EOTA

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European Assessment Document for

Cast-in anchor bolts

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) 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 anchor bolts type 1 and type 2 made of steel, stainless steel, ribbed reinforcing steel and stainless ribbed reinforcing steel, one or two hexagonal nuts and respectively one or two washers (in the following referred to as anchor bolts) with the following specifications:

Anchor bolt type 1:

- single anchor bar according to Figure 1.1.1a
- one of the ends of the anchor bar is provided with an anchor head, the other one with a thread
- washers similar to EN ISO 7090[1] [11]
- hexagonal nuts according to EN ISO 4032 [12]

Anchor bolt type 2:

- multiple anchor bars according to Figure 1.1.1b
- one of the ends of the anchor bar is provided with an anchor head
- 2, 3 or 4 anchor bars are symmetrically arranged around and welded to a central threaded bar made of steel or stainless steel
- all anchor bars welded to the central threaded bar are of the same material, size and length
- washers similar to EN ISO 7090 [11]
- hexagonal nuts according to EN ISO 4032 [12]

Anchor bars are made of:

- ribbed reinforcing steel B500B (or B500C) according to EN 1992-1-1 [13], Annex C with the following characteristics:

yield strength:	f_{yk}	≥ 500 N/mm²	(≥ 500 N/mm²)
ratio of tensile strength over yield strength:	$(f_u/f_y)_k$	≥ 1,08	(≥ 1,15 ≤ 1,35)
characteristic elongation at maximum force	ε_{uk}	≥ 5%	(≥ 7,5 %)

- steel according to EN 10025 series [9];
- stainless ribbed reinforcing steel;
- stainless steel according to EN 10088 series [10].

The tensile strength of anchor bars is $f_{uk} \leq 1000$ N/mm².

The ratio between head and diameter of the anchor bar is $d_h / d \geq 1{,}6$.

The inclination angle of the head of the anchor bar is $0° \leq \beta \leq 30°$.

Central threaded bars are made of:

- steel similar to EN 10025 series [9];
- stainless steel according to EN 10088 series[10].

Washers are made of:

- steel according to EN 10025 series [9];
- stainless steel according to EN 10088 series [10].

Hexagonal nuts are made of:

- steel with strength class 8 and 10 according to EN ISO 898-2 [14];
- stainless steel with strength class A4-50 or A4-70 according to EN ISO 3506-2 [15]

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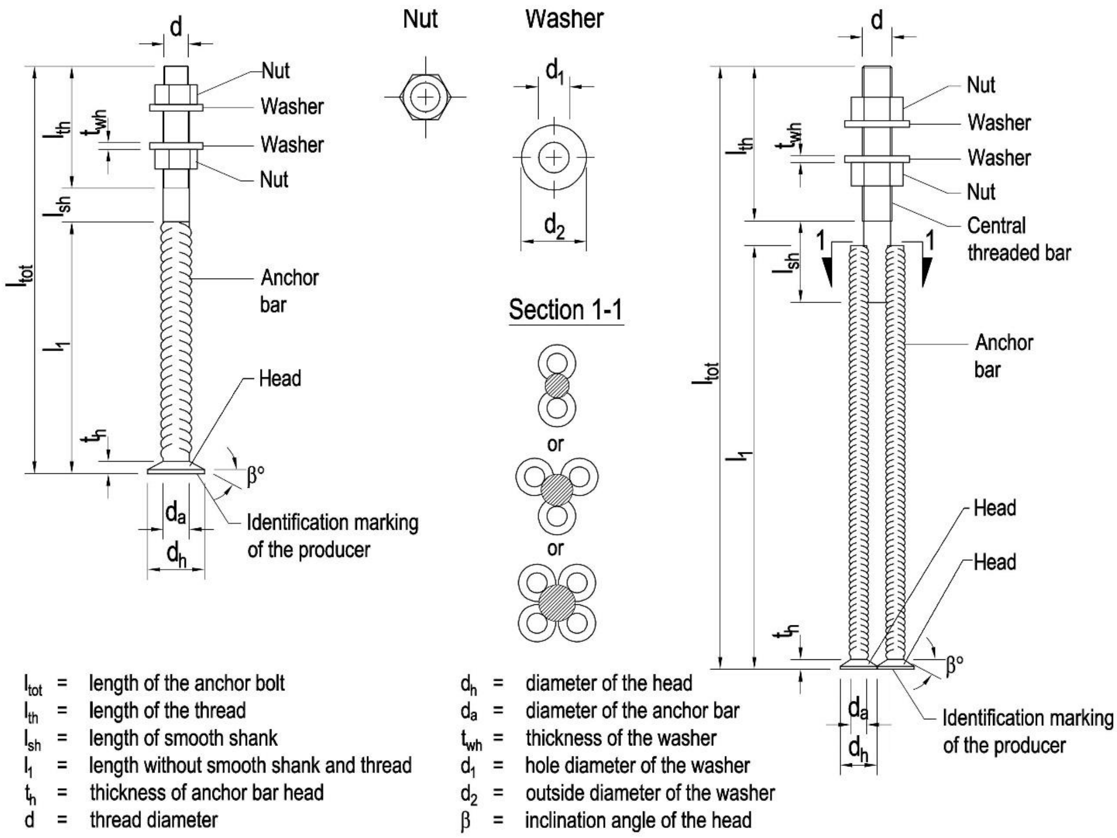
1 All undated references to standards or to EADs in this EAD are to be understood as references to the dated versions listed in chapter 4.



a) anchor bolt type 1 b) anchor bolt type 2

Figure 1.1.1: Example for anchor bolt with typical dimensions

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

The product is not fully covered by EAD 330924-00-0601 [21]. Compared to the previous version of the EAD, the following changes are introduced:

- Addition of scope for steel, hot-dip galvanized steel, stainless steel and stainless ribbed reinforcing steel,
- Addition of scope and assessment for anchor bolt type 2 with multiple anchor bars around one central threaded bar,
- Deletion of tests for checking characteristic resistance under tension due to concrete cone failure without influence of spacing and edge distance for sizes > 25 mm,
- Substitution of CEN/TS 1992-4 by EN 1992-4 concerning scope, nomenclature, referenced cylinder concrete strength et al.

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use of the construction product

1.2.1 Intended use

The anchor bolts are intended to be used for general application according to Figure 1.2.1.1a or for steel to steel contact according to Figure 1.2.1.1b. Depending on the application one nut and washer or two nuts and washers are used for installation.

