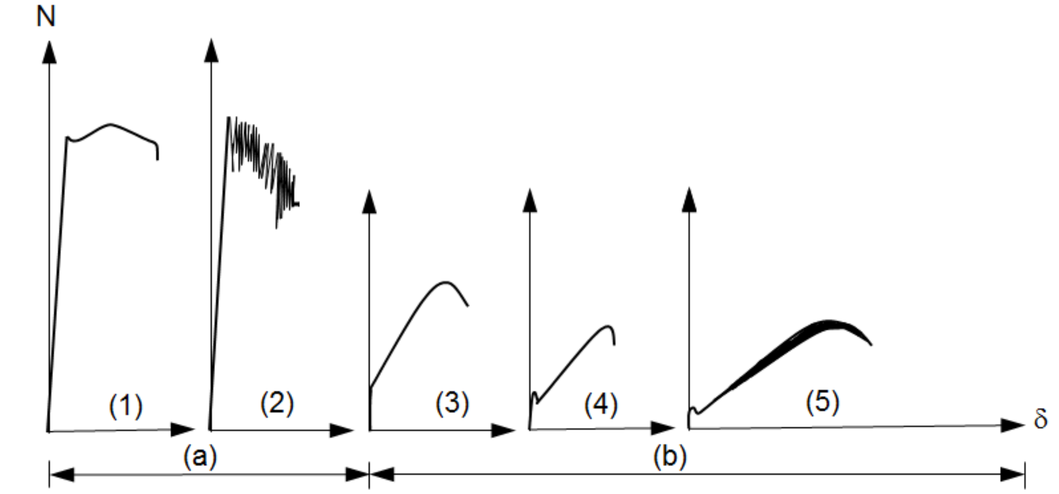


Figure B.5.1 Requirements for the load/displacement curve

Uncontrolled slip can be recognized by a reduction in load and/or a horizontal or nearly horizontal part in the load/displacement curve (compare Figure B.5.1).

The differences in static friction and sliding friction can lead to fluctuations in the load/displacement curve as shown in Figure B.5.2 (2) and (5). Furthermore, in cracked concrete after overcoming the friction resistance the tension load is transferred by mechanical interlock, resulting in a much lower stiffness. This may also lead to a reduction of the load over a rather short displacement interval as shown in Figure B.5.2 (4) and (5). This cannot be considered as uncontrolled slip.

The ultimate load is the maximum load recorded in the test independently of the displacement.



(a uncracked concrete (b) cracked concrete

Figure B.5.2 Typical load/displacement behaviour

Uncontrolled slip can be recognized when the extension of the load/displacement curve is cutting the displacement axis at displacements $\delta \geq 0$ (see Figure B.5.3). The load N_{sl} is defined by the horizontal branch of the load/displacement curve.

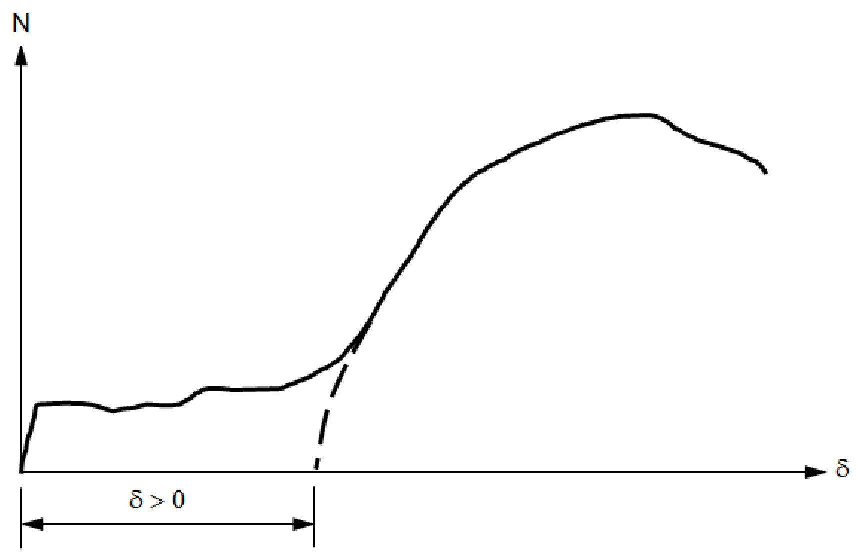


Figure B.5.3 Load/displacement behaviour with uncontrolled slip

Because it may be difficult to draw an extension to a curved line the following simplification may be used. It is an indication of uncontrolled slip if the load/displacement curve falls below the linear connection between the peak load (ultimate load) and the zero point in any area (see Figure B.5.4).

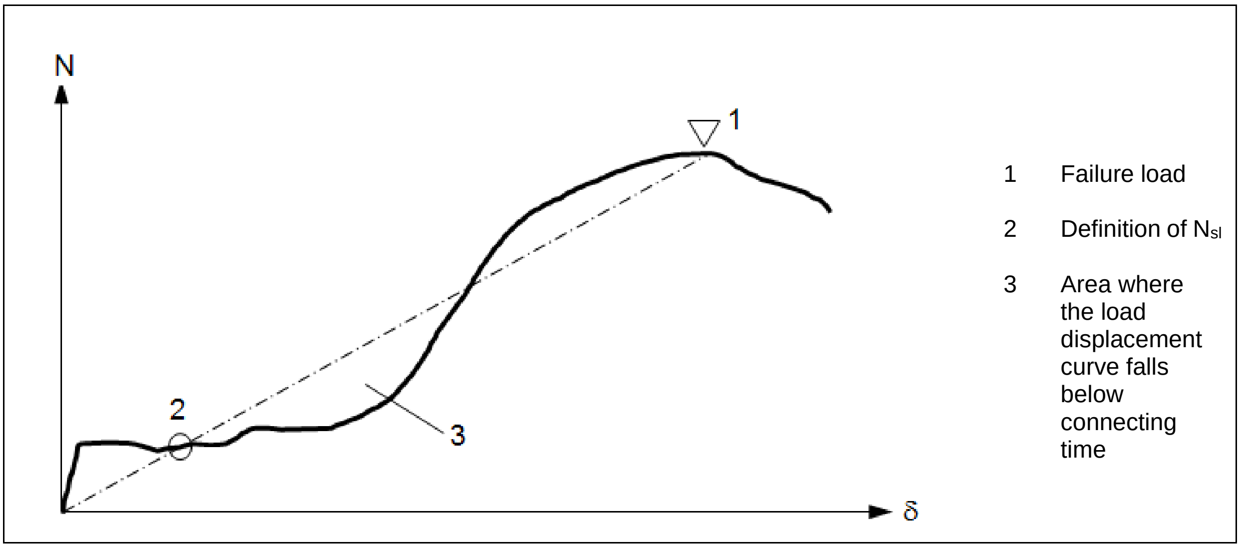


Figure B.5.4 Load/displacement behaviour with uncontrolled slip

The load N_{sl} as given above may be defined as the lower intersection point of the straight line with the load/displacement curve.

In comparing results of assessments according to Figure B.5.3 and Figure B.5.4, the type given in Figure B.5.3 will govern.

B.6 Limitation of the scatter of displacements

In order to properly activate all anchors of an anchor group, the displacement behaviour (stiffness) of individual anchors shall be similar.

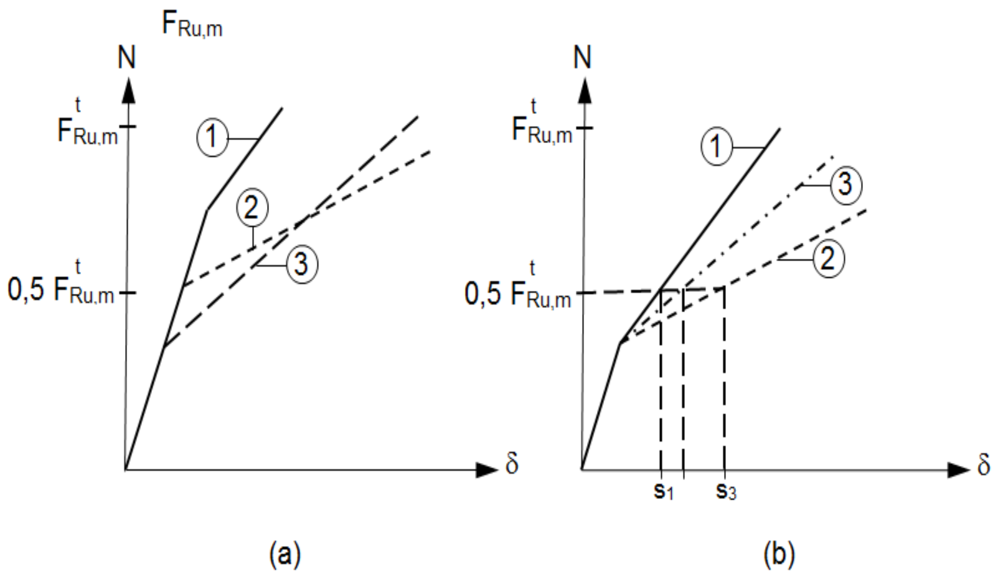
The coefficient of variation of the mean displacement at the load level of 0,5 $N_{u,m}$ in basic tension tests shall fulfil the limit given in equation (B.6.1) and for any other tests the limit given in equation (B.6.2) shall be kept.

$cv_{\delta} \leq 0,25$ (test series according to Table A.1.1.1) (B.6.1)

$cv_{\delta} \leq 0,40$ (test series according to Table A.1.2.1.1) (B.6.2)

The load displacement curves may be shifted according Figure B.6.1 for determination of the displacement at 0,5 $N_{u,m}$.

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



①-③

Examples for load / displacement curves

Figure B.6.1 Influence of pre-stressing on load/displacement curves

(a) original curves

(b) shifted curves for evaluation of scatter at $N = 0{,}5\ N_{u,m}$

ANNEX C DETAILS OF TESTS

C.1 Details of Tests

C.1.1 Test samples

Anchors with inner threads may be supplied without the fixing elements such as screws or nuts, but the manufacturer of the anchor shall specify the screws or nuts to be used. If according to the chosen design method the characteristic resistance for concrete failure is needed, it may be necessary to use screws or bolts of higher strength than those specified, in order to achieve a concrete failure in tests. If higher strength screws or bolts are used, the functioning of the anchors must not be influenced in any way. The use of such test specimens shall be clearly recorded.