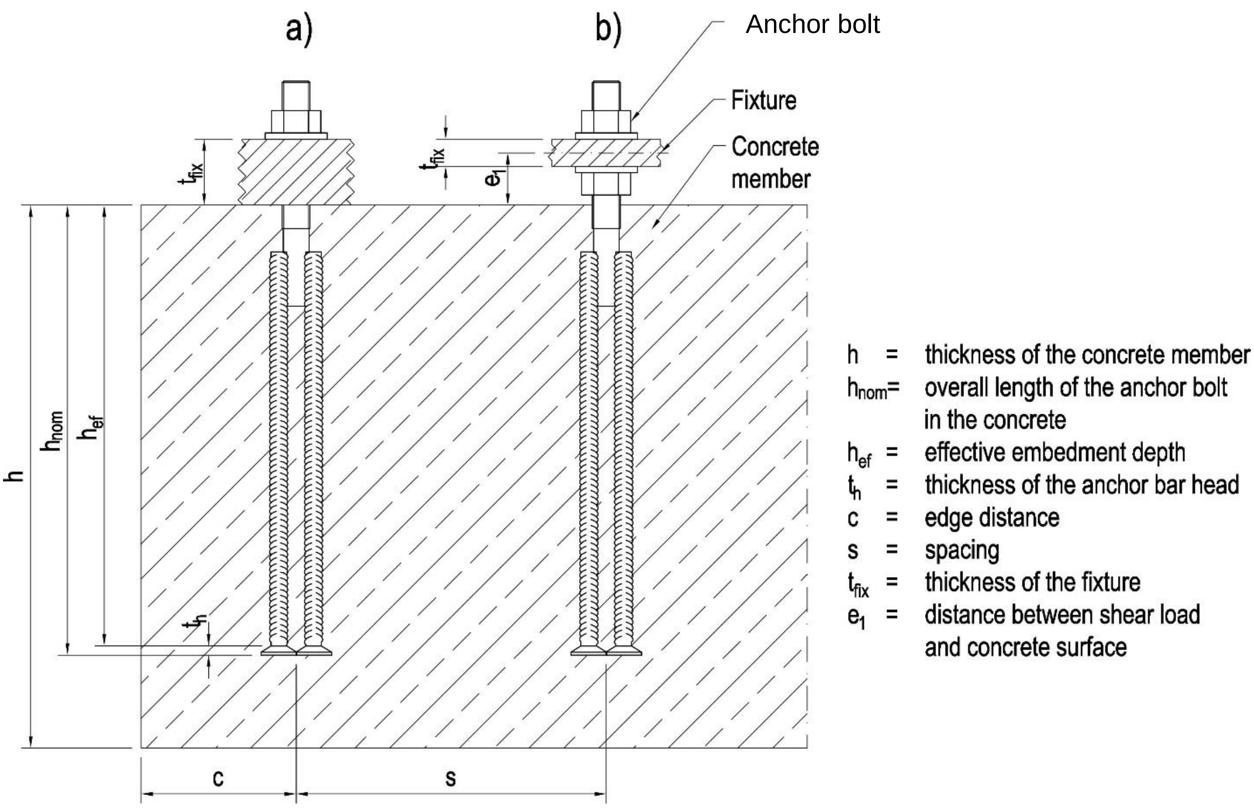


Figure 1.2.1.1: Intended use of the anchor bolt
a) General b) Steel to steel contact

This EAD covers the following specifications of the intended use:

- anchor bolt types 1 and 2 according to Figure 1.1.1 cast-in in reinforced compacted normal weight concrete of a minimum strength class of C20/25 and a maximum strength class of C90/105 without fibres according to EN 206 [4]
- cracked and uncracked concrete
- static and quasi-static loading

Specific provisions according to EN 1992-4 [1], 7.2.1.7 can be taken to prevent splitting of the concrete.

Depending on the materials used for the anchor bolt, the anchor bolt is used in structures subjected to the following conditions:

(1) Anchor bars made of steel or ribbed reinforcing steel, if applicable central threaded bar, washer and hexagonal nut are made of steel:
Anchor bolts for use in structures subject to dry internal conditions.

(2) Anchor bars made of steel or ribbed reinforcing steel, if applicable central threaded bar, washer and hexagonal nut are made of steel hot dip galvanised according to EN ISO 1461 [16] or EN ISO 10684 [17] with at least 50 μm thickness:
Anchor bolts for use in structures subject to internal conditions with usual humidity (exceptional permanently damp conditions and application under water).

(3) Anchor bars made of steel or ribbed reinforcing steel, if applicable central threaded bar, washer and hexagonal nut are made of steel with concrete cover according to EN 1992-1-1 [13]:
Anchor bolts for use in structures subject to appropriate exposition relating to the concrete cover

(4) Anchor bars made of stainless steel or stainless ribbed reinforcing steel, if applicable central threaded bar, washer and hexagonal nut are made of stainless steel:
Anchor bolts for use according to EN 1993-1-4 [18] relating to the corrosion resistance class (CRC) of all parts of the anchor bolts.

In this EAD the assessment is made to determine the characteristic values of the anchor bolt for calculation according to EN 1992-4 [1].

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 anchor bolt 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.

1.3 Specific terms used in this EAD

1.3.1 Symbols

$\sum A_h$	[mm²]	=	summarized projected load bearing area of all heads of the anchor bars of an anchor bolt
A_s	[mm²]	=	stressed cross section of the thread of the anchor bar respectively the central threaded bar (see relevant equation)
$\sum A_{s,a}$	[mm²]	=	summarized stressed cross-section of all anchor bars of anchor bolt type 2
A_5	[-]	=	rupture elongation of steel
$\sum A_w$	[mm²]	=	summarized stress area of the weld joints of anchor bars
β	[°]	=	inclination angle of the head
c_1	[mm]	=	edge distance in direction 1
c_2	[mm]	=	edge distance in direction 2

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.

$c_{cr,N}$	[mm]	=	edge distance for ensuring the transmission of the characteristic resistance in tension of a single anchor bolt without edge and spacing effects in case of concrete cone failure
$c_{cr,sp}$	[mm]	=	edge distance for ensuring the transmission of the characteristic resistance in tension of a single fastener without edge and spacing effects in case of splitting failure
c_{min}	[mm]	=	minimum allowable edge distance
cv_F	[-]	=	coefficient of variation [%] related to loads
d	[mm]	=	thread diameter of the anchor bar respectively the central threaded bar (see relevant equation)
d_h	[mm]	=	diameter of the anchor bar head
d_a	[mm]	=	diameter of the anchor bar(s) (correspond for reinforcing bars to ϕ in EN 1992-1-1)
d_{nom}	[mm]	=	outside diameter of the fastener
d_1	[mm]	=	hole diameter of the washer
d_2	[mm]	=	outside diameter of the washer
d_f	[mm]	=	diameter of clearance hole in the fixture
d_m	[mm]	=	minor diameter according to EN ISO 7093-1 [8] (correspond to d_3 in that standard)
d_p	[mm]	=	basic pitch diameter according to EN ISO 7093-1 [8] (correspond to d_2 in that standard)
d_s	[mm]	=	equivalent diameter of the stressed cross section of the thread
δ_{N0}	[mm]	=	Short-term displacement of the anchor bolt at the concrete surface relative to the concrete surface outside the failure area in direction of the load under tension load. The displacement includes steel and concrete deformations.
$\delta_{N\infty}$	[mm]	=	Appropriate long-term displacement under tension load
δ_{V0}	[mm]	=	Short-term displacement of the anchor bolt at the concrete surface relative to the concrete surface outside the failure area in direction of the load under shear load. The displacement includes steel and concrete deformations.
$\delta_{V\infty}$	[mm]	=	Appropriate long-term displacement under shear load
e_1	[mm]	=	distance between shear load and concrete surface
$\varepsilon_{uk,a}$	[-]	=	characteristic elongation at maximum force of the anchor bar
F	[N]	=	force in general (for the relevant test series N or V applies)
f_c	[N/mm²]	=	nominal characteristic concrete compressive strength (based on same test members as $f_{c,test}$)
$f_{c,test}$	[N/mm²]	=	mean value of concrete compressive strength in a test series with test members stored and tested at the same time as the test for which the failure loads have to be converted
f_{ck}	[N/mm²]	=	nominal characteristic concrete compressive cylinder strength
$f_{ck,test}$	[N/mm²]	=	concrete compressive strength at the time of testing measured on cylinders