C.1.2 Test members

General

Anchors are tested in concrete members using compacted normal weight concrete without fibres with strength classes in the range of C20/25 - C50/60 in accordance with EN 206 [12].

The test members shall comply with the following:

Aggregates

Aggregates shall be of natural occurrence (i.e., non-artificial) and with a grading curve falling within the boundaries given in Figure C.1.2.1. 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 [12] and ISO 6783 [19]).

The boundaries reported in Figure C.1.2.1 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 Technical Assessment Body.

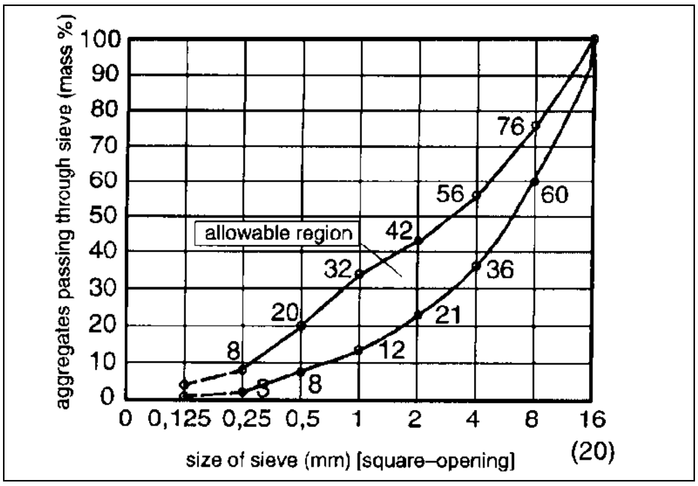


Figure C.1.2.1 Admissible region for the grading curve

Cement

The concrete shall be produced using Portland cement Type CEM I or Portland-Composite cement Type CEM II/A-LL, CEM II/B-LL (see EN 197-1:2014).

Water/cement ratio and cement content

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 mixture.

<u>Concrete strength</u>

For the tests carried out in low strength concrete (strength class C20/25) and high strength concrete (strength class C50/60) the following mean compressive strengths at the time of testing anchors shall be obtained for the two classes:

C20/25	f_c	=	20-30 MPa (cylinder: diameter 150 mm, height 300 mm)
	f_{cube}	=	25-35 MPa (cube:150 x 150 x 150 mm)
C50/60	f_c	=	50-60 MPa (cylinder: diameter 150 mm, height 300 mm)
	f_{cube}	=	60-70 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.

The following conversion factors for concrete compressive strength from cube to cylinder may be used:

C20/25 $$f_c = \frac{1}{1{,}25} f_{cube} \qquad \text{(C.1.2.1)}$$

C50/60 $$f_c = \frac{1}{1{,}20} f_{cube} \qquad \text{(C.1.2.2)}$$

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

$$f_{cube100} = \frac{1}{0{,}95} f_{cube} \qquad \text{(C.1.2.3)}$$

$$f_{cube} = \frac{1}{0{,}95} f_{cube200} \qquad \text{(C.1.2.4)}$$

$f_{cube} = f_{core100}$ (according to EN 13791:2007, 7.1) (C.1.2.5)

For every concreting operation, specimens (cylinder, cube) shall be prepared having the dimensions conventionally employed in the member country. The specimens shall be made, cured and conditioned in the same way as the test members.

Generally, the concrete control specimens shall be tested on the same day as the anchors to which they relate. 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 anchor tests, e.g., at the beginning and at the end of the tests. In this case the concrete strength at the time of testing can be determined by interpolation.

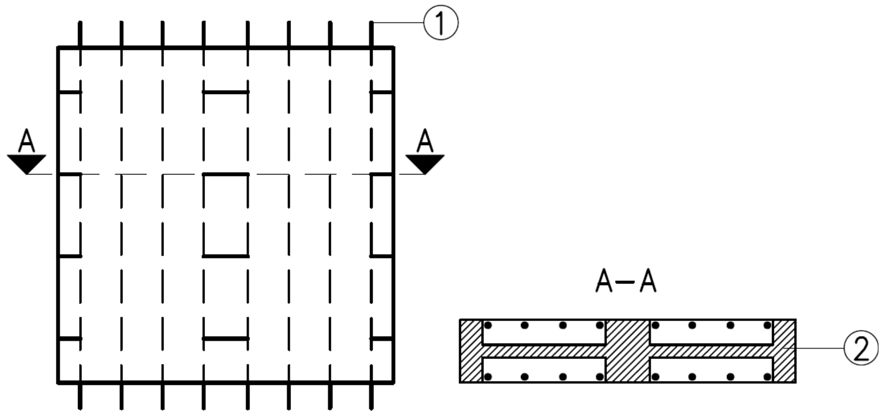
The concrete strength at a certain age shall be measured on at least 3 specimens. The mean value of the measurements governs.

If, when evaluating the test results, there should be doubts whether the strength of the control specimens represents the concrete strength of the test members, at least three cores of 100 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 may be converted into the strength of cubes by equation (C.1.2.5).

<u>Test members for tests in cracked concrete</u>

The tests are carried out on test members with unidirectional cracks. The crack width shall be approximately constant throughout the member thickness. The thickness of the test member shall be $h \geq 2\, h_{ef}$ but at least 100 mm. To control cracking, so-called 'crack-inducers' 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 C.1.2.2.

In the test with variable crack width the reinforcement ratio (top and bottom reinforcement) shall be $\mu = A_s / (b \cdot h) \sim 0{,}01$ and the spacing of the bars ≤ 250 mm.



1 Reinforcement

2 Crack inducers

Figure C.1.2.2 Example of a test member for anchors tested in cracked concrete

<u>Test members for tests in uncracked concrete</u>

Generally, the tests are carried out on unreinforced test members. 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 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°.

<u>Casting and curing of test members</u>

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 compression and tension strength. When testing the anchors, the concrete shall be at least 21 days old.

Test members and concrete specimen shall be stored in the same way.

C.1.3 Unconfined test setup

Unconfined tests allow an unrestricted formation of the rupture concrete cone. An example for an unconfined test setup is shown in Figure C.1.3.1

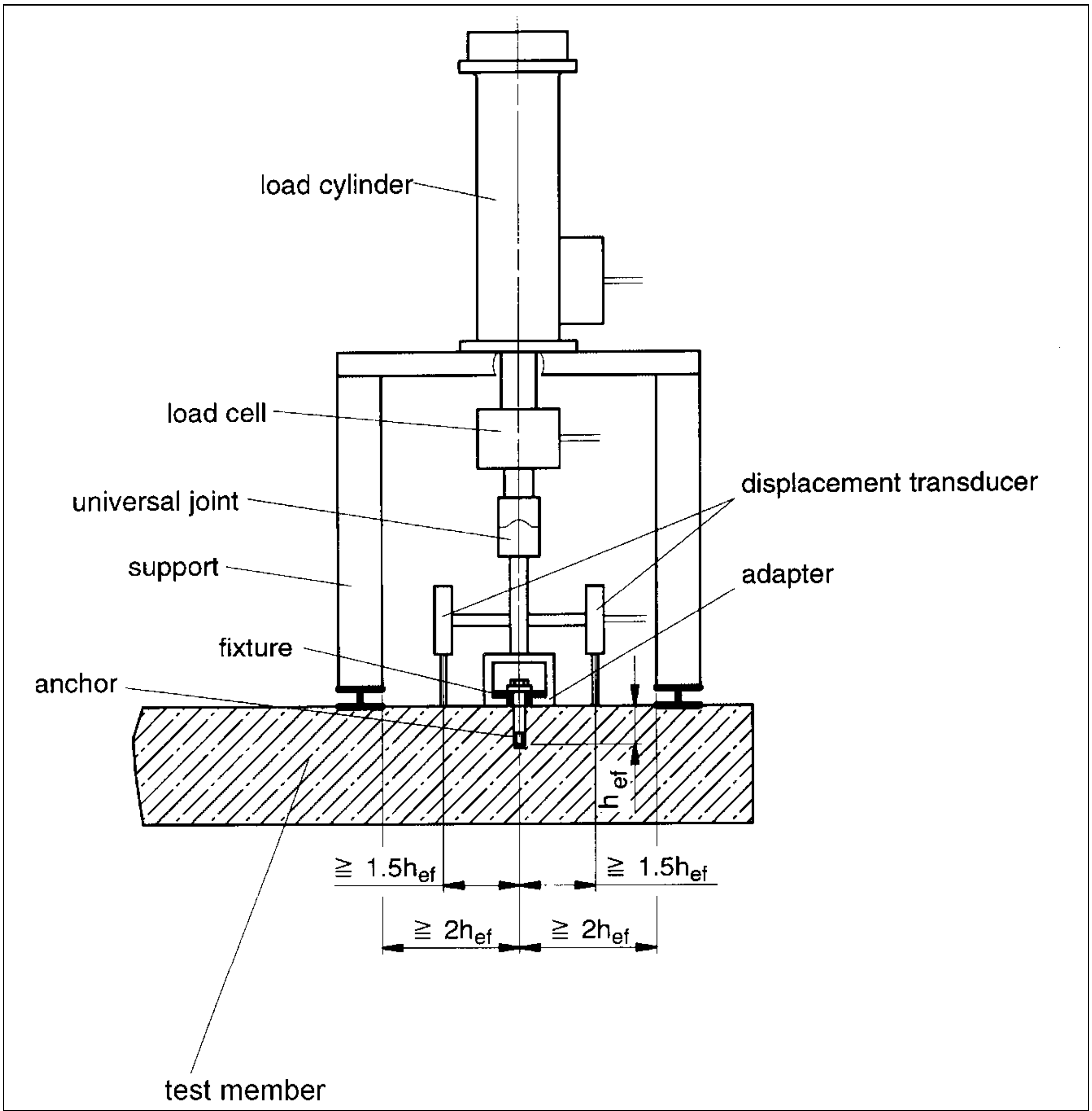


Figure C.1.3.1 Example of a tension test rig for unconfined tests

C.1.4 Installation of anchors

The anchors shall be installed in accordance with the manufacturer's product installation instructions (MPII).

Torque moments, where appropriate, shall be applied to the screw by a torque wrench that has a documented calibration. The measuring error shall not exceed 5 % of the applied torque throughout the whole measurement range.