F_{Rk} (N_{Rk},V_{Rk})	[N]	=	characteristic resistance (under tension, under shear load) stated in the ETA for different failure modes
$F_{u,m,test}$	[N]	=	mean failure (ultimate) load in a test series
$F_{u,c}$	[N]	=	converted concrete failure (ultimate) load in a test
$F_{u,s}$	[N]	=	converted steel failure (ultimate) load in a test
$F_{u,test}$	[N]	=	failure (ultimate) load in a test
$F_{u,5\%,20}$	[N]	=	5% fractile of failure (ultimate) loads of a test series normalised to concrete strength C20/25
$F_{u,5\%}$ (N_u,5%, V_u,5%)	[N]	=	5% fractile of failure (ultimate) loads (tension or shear) of a test series
$F_{u,95\%}$	[N]	=	95% fractile of failure (ultimate) loads of a test series
$F_{u,m}$	[N]	=	mean value of failure (ultimate) loads of a test series
$f_{uk,test}$ or $f_{u,test}$	[N/mm²]	=	characteristic tensile strength of the anchor bar respectively the central threaded bar in the test (see relevant equation)
f_{uk} or f_u	[N/mm²]	=	nominal characteristic tensile strength of the of the anchor bar respectively the central threaded bar (see relevant equation)
$f_{vw,k}$	[N/mm²]	=	nominal characteristic steel ultimate tensile strength of the weld
$f_{yk,test}$	[N/mm²]	=	characteristic tensile yield strength of the anchor bar respectively the central threaded bar in the test (see relevant equation)
f_{yk}	[N/mm²]	=	nominal characteristic steel yield strength of the of the anchor bar respectively the central threaded bar in the test (see relevant equation)
h	[mm]	=	thickness of the concrete member
h_{ef}	[mm]	=	effective embedment depth
h_{min}	[mm]	=	minimum allowed thickness of concrete member
h_{nom}	[mm]	=	overall length of the anchor bolt in the concrete
$k_{cr,N}$	[-]	=	factor to take into account the influence of load transfer mechanism for applications in cracked concrete under tension load
$k_{ucr,N}$	[-]	=	factor to take into account the influence of load transfer mechanism for applications in uncracked concrete under tension load
k_s	[-]	=	coefficient for estimation of fractiles for normal distribution when the population standard deviation s is unknown and for confidence level of 90% according to ISO 16269-6 [6]
k_6	[-]	=	relation factor between characteristic resistance to steel failure under shear load and characteristic resistance to steel failure under tension load
k_7	[-]	=	factor to take into account the influence of load transfer mechanism in a group of anchors under shear
k_8	[-]	=	ratio of characteristic resistance for concrete pry-out failure to characteristic resistance for concrete cone failure
k_{11}	[-]	=	exponent for combined tension and shear load

l_1	[mm]	=	length of the anchor bolt without smooth shank and thread
l_f	[mm]	=	effective length of the anchor bolt
l_{th}	[mm]	=	length of the thread
l_{tot}	[mm]	=	total length of the anchor bolt
l_{sh}	[mm]	=	length of the shank
$M^0_{Rk,s}$	[Nm]	=	characteristic bending resistance
N	[N]	=	normal force (+N = tension force)
N_v	[N]	=	prestressed tensile load due to installation torque
$N_{u,m}$	[N]	=	mean (failure) ultimate tensile load of the tests in concrete
n	[-]	=	number of tests of a test series
n_a	[-]	=	number of anchor bars in an anchor bolt type 2
$s_{cr,N}$	[mm]	=	spacing for ensuring the transmission of the characteristic resistance in tension of a single fastener without edge and spacing effects in case of concrete cone failure
$s_{cr,sp}$	[mm]	=	spacing for ensuring the transmission of the characteristic resistance in tension of a single fastener without edge and spacing effects in case of splitting failure
s_{min}	[mm]	=	minimum allowable spacing
s_1	[mm]	=	spacing of fasteners in an fastener group in direction 1
s_2	[mm]	=	spacing of fasteners in an fastener group in direction 2
T	[Nm]	=	installation torque
T_{inst}	[Nm]	=	maximum recommended installation torque
t_{fix}	[mm]	=	thickness of fixture
t_h	[mm]	=	thickness of anchor bar head
t_{wh}	[mm]	=	thickness of the washer (correspond to h in EN ISO 7089 [22] and EN ISO 7093-1 [8])
V	[N]	=	shear force
W_{el}	[mm³]	=	elastic section modulus of thread calculated with the equivalent diameter of the stressed cross section
γ_M	[-]	=	recommended material partial factor according to EN 1992-4 [1] of the corresponding failure mode

1.3.2 Indices

cr	=	cracked concrete
c	=	concrete
calc	=	calculated value
cb	=	concrete blowout

fi	=	fire
p	=	pull-out
s	=	steel
sp	=	splitting
test	=	tested result
u	=	ultimate – situation when failure occurs
ucr	=	uncracked concrete
5%	=	5% fractile of a test series
95%	=	95% fractile of a test series
20	=	related to concrete strength class C20/25

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 anchor bolt is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the cast-in anchor bolt 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 resistance under static and quasi-static tension load			
1	Characteristic resistance to steel failure under static and quasi-static tension load	2.2.1	Level $N_{Rk,s}$ [kN]
2	Characteristic resistance to pull-out failure under static and quasi-static tension load	2.2.2	Level $N_{Rk,p}$ [kN]
3	Characteristic resistance to concrete cone failure under static and quasi-static tension load	2.2.3	Level $k_{cr,N}$, $k_{ucr,N}$ [-], h_{ef}, $c_{cr,N}$, $s_{cr,N}$ [mm]
4	Edge distance to prevent splitting failure	2.2.4	Level $c_{cr,sp}$, $s_{cr,sp}$ [mm]
5	Minimum edge distance, spacing and thickness of concrete member	2.2.5	Level c_{min}, s_{min}, h_{min} [mm]
6	Maximum installation torque	2.2.6	Level T_{inst} [Nm]
Characteristic resistance under static and quasi-static shear load			
7	Resistance to steel failure under static and quasi-static shear load	2.2.7	Level $V^0_{Rk,s}$ [kN], k_7 [-], $M^0_{Rk,s}$ [Nm]
8	Resistance to concrete edge failure under static and quasi-static shear load without supplementary reinforcement	2.2.8	Level l_f, d_{nom} [mm]
9	Resistance to pry-out failure under static and quasi-static shear load	2.2.9	Level k_8 [-]
Characteristic resistance under static and quasi-static tension and/ or shear load			
10	Combined tension and shear load under static and quasi-static load	2.2.10	Level k_{11} [-]
Displacement under static and quasi-static tension or shear			
11	Displacement under static and quasi-static tension or shear load	2.2.11	Level δ_{N0}, $\delta_{N\infty}$, δ_{V0}, $\delta_{V\infty}$ [mm]
Basic Works Requirement 2: Safety in case of fire			
12	Reaction to fire	2.2.12	Class
13	Resistance to fire	2.2.13	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 Characteristic resistance to steel failure under static and quasi-static tension load

Purpose of the assessment

Determination of the characteristic resistance to steel failure of the anchor bolt type 1 and type 2 on the basis of calculations and tests according to Table A.1.1, Line S1 on thread and head according to Figure 1.1.1 for anchor bolt diameters given in Table A.1.1.

Assessment method Anchor bolt type 1

The characteristic resistance for steel failure shall be determined for the thread diameter as follows and shall be confirmed by the 5%-fractile of the failure loads of the test series of Table A.1.1, line S1a.

$N_{Rk,s,calc}$	=	$A_s \cdot f_{uk}$	[N]	(2.2.1.1)
A_s	=	stressed cross section of the thread of the anchor bar	[mm²]	
f_{uk}	=	nominal characteristic steel ultimate tensile strength of anchor bar	[N/mm²]	

The tests shall be carried out on anchors not cast into concrete according to Table A.1.1, Line S1a with a tension load applied to thread and head. A typical test setup is shown in Figure A.4.1. Apply the load until failure.

Determine the 5%-fractile of the failure loads. This value shall be normalized to account for over-strength of tested samples according to equation (B.1.2).

If the normalized 5%-fractile of the failure loads in the series S1a is larger than $N_{Rk,s,calc}$ than:

$N_{Rk,s}$	=	$N_{Rk,s,calc}$ /1000	[kN]
else			
$N_{Rk,s}$	=	$N_{u,5\%}$	[kN]
$N_{u,5\%}$		normalized (according to equation (B.1.2)) 5%-fractile of the failure loads measured in the test series S1a	[kN]

Assessment method Anchor bolt type 2

The characteristic resistance for steel failure shall be determined as follows and shall be confirmed by the 5%-fractile of the failure loads of the test series of Table A.1.1, line S1.

$$N_{Rk,s,calc} = MIN \begin{Bmatrix} A_s \cdot f_{uk} \\ \sum A_w \cdot f_{vw,k} \\ \sum A_{s,a} \cdot f_{uk,a} \end{Bmatrix} \quad [N] \qquad (2.2.1.2)$$

A_s	=	stressed cross section of the thread of the central threaded bar	[mm²]
f_{uk}	=	nominal characteristic steel ultimate tensile strength of the central threaded bar	[N/mm²]
$\sum A_w$	=	summarized stress area of the weld joints of anchor bars	[mm²]
$f_{vw,k}$	=	nominal characteristic steel ultimate tensile strength of the weld	[N/mm²]
$\sum A_{s,a}$	=	summarized stressed cross section of all anchor bars	[mm²]
$f_{uk,a}$	=	nominal characteristic steel ultimate tensile strength of anchor bar	[N/mm²]

The tests shall be carried out on anchors not cast into concrete according to Table A.1.1, Line S1a and S1b. Therefore, the anchor bolt is cut according to clause A.4 into two parts. For the part headed anchor bar a tension load is applied to cut end and head according to Figure A.4.5. For the part with the central threaded bar a tension load is applied to both threads according to Figure A.4.4. A typical test setup for tests according to Table A.1.1, Line S1a is shown in Figure A.4.5 and for tests according to Table A.1.1, Line S1b is shown in Figure A.4.4. Apply the load until failure.

Determine the 5%-fractile of the failure loads for tests according to Table A.1.1, Line S1a and S1b. Both values shall be normalized to account for over-strength of tested samples according to equation (B.1.2).

If the minimum of the normalized 5%-fractile of the failure loads in the series S1a and S1b is larger than $N_{Rk,s,calc}$ than:

$$N_{Rk,s} = N_{Rk,s,calc} / 1000 \quad [kN]$$

else

$$N_{Rk,s} = MIN\{n_a \cdot N_{u,5\%}(S1a); N_{u,5\%}(S1b)\} \quad [kN]$$

n_a	number of anchor bars in an anchor bolt Type 2	[-]
$N_{u,5\%}$(S1a)	normalized (according to equation (B.1.2)) 5%-fractile of the failure loads measured in the test series S1a	[kN]
$N_{u,5\%}$(S1b)	normalized (according to equation (B.1.2)) 5%-fractile of the failure loads measured in the test series S1b	[kN]

Expression of results: $N_{Rk,s}$ [kN]

2.2.2 Characteristic resistance to pull-out failure under static and quasi-static tension load

Purpose of the assessment

Determination of the characteristic resistance to pull-out failure of the anchor bolt on the basis of calculation.

Assessment method

The characteristic resistance $N_{Rk,p}$ for pull-out failure shall be calculated according to equation (2.2.2.1) and (2.2.2.2).

$N_{Rk,p}$	=	$7{,}5 \cdot \sum A_h \cdot f_{ck}$ /1000 for cracked concrete	[kN]	(2.2.2.1)
	=	$10{,}5 \cdot \sum A_h \cdot f_{ck}$ /1000 for uncracked concrete		(2.2.2.2)
f_{ck}	=	nominal characteristic concrete compressive cylinder strength, measured on cubes with 150 mm side length	[N/mm²]	
$\sum A_h$	=	summarized projected load bearing area of all heads of the anchor bars of an anchor bolt	[mm²]	
	=	$n_a \cdot \frac{\pi}{4} \cdot (d_h^2 - {d_a}^2)$	[mm²]	(2.2.2.3)
d_h	=	head diameter of anchor bars	[mm]	
d_a	=	nominal diameter of anchor bar-according to EN 10080 [23], Table 6	[mm]	
n_a	=	number of anchor bars (for anchor bolts type 1 is n_a= 1)	[-]	

Expression of results: $N_{Rk,p}$ [kN] for C20/25 in cracked and uncracked concrete

2.2.3 Characteristic resistance to concrete cone failure under static and quasi-static tension load

Purpose of the assessment

Determination of values for the calculation of the characteristic resistance to concrete cone failure of the anchor bolt.

Assessment method

For anchor bolts according to Figure 1.1.1 following values apply:

$k_{cr,N}$	=	8,9	[-]	(2.2.3.1)
$k_{ucr,N}$	=	12,7	[-]	(2.2.3.2)

and

h_{ef}	=	$h_{nom} - t_h$	[mm]	(2.2.3.3)
h_{nom}	=	overall length of the anchor bolt in the concrete	[mm]	
t_h	=	thickness of anchor bar head	[mm]	

The characteristic spacing and edge distance for the resistance under tension load is:

$s_{cr,N}$	=	$3 \cdot h_{ef}$	[mm]	(2.2.3.4)
$c_{cr,N}$	=	$\frac{1}{2} \cdot s_{cr,N}$	[mm]	(2.2.3.5)

Expression of results: k_{cr} [-], k_{ucr} [-], h_{ef} [mm], $c_{cr,N}$ [mm], $s_{cr,N}$ [mm]

2.2.4 Edge distance to prevent splitting failure

Purpose of the assessment

Determination of values for the calculation of the characteristic resistance to splitting failure of the anchor bolt on the basis of tests according to Table A.1.1, Line C1.

If according to the intended use specific provisions according to EN 1992-4 [1], 7.2.1.7 are taken to prevent splitting the concrete, tests may be omitted.

Assessment method

The tests shall be carried out on single anchor bolts cast into concrete C20/25, unconfined according to A.5 with minimum thickness h_{min} and with edge distances $c_1 = c_2 = c$ with c = estimated $c_{cr,sp}$. Apply a tension load to the tread of the anchor bolt until failure.

The characteristic edge distance $c_{cr,sp}$ is evaluated from the results of tension tests according to Table A.1.1, Line C1. The mean failure load in the tests with anchor bolt at the corner shall be statistically equivalent the same as for a anchor bolt without edge and spacing effects for the same concrete strength. In this case is:

$c_{cr,sp}$	=	$c_{cr,N}$	[mm]	(2.2.4.1)
$c_{cr,N}$	=	Characteristic edge distance for ensuring the transmission of the characteristic resistance of a single anchor bolt	[mm]	

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

$s_{cr,sp}$	=	$2 \cdot c_{cr,sp}$	[mm]	(2.2.4.2)

Expression of results: $c_{cr,sp}$ [-], $s_{cr,sp}$ [-]

2.2.5 Minimum edge distance, spacing and thickness of concrete member

Purpose of the assessment

Determination of minimum values for installation parameters of the anchor bolt of applications according to Figure 1.2.1.1a on the basis of tests according to Table A.1.1, Line C2.