C.1.5 Test equipment

Tests shall be carried out using measuring equipment having a documented calibration according to international standards. The load application equipment shall be designed to avoid sudden increase in load especially at the beginning of the test. The measurement bias of the measuring chain of the load shall not exceed 2% of the measured quantity value.

Displacements shall be recorded continuously (e.g., by means of electrical displacement transducers) with a measuring bias not greater than 0,020 mm or 2,0 % for displacements > 1 mm.

For unconfined tests the test rigs shall allow the formation of an unrestricted rupture cone. For this reason, the distance between the support reaction and an anchor (single anchor) or an outer anchor (anchor group) respectively shall be at least 2 h_{ef} (tension test) as shown in Figure C.1.3.1 or 2 c_1 (shear test at the edge with load applied towards the edge, with c_1 = edge distance in load direction) as shown in Figure C.1.5.2. Only in shear tests without edge influence where steel failure is expected this distance may be less than 2 c_1.

During all tests, the load shall be applied to the anchor by a fixture representing the conditions found in practice.

In tests on single anchors without edge and spacing influences the centre-to-centre distance and the distances from free edges shall be large enough to allow the formation of an unrestricted rupture cone of vertex angle 120° in the concrete.

During tension tests the load shall be applied concentrically to the anchor. To achieve this, hinges shall be incorporated between the loading device and the anchor. Requirements for the diameter of the clearance hole of the fixture may be given in the EADs. An example of a tension test rig is illustrated in Figure C.1.3.1.

In shear tests (see C.6), the load shall be applied parallel to the concrete surface. A plate with interchangeable sleeves may be used for testing the different sizes of anchors (see Figure C.1.5.1). The sleeves shall be made of quenched steel and have radiused edges (0,4 mm) where in contact with the screw. The height of the sleeves shall be approximately equal to the outside diameter of the anchor. To reduce friction, smooth sheets (e.g., PTFE) with a maximum thickness of 2 mm shall be placed between the plate with sleeve and the test member.

An example of a shear test rig is illustrated in Figure C.1.5.2. As there is a lever arm between the applied load and the support reaction, the test member is stressed by a torsion moment. This shall be taken up by additional reaction forces placed sufficiently far away from the anchor.

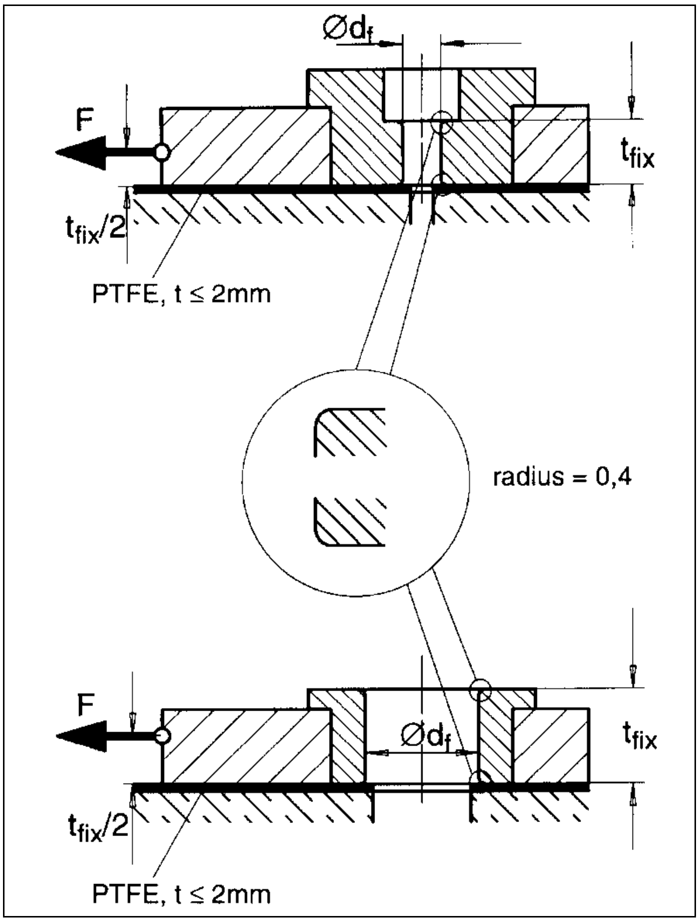
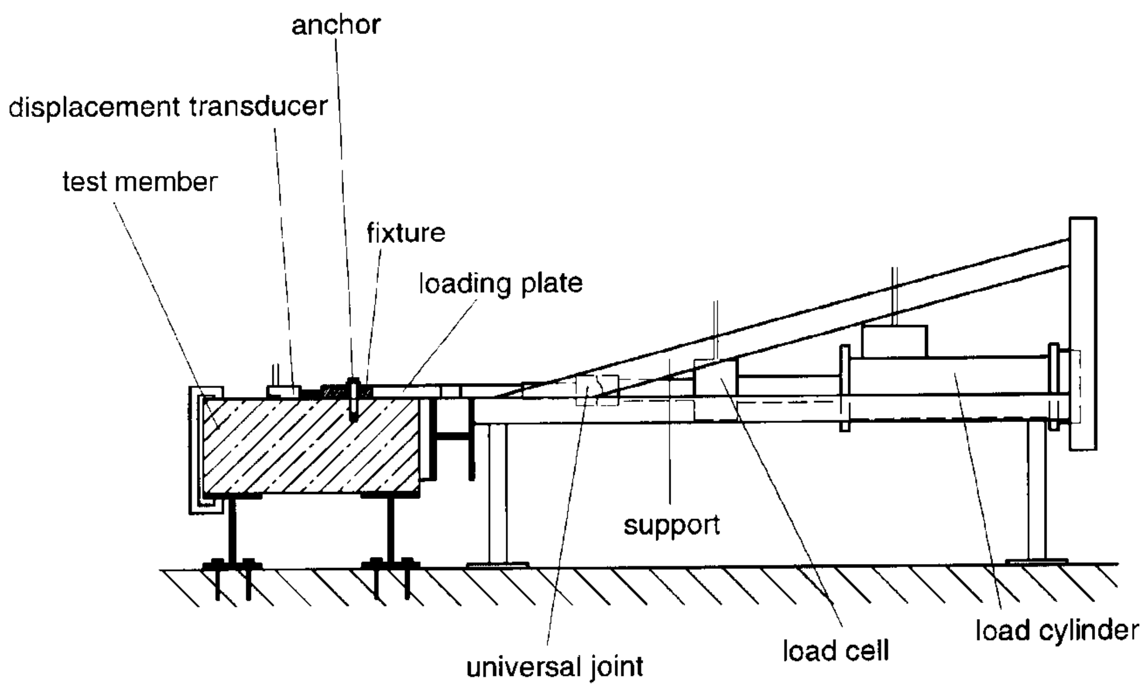