If according to the intended use specific provisions according to EN 1992-4 [1], 7.2.1.7 are taken to prevent splitting the concrete, tests may be omitted.

Assessment method

The tests are carried out with two anchor bolts with a spacing $s=s_{min}$ and an edge distance $c=c_{min}$ at a concrete member made of C20/25 with minimum thickness h_{min}.

The minimum edge distance c_{min}, minimum spacing s_{min} and minimum member thickness h_{min} are specified by the manufacturer. If the manufacturer does not specify c_{min} and s_{min} and no experience exists, $c_{min} = 1{,}5\ h_{ef}$ and $s_{min} = 3\ h_{ef}$ are recommended for the test lab. If the manufacturer does not specify h_{min}, $h_{min} = h_{nom} + 50$ mm.

The dimensions of the fixture shall be width = 3 d_f, length = s_{min} + 3 d_f and thickness ≅ d_f.

The maximum installation torque is specified by the manufacturer. If the manufacturer does not specify T_{inst}, T_{inst} = 2 Nm.

The anchors shall be alternately torqued in steps of 0,2 T_{inst} with a calibrated torque wrench.

After each load step the concrete surface shall be inspected for cracks. The test is stopped when the torque moment cannot be increased further or hairline cracks on the concrete surface are observed. The number of revolutions per load step shall be measured for both anchor bolts. Furthermore, the torque at the formation of the first hairline crack at one or both anchor bolts and the maximum torque that can be applied to the two anchor bolts shall be recorded.

The geometrical parameters c_{min}, s_{min} and h_{min} are assessed by the tests according to Table A.1.1, Line C2. These values are confirmed if until the normalized 5% fractile of the torque moment reached 1,7 T_{inst} according to equation (2.2.5.1) no cracks arise.

$T_{5\%}$	≥	$1{,}7 \cdot T_{inst} \cdot \sqrt{\frac{f_{ck,test}}{f_{ck}}}$	[Nm]	(2.2.5.1)
T_{inst}	=	maximum installation torque	[Nm]	
$f_{ck,test}$	=	concrete compressive strength at time of testing measured on cylinders	[N/mm²]	
f_{ck}	=	nominal characteristic concrete compressive cylinder strength	[N/mm²]	

If the condition in equation (2.2.5.1) is not fulfilled in tests according to Table A.1.1, Line C2, c_{min}, s_{min} and/or h_{min} has to be increased accordingly or T_{inst} has to be decreased accordingly.

Expression of results: c_{min} [mm], s_{min} [mm], h_{min} [mm]

2.2.6 Maximum installation torque

Purpose of the assessment

Determination of maximum installation torque of the anchor bolt on the basis of tests according to Table A.1.1, Line S2.

Yielding of the steel or concrete failure of the member may occur during fixture installation when the anchor is placed according to Figure 1.2.1.1a or yielding of the steel may occur during fixture installation when the anchor is placed according to Figure 1.2.1.1b. Maximum values for installation torque according to Figure 1.2.1.1a and according to Figure 1.2.1.1b are required to avoid this yielding respectively concrete failure.

The tests may be omitted if the prestressed tension force is calculated with a friction factor of k = 0,1 according to equation (2.2.6.1):

$N_{v95\%}$	=	$1{,}3 \cdot \frac{T_{inst}}{0{,}1 \cdot d}$	[N]	(2.2.6.1)
T_{inst}	=	maximum installation torque	[Nm]	
d	=	thread diameter of anchor bar for anchor bolt type 1 and of central threaded bar for anchor bolt type 2	[mm]	

Assessment method

In the tests the torque moment is applied on a cast in anchor bolt with a calibrated torque wrench until failure of the anchor bolt. The tension force in the anchor bolt shall be measured as a function of the applied torque moment.

After the test the connection between nut and bolt is capable of being unscrewed.

The 95%-fractile of the prestressed tension force N_v generated in the torque tests at a torque moment T = 1,3 T_{inst} shall be smaller than the nominal yield force of the anchor bolt respectively the minimum concrete failure load.

The nominal yield force of the anchor is the tension load which reaches at minimum the yield limit of all steel parts of the anchor.

For the calculation of the maximum installation torque T_{inst} the two different installation possibilities, as shown in Figure 1.2.1.1, have to be taken into account:

(a) General

In case of general application the maximum installation torque T_{inst} has to be determined taking into account the decisive failure mode between the steel one (the condition according to equation (2.2.6.2) or the concrete ones (the condition according to equation (2.2.6.3) shall be fulfilled). The characteristic tension resistances are evaluated with the minimum edge distance, spacing and member height as defined in clause 2.2.5.

$\frac{N_{V95\%}}{MIN\left\{A_s \cdot f_{yk}\right\}}$	≤	1,0	[-]	(2.2.6.2)
$\frac{N_{V95\%}}{MIN\left\{N_{Rk,p}; N_{Rk,c}; N_{Rk,sp}; N_{Rk,cb}\right\}}$	≤	1,0	[-]	(2.2.6.3)
$N_{V95\%}$	=	95%-fractile of the prestressed tension force in tests S2	[N]	
A_s	=	stressed cross section of each part of the anchor bolt (for type 2 consider the sum of anchor bars)	[mm²]	
f_{yk}	=	appropriate nominal yield force	[N/mm²]	
$N_{Rk,p}$	=	characteristic resistance for pull-out failure for C20/25 according to EN 1992-4 [1], Equation (7.11)	[N]	
$N_{Rk,c}$	=	characteristic resistance for concrete cone failure for C20/25 according to EN 1992-4 [1], Equation (7.1)	[N]	
$N_{Rk,sp}$	=	characteristic resistance for splitting failure for C20/25 according to EN 1992-4 [1], Equation (7.23)	[N]	
$N_{Rk,cb}$	=	characteristic resistance for blow-out failure for C20/25 according to EN 1992-4 [1], Equation (7.25)	[N]	

(b) Steel to steel contact

In case of steel to steel contact T_{inst} is calculated based on the bolt yield strength, as the tension force (prestressing) is only applied on the anchor bar respectively the central threaded bar. The condition according to equation (2.2.6.2) shall be fulfilled.

Expression of results: T_{inst} [Nm]

2.2.7 Resistance to steel failure under static and quasi-static shear load

Purpose of the assessment

Determination of the characteristic resistance to steel failure under shear load.

Assessment method

(a) Without lever arm

For the verification of steel failure under shear load according to EN 1992-4 [1], Table 7.2, Line 1 and clause 7.2.2.3.1 the following basic value is used:

The characteristic resistance $V^0_{Rk,s}$ is determined for the cross-section:

$V^0_{Rk,s}$	=	$k_6 \cdot A_s \cdot f_{uk}$	[N]	(2.2.7.1)
k_6	=	0,6 for anchor bolts with $f_{uk} \leq 500 \frac{N}{mm^2}$	[-]	
		0,5 for anchor bolts with $500 \frac{N}{mm^2} < f_{uk} \leq 1000 \frac{N}{mm^2}$		
A_s	=	stressed cross section of the thread test (for type 1 of the anchor bar, for type 2 of the central threaded bar)	[mm²]	
f_{uk}	=	nominal characteristic steel ultimate tensile strength of test (for type 1 of the anchor bar, for type 2 of the central threaded bar)	[N/mm²]	

For more precise value of the factor k_6 this factor may be determined by test series according to Table A.1.1, Line S3.

Determine the 5%-fractile of the failure loads. This value shall be normalized to account for over-strength of tested samples according to equation (B.1.2).

The factor k_6 is calculated according to:

k_6	=	$V_{u,5\%} / A_{s,test} / f_{uk,test} \leq 0{,}6$	[-]	(2.2.7.2)
$V_{u,5\%}$	=	normalized 5 %-fractile of the failure loads measured in the test series S3	[N]	
$A_{s,test}$	=	stressed cross section of the thread in the test (for type 1 of the anchor bar, for type 2 of the central threaded bar)	[mm²]	
$f_{uk,test}$	=	characteristic tensile strength of the anchor bar for anchor bolt type 1 and the central threaded bar for anchor bolt type 2 in the test	[N/mm²]	

The factor k_7 for fasteners in a group is:

k_7	=	1,0	for fasteners made of steel with normal ductility and A_5 > 8%	[-]	or
k_7	=	0,8	for fasteners made of steel with rather low ductility and A_5 ≤ 8%	[-]	

(b) With lever arm

For the verification of steel failure under shear load according to EN 1992-4 [1], Table 7.2, Line 2 and clause 7.2.2.3.2 the following basic values are used. The characteristic resistance $M^0_{Rk,s}$ is determined for the cross-section of the thread

$M^0_{Rk,s}$	=	$1{,}2 \cdot W_{el} \cdot f_{uk}$	[Nm]	(2.2.7.3)
W_{el}	=	elastic section modulus of the thread calculated with the equivalent diameter of the stressed cross section	[mm³]	
	=	$\left(\frac{d_s}{2}\right)^3 \cdot \frac{\pi}{4}$		
f_{uk}	=	nominal characteristic steel ultimate tensile strength of test (for type 1 of the anchor bar, for type 2 of the central threaded bar)	[N/mm²]	

d_s	=	diameter of the stressed cross section of thread test (for type 1 of the anchor bar, for type 2 of the central threaded bar)	[mm]

Expression of results: $V^0_{Rk,s}$ [N], k_7 [-], $M^0_{Rk,s}$ [Nm]

2.2.8 Resistance to concrete edge failure under static and quasi-static shear load without supplementary reinforcement

Purpose of the assessment

Providing geometrical input values l_f and d_{nom} of the anchor bolt for the calculation of the characteristic resistance to concrete edge failure without supplementary reinforcement according to EN 1992-4 [1], clause 7.2.2.5, equation (7.41) to (7.43).

Assessment method

Determination of geometrical input values l_f and d_{nom}:

l_f	=	effective length of the anchor bolt	[mm]
	=	h_{ef} [mm] in case of uniform diameter of the anchor bar for anchor bolt type 1 and the central threaded bar for anchor bolt type 2	[mm]
	≤	$8 \cdot d_{nom}$	[mm]
h_{ef}	=	effective embedment depth according to equation (2.2.3.3)	[mm]
d_{nom}	=	d	[mm]
	≤	60 mm	
d	=	thread diameter of the anchor bar for anchor bolt type 1 and the central threaded bar for anchor bolt type 2 according to Figure 1.1.1	[mm]

Expression of results: l_f [mm], d_{nom} [mm]

2.2.9 Resistance to pry-out failure under static and quasi-static shear load

Purpose of the assessment

Providing input value k_8 for the calculation of the characteristic resistance to pry-out failure of the anchor bolt according to EN 1992-4 [1], clause 7.2.2.4, equation (7.39a) and (7.39b).

Assessment method

Determination of k_8:

k_8	=	1,0	for anchorages with $h_{ef} < 60\ mm$	[-]	or
k_8	=	2,0	for anchorages with $h_{ef} \geq 60\ mm$	[-]	

Expression of results: k_8 [-]

2.2.10 Combined tension and shear load under static and quasi-static load

Purpose of the assessment

Providing input value k_{11} (exponent) for the calculation of the anchor bolt under combined tension and shear load for fastenings with supplementary reinforcement according to EN 1992-4 [1], clause 7.2.3.1, equation (7.57).

Assessment method

Determination of k_{11}:

k_{11}	=	$2/3$	[-]

Expression of results: k_{11} [-]

2.2.11 Displacement under static and quasi-static tension or shear load

Purpose of the assessment

Determination of characteristic displacements of the anchor bolt under service tension and service shear load.

Assessment method

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

N	=	$N_{Rk,p}/(1{,}4 \cdot 1{,}5)$	[N]	(2.2.11.1)
V	=	$V^0{}_{Rk,c}/(1{,}4 \cdot 1{,}5)$	[N]	(2.2.11.2)
$N_{Rk,p}$	=	characteristic resistance to tension load for pull-out failure	[N]	
$V^0{}_{Rk,c}$	=	initial value of characteristic resistance to shear load for concrete edge failure	[N]	

The displacements δ_{NO} under short term tension loading are calculated according to [7] if the product is according to the assumptions of [7].

In all other cases and for more precise values the displacements under short term tension loading (δ_{NO}) is evaluated from the tests with single anchors in concrete (test series according to Table A.1.1, Line C1). The value derived shall correspond to the mean value.

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

The displacements under short term shear loading (δ_{VO}) are evaluated from the corresponding shear tests with single anchors in concrete (test series according to Table A.1.1, Line S3). The value derived shall correspond to the mean value.

The displacements determined from tests under shear load with anchors type 1 can be used for anchors Type 2 for the same size d if it is shown that the stiffness of the central threaded bar of type 2 ($A_S \cdot f_{uk}$ according to equation (2.2.1.2)) is greater than the stiffness of the anchor bolt of type 1 ($A_S \cdot f_{uk}$ according to equation (2.2.1.1)).

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

Under shear loading the displacements might increase due to a gap between fixture and anchor. Therefore, in the ETA shall be stated clearly if this gap is taken into account in the assessment.

The displacements for tension and shear (in mm) are rounded up to zero or five on the first place after the decimal point.

Expression of results: δ_{N0} [mm], $\delta_{N\infty}$ [mm], δ_{V0} [mm], $\delta_{V\infty}$ [mm]

2.2.12 Reaction to fire

The anchor bolt is considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with 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.

2.2.13 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 [5], 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 [5], clause 2.2.18.

The fire resistance to steel failure due to shear load $V_{Rk,s,fi}$, $M^0_{Rk,s,fi}$ shall be determined according to EAD 330232-01-0601 [5], clause 2.2.19.

Expression of results: $N_{Rk,s,fi}$, $N_{Rk,p,fi}$, $V_{Rk,s,fi}$ [kN], $M^0_{Rk,s,fi}$ [Nm]

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 the product 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)					
1	Raw material and components: mechanical characteristics	control of inspection documents and comparison with nominal values	1)	all	Each delivery
2	Dimensions (diameter of reinforcing bar, diameter of head, thread diameter, overall length, thread length etc.) 4)	Measuring by calliper and/ or gauge or optical	1)	3 each size 2)	Per 10.000 anchors or once per production week 3)
3	characteristic yield strength	EN ISO 6892-1 [2]	$f_{yk} \geq 500$ [N/mm²]		
4	characteristic ratio tensile strength / yield strength	according to Annex A	$(f_u/f_y)_k \geq 1{,}08$ (1,15) [-]		
5	characteristic strain at maximum force	according to Annex A	$\varepsilon_{uk} \geq 5{,}0$ (7,5) [%]		

1) according to the manufacturer technical file respectively control plan

2) each type of material

3) whichever criterion is the more rigorous

4) The geometrical characteristics according to Table 3.2.1 shall be determined by means of measuring. Possible tolerances as specified by the manufacturer shall be considered.