Figure C.1.5.1 Examples of shear test sleeves

<u>**Side view:**</u>



Top view:

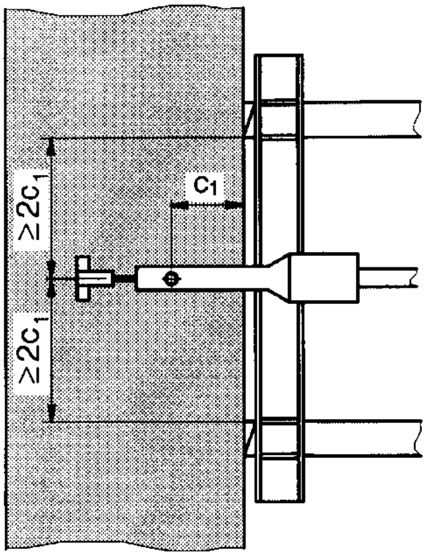


Figure C.1.5.2 Example of a shear test rig

In torque tests (see C.5) the relation between the applied torque moment and the tension force in the bolt is measured. For this, a calibrated load cell with a measuring error ≤ 3,0 % throughout the whole measuring range is used as a fixture (see Figure C.1.5.3).

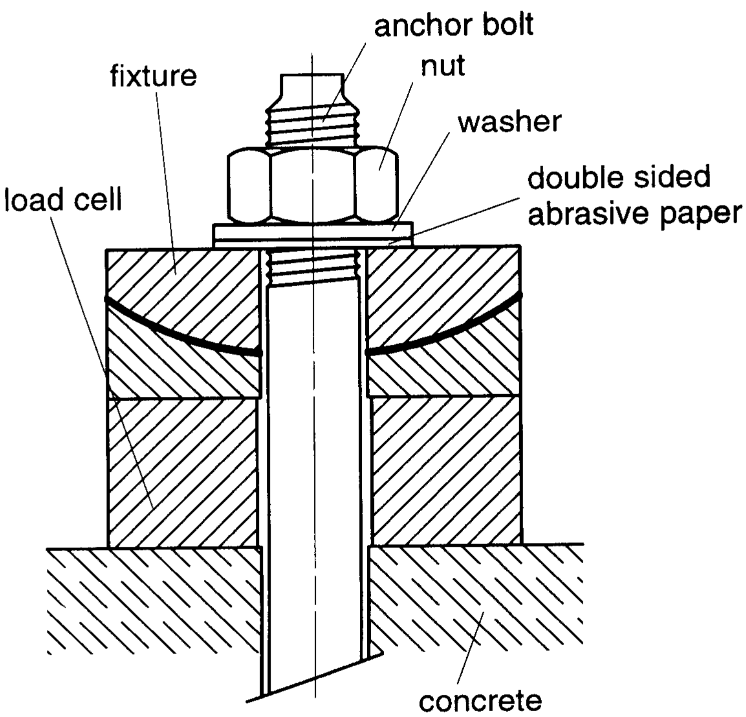


Figure C.1.5.3 Example for torque test (schematic)

Any rotation of the spherical part of the fixture shall be prevented.

C.2 Test procedure – general aspects

The tests in cracked concrete are undertaken in unidirectional cracks at crack width Δw. After installation of the screw the crack is widened to the required crack width while the anchor is unloaded. The crack width shall be set to within +10 % of the specified value.

Use one-sided tolerance for crack width.

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

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

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

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 continuously. The tests may be carried out with load, displacement or hydraulic control. In case of displacement control the test shall be continued beyond the peak of the load/displacement curve to at least 75 % of the maximum load to be measured (to allow the drop of the load/displacement curve). In case of displacement-controlled test setup the speed shall be kept constant.

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

C.3 Tension tests

C.3.1 Single anchor under tension load

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

When testing anchors at the corner of a non-cracked test member, the test rig shall be placed such that an unrestricted concrete failure towards the corner is possible (see Figure C.3.1.1). It may be necessary to support the test rig outside the test member.