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for anchor bolts 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					
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 anchor bolts	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					
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]	EN 1992-4:2018:	Eurocode 2: Design of concrete structures. Part 4: Design of Fastenings for Use in Concrete
[2]	EN ISO 6892-1:2019	Metallic materials – Tensile testing – Part 1: Method of test at room temperature
[3]	ISO 6783:1982	Coarse aggregates for concrete; Determination of particle density and water absorption; Hydrostatic balance method
[4]	EN 206:2013+A2:2021	Concrete – Part 1: Specification, performance, production and conformity,
[5]	EAD 330232-01-0601:2019-12	Mechanical fasteners for use in concrete
[6]	ISO 16269-6:2014-01	Statistical interpretation of data – Part 6: Determination of statistical tolerance intervals
[7]	Doctor thesis	Furche, J.: "Zum Trag- und Verschiebungsverhalten von Kopfbolzen bei zentrischem Zug", Universität Stuttgart
[8]	EN ISO 7093-1:2000	Plain washers – Large series – Part 1: Product grade A
[9]	Series EN 10025	Hot rolled products of structural steels
	EN 10025-1:2004	Part 1: General technical delivery conditions
	EN 10025-2:2019	Part 2: Technical delivery conditions for non-alloy structural steels
	EN 10025-3:2019	Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels
	EN 10025-4:2019+A1:2022	Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels
	EN 10025-5:2019	Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
	EN 10025-6:2019+A1:2022	Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition
[10]	Series EN 10088	Stainless steels
	EN 10088-1:2014	Part 1: List of stainless steels
	EN 10088-2:2014	Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes
	EN 10088-3:2014	Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes
	EN 10088-4:2009	Part 4: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes
	EN 10088-5:2009	Part 5: Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes
[11]	EN ISO 7090:2000	Plain washers, chamfered – Normal series, Product grade A
[12]	EN ISO 4032:2012	Hexagon regular nuts (style 1) – Product grades A and B

[13]	EN 1992-1-1:2004 + AC:2010 A1:2014	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
[14]	EN ISO 898-2:2022	Mechanical properties of fasteners made of carbon and alloy steel. Part 2: Nuts with specified property classes – coarse thread and fine pitch thread
[15]	EN ISO 3506-2:2020	Mechanical properties of corrosion-resistant stainless steel fasteners. Part 2: Nuts
[16]	EN ISO 1461:2022	Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods
[17]	EN ISO 10684:2004+AC 2009	Fasteners – Hot dip galvanized coatings
[18]	EN 1993-1-4: 2006+A1 2015+ A2:2020	Eurocode 3: Design of steel structures. Part 1-4: General rules – Supplementary rules for stainless steel
[19]	EN 197-1:2011	Cement – Part 1: Composition, specifications and conformity criteria for common cements
[20]	EN 13791:2019	Assessment of I-situ compressive strength in structures and precast concrete components
[21]	EAD 330924-00-0601:2017-12	Cast-in anchor bolt of ribbed reinforcing steel
[22]	EN ISO 7089:2000	Plain washers – Normal series, Product grade A
[23]	EN 10080:2005	Steel for the reinforcement of concrete – Weldable reinforcing steel – General

ANNEX A GENERAL ASPECTS OF TESTS

A.1 Test program for resistance under static and quasi-static tension and shear load

Test shall be done according to Table A.1.1.

Table A.1.1 Tests under static and quasi-static tension and shear load

No	Test	h_{ef} [mm]	Concrete strength	Number of tests	Anchor bolt diameter [mm]		
					d_a = 12-16 small	d_a = 20-25 medium	d_a = > 25 max
Steel failure under tension							
S1	centric tension pure steel test						
a	single anchor bolt, type 1 (thread and head) or type 2 (Part with headed anchor bar) [5)]	-	-	5 each	X	X	X
b	single anchor bolt, type 2 (Part with central threaded bar) [5)]			5 each	X	X	X
S2	torque test to steel failure, single fastening [3)]	-	C20/25	5 each	X	X	X
Concrete failure under tension							
C1	centric tension, unconfined single fastening at a corner [1)] $c_1 = c_2 \leq 80$ mm	≥ 160	C20/25	≥ 4	-	X	-
C2	torque test to splitting failure double fastening at the edge [2)] c_{min}, s_{min}, h_{min}	-	C20/25	≥ 5	X	X	X
Steel failure under shear							
S3	Single fastening without influence of spacing and edge distance [4)]	≥ 160	C50/60	5 each	X	X	X

1) for the determination of c_{crsp}, s_{crsp} and h_{min}, else reinforcement to resist splitting forces according to EN 1992-4 [1], clause 7.2.1.7 is placed close to the anchorage

2) only for intended use according to Figure 1.2.1.1a for the determination of c_{min}, s_{min} and h_{min}, else reinforcement to resist splitting forces according to EN 1992-4 [1] 7.2.1.7 is placed close to the anchorage

3) for the determination of prestressed tension Force N_v, else friction factor k=0,1

4) for the determination of $V_{Rk,s}$, else calculation according to clause 2.2.8

5) for type 2 cut anchor bolt into two parts according to Figure A.4.4 and conduct with both parts tests according to Line S1a and S1b

For the individual tests the maximum loads shall be determined by indicating the failure mode. The load/displacement curves shall be recorded.

A.2 Concrete

The concrete test member shall be manufactured in accordance with EN 206 [4].

The test members shall comply with the following:

Aggregates shall be of natural occurrence (i.e., non-artificial) and with a grading curve falling within the boundaries given in Figure A.2.1. The maximum aggregate size shall be 16 mm. The aggregate density shall be between 2,0 and 3,0 t/m³ (see EN 206 [4] and ISO 6783 [3]).

The boundaries reported in Figure A.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 TAB.

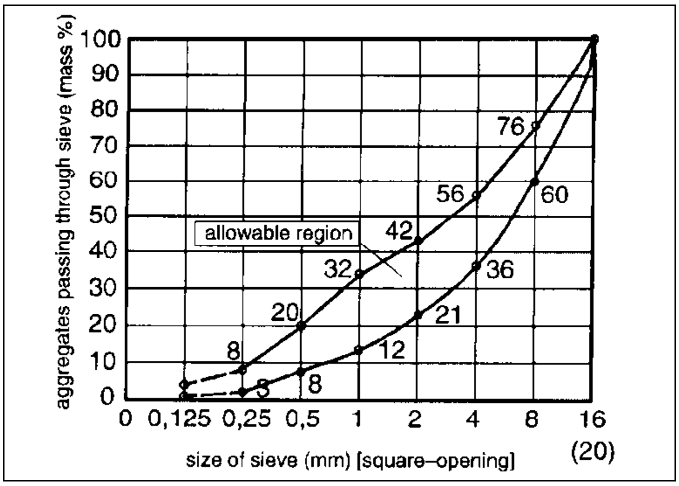


Figure A.2.1 Admissible region for the grading curve

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 [19]).

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.

For the tests carried out in low strength concrete (strength class C20/25) the following mean compressive strengths at the time of testing the anchor bolt 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)

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 $$f_c = \frac{1}{1{,}25} f_{cube} \quad (A.2.1)$$

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

$$f_{cube100} = \frac{1}{0{,}95} f_{cube} \quad (A.2.2)$$

$$f_{cube} = \frac{1}{0{,}95} f_{cube\,200} \tag{A.2.3}$$

$$f_{cube} = f_{core100} \text{ (according to EN 13791 [20], clause 7.1)} \tag{A.2.4}$$

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.