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

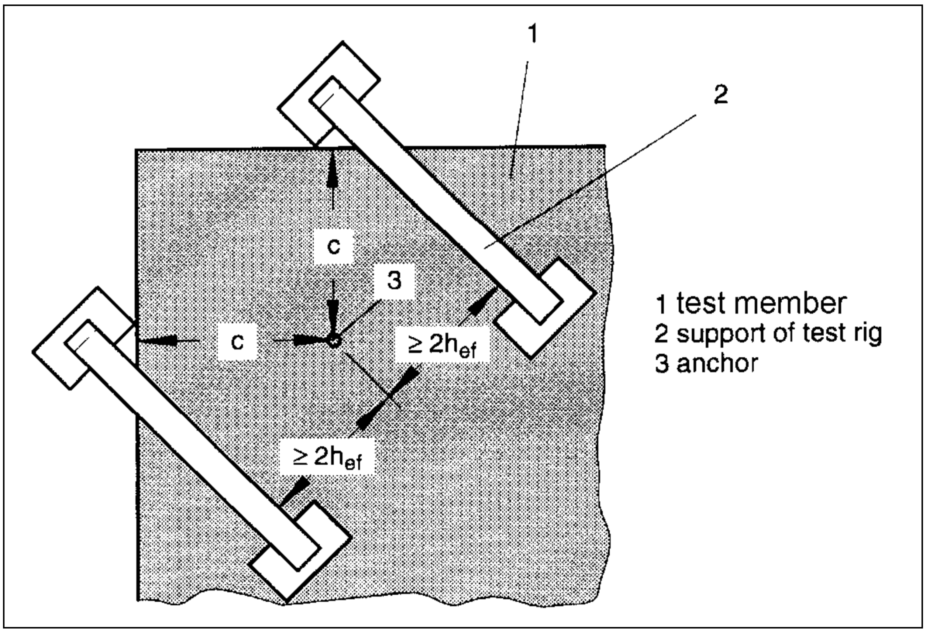


Figure C.3.1.1 Example of the test rig for tension tests on anchors at a corner

C.3.2 Crack cycling under load

The maximum (max N_s) and minimum (min N_s) loads applied to the test member shall be determined such that the crack width under max N_s is Δw_1 = 0,3 mm and under min N_s is Δw_2 = 0,1 mm. To stabilize crack formation, up to 10 load changes varying between max N_s and min N_s may be applied. Then a tensile load N_p according to equation (A.1.2.3.1) is applied to the anchor after opening the crack to Δw_1 = 0,3 mm.

N_p shall remain constant during the test (variation ± 5%). Then the crack is opened and closed 1000 times (frequency approximately 0,2 Hz). During opening of the cracks, the crack width Δw_1 is kept approximately constant (see Figure C.3.2.1); for this purpose, the load max N_s applied to the test member may have to be reduced. The load min N_s is kept constant. Therefore, the crack width Δw_2 may increase during the test (see Figure C.3.2.1). The crack width difference $\Delta w_1 - \Delta w_2$, however, shall be ≥ 0,1 mm during the 1000 movements of the crack. If this condition cannot be fulfilled with Δw_1 = 0,3 mm, then either min N_s shall be reduced or Δw_1 shall be increased accordingly.

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

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

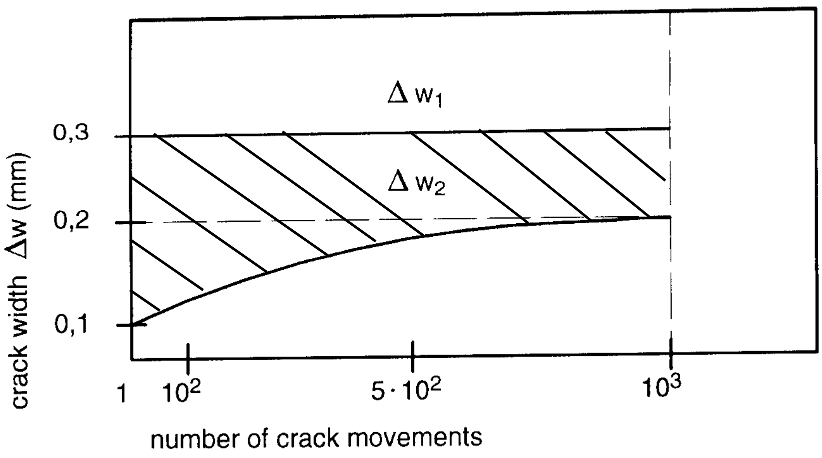


Figure C.3.2.1 **Allowable crack opening variations during the crack movement test**

C.3.3 Repeated loads

The test is performed in non-cracked concrete. The anchor is subjected to 10^5 load cycles with a maximum frequency of approximately 6 Hz. During each cycle the load shall change as a sine curve between maximum and minimum value, i.e., max N according to equation (A.1.2.4.1) and min N according to equation (A.1.2.4.2), respectively, given in the relevant EAD. The displacements shall be measured during the first loading up to max N and then either continuously or at least after 1, 10, 10^2, 10^3, 10^4 and 10^5 load cycles.

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

C.4 Test for minimum edge distance and spacing

The tests shall be performed in uncracked concrete of strength class C20/25 (minimum concrete strength class).

The tests are carried out with double anchors with a spacing $s = s_{min}$ and an edge distance $c = c_{min}$. The double anchors are placed with a distance $a > 3\ h_{ef}$ between neighbouring groups. The dimensions of the fixture shall be width = 3 d_f, length = s_{min} + 3 d_f and thickness ≅ d_f (d_f as required in the relevant EAD).

The tests may be performed with higher steel strength of the screw to avoid steel failure of the screw.

The anchors shall be torqued alternately in steps of 0,2 T_{inst}. 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 shall be measured for both anchors. Furthermore, the torque moment at the formation of the first hairline crack at one or both anchors and the maximum torque moment that can be applied to the two anchors shall be recorded.

C.5 Maximum torque moment

The tests may be performed with higher steel strength of the screw to avoid steel failure of the screw.

The torque moment is applied with a calibrated torque wrench until it cannot be increased further or at least to 1,3 T_{inst}.

The tension force in the screw shall be measured as a function of the applied torque moment.

C.6 Tests under shear load

After installation, the anchor is connected to the test rig without gap between the anchor and the interchangeable sleeve in the loading plate and is then loaded to failure. The displacements of the anchor relative to the concrete shall be measured in the direction of the load application, e.g., by use of a displacement transducer fixed behind the anchor (seen from the direction of load application) on the concrete (see Figure C.1.5.2).

When testing in cracked concrete, C.2 applies. However, the crack widths shall be measured at a distance of approximately h_{ef} behind the anchor. The load shall be applied in the direction of the crack towards the edge.

If the anchor is requested to be assessed for different embedment depths for a specific diameter, the most unfavourable condition shall be tested. If the most unfavourable condition cannot be determined all embedment depths have to be tested.

Below the fixture, a sheet of PTFE (sliding layer) with a maximum thickness of 2 mm shall be placed. The shear force may be applied to the front or back side of the fixture.

The load on the anchor and the shear mean displacement of the fixture relative to the concrete outside the rupture cone shall be measured.

C.7 Test records

The following information shall be recorded for the particular test series. Since only relevant parameter shall be followed for each test series this table is meant as a check list.

1. Description test specimen		
Anchor type		Manufacturer, trade name, dimensions, material
status of specimen		serial product / prototype
production lot / batch		
Steel parts	Mechanical properties (tensile strength, yield limit, fracture elongation), type of coating	e.g., (f_u = 970 N/mm², R_{p02} = 890 N/mm², A_5 = 18%, galvanized 5 μm, functional coating)
2. Test member		
element type / drawing no.		sketch according to "examples cross section" and "example for test member with bond breaking pipes"
dimensions		(l / w / h)
concrete mix		e.g., cement, aggregate type and content, w/c-ratio
curing conditions		
age of concrete member at time of testing		
type and grade of reinforcement		
longitudinal reinforcement quantity		
longitudinal reinforcement size		
pre-debonding length		
type of bond breaker sheets		e.g., wood/ plastic/ metal/ none
reinforcement spacing		e.g., 254 mm horizontal, 50 mm from edges
distribution of reinforcement over depth of member		e.g., two rows, 100 mm from top and bottom
reinforcement is distributed double symmetrically		
3. Setting/ Installation information		
ratio member thickness / h_{nom}		e.g., 2,2
place of anchor installation		formwork side
diameter of support		d = 450 mm
spacing between rebar and anchor		200 mm
nominal / effective embedment depth h_{nom}/h_{ef}		
thickness of fixture (t_{fix}) [mm]		
clearance hole d_f [mm]		
installation torque T_{Inst} [Nm]		
position of the anchor over load transfer zone in the crack		sketch
verification method of anchor position in crack		e.g., sketch of crack formation over load transfer zone

4. Test parameter	
crack opening mechanism	Describe how the crack width in the area of the load transfer zone is ensured
loading/ unloading rates [sec.]	e.g., 2,5 / 2,5
measuring of anchor displacement	e.g., continuously / at the anchor
no. of replicates tested in one specimen/ crack	e.g., 6 per specimen / 2 per crack
amount / type of crack width measurement	e.g., 4 / capacitive sensor
position of the crack width sensors	sketch with distances
determination of crack width at anchor	e.g., (linear interpolation)
Diagram containing: - crack width at the anchor position for the top and bottom of the load transfer zone - plot the cycles in normal logarithmic scale - plot the upper and the lower crack width	
measuring uncertainty for crack width transducers	e.g., ±0,005 mm.
minimal frequency during the test	
maximal frequency during the test	
5. Test results	
Load at failure	
Displacement at failure	
Displacement at 50% of failure load	
Diagram with load displacement curve	
Failure mode (If initial failure is not clear, a combination of failure modes may be reported.)	- (cc) concrete cone failure – give diameter and depth of concrete cone - (sp) splitting– test condition for tests in uncracked concrete in case when a first crack of the concrete is observed - (po) pull-out – pull-out failure may be combined with a shallow concrete breakout - (s) steel failure– define position of the steel rupture over length of the anchor - (pr) pry-out – concrete breakout opposite to the load direction (may occur for shallow embedment)
Torque at failure (torque tests only)	
Diagram with displacement over time of testing (long term tests only)	