The concrete control specimens shall be tested on the same day as the anchor channels 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 bolt tests, e.g., at the beginning and at the end of the tests. In this case the concrete strength at the time of testing shall 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 are 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 (A.2.4).

The tests are carried out in uncracked unreinforced concrete 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 anchor channel 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°.

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 anchor bolt the concrete shall be at least 21 days old.

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

A.3 Installation

The product shall be fixed with the formwork such, that it does not move during the laying of the reinforcement and the application and compaction of the concrete.

During the concrete placing care shall be taken, that the concrete is well compacted under the head of the bolt.

A.4 Steel tests

Steel tests for anchor bolts type 1 and type 2 according to Figure 1.1.1a and Figure 1.1.1b are different concerning bearing devices. All tests have to be performed deformation controlled and statically loaded.

<u>Type 1</u>

The steel tests have to be performed with the end product consisting of the anchor bolt with one washer and one nut. The anchor bolt shall be born on one end at the washer with nut and on the other end at the head of the anchor bar (Figure A.4.1). The bearing shall be done on both sides with a plate with a hole. Both plates shall confirm to Figure A.4.2 (head) and A.4.3 (thread).

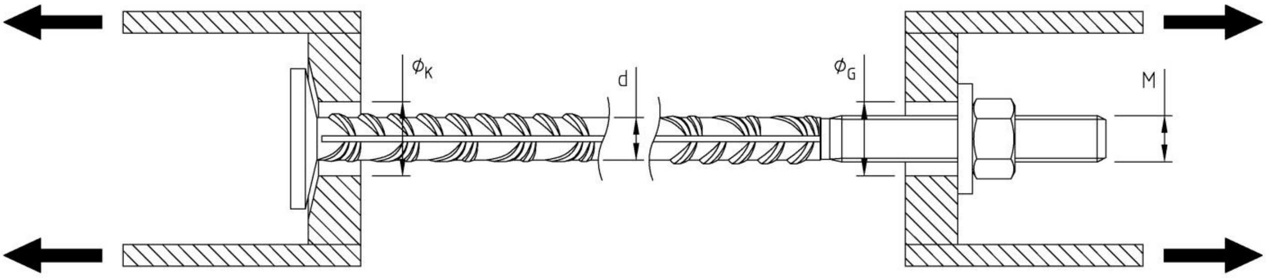
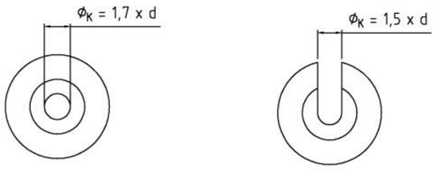


Figure A.4.1: Sectional view of test rig for tension tests with bearing plates at both ends for anchor bolt type 1

Version A	Version B
Closed hole in plate	Open hole in plate



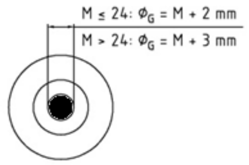


Figure A.4.2: Top view of plate for head of the anchor bar with two possible versions (anchor bolt not shown)

Figure A.4.3: Top view of plate for thread of the anchor bolt (anchor bolt shown)

<u>Type 2</u>

The steel tests have to be performed with the end product consisting of the anchor bolt with one washer and one nut. All anchor bars are cut at the same length L_{test} according to Figure A.4.4 into two parts.
One test series is performed with the part with the central threaded bar and one test series is performed with the other part with the headed anchor bar.

<u>The part with the central threaded bar</u> is welded with the cut anchor bars to an additional threaded bar. A washer and a nut are added to this threaded bar. All added items are dimensioned in a way that they do not fail while testing. The transformed anchor bolt shall be born on both ends at the washer with nut (Figure A.4.4). The bearing shall be done on both sides with a plate with a hole. Both plates shall confirm to Figure A.4.2 and A.4.3.

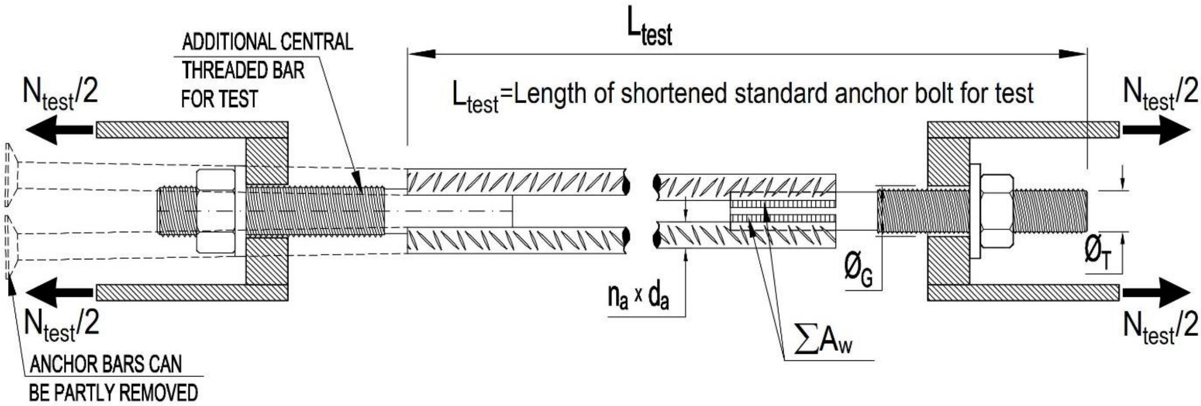


Figure A.4.4: Sectional view of test rig for tension tests with bearing plates at both ends for anchor bolt type 2, series for part with central threaded bar

<u>The part with the headed anchor bar</u> is born on one end in a clamping jaw and on the other end at the head of the anchor bar (Figure A.4.5). The bearing shall be done on the headed side with a plate with a hole. This plate shall confirm to Figure A.4.2.

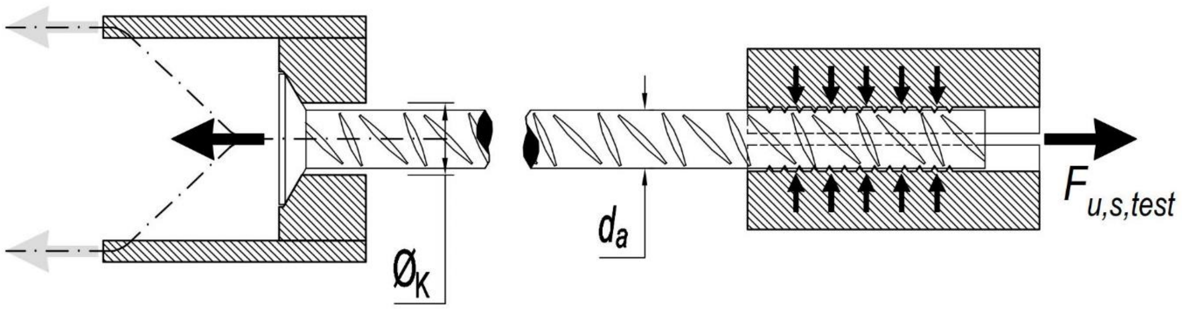


Figure A.4.5: Sectional view of test rig for tension tests with bearing plate at one end and clamping jaw at the other end for anchor bolt type 2, series for part with headed anchor bar

A.5 Unconfined tests in concrete

Unconfined tests allow an unrestricted formation of the rupture concrete cone. An example for an unconfined test setup is shown in Figure A.5.1.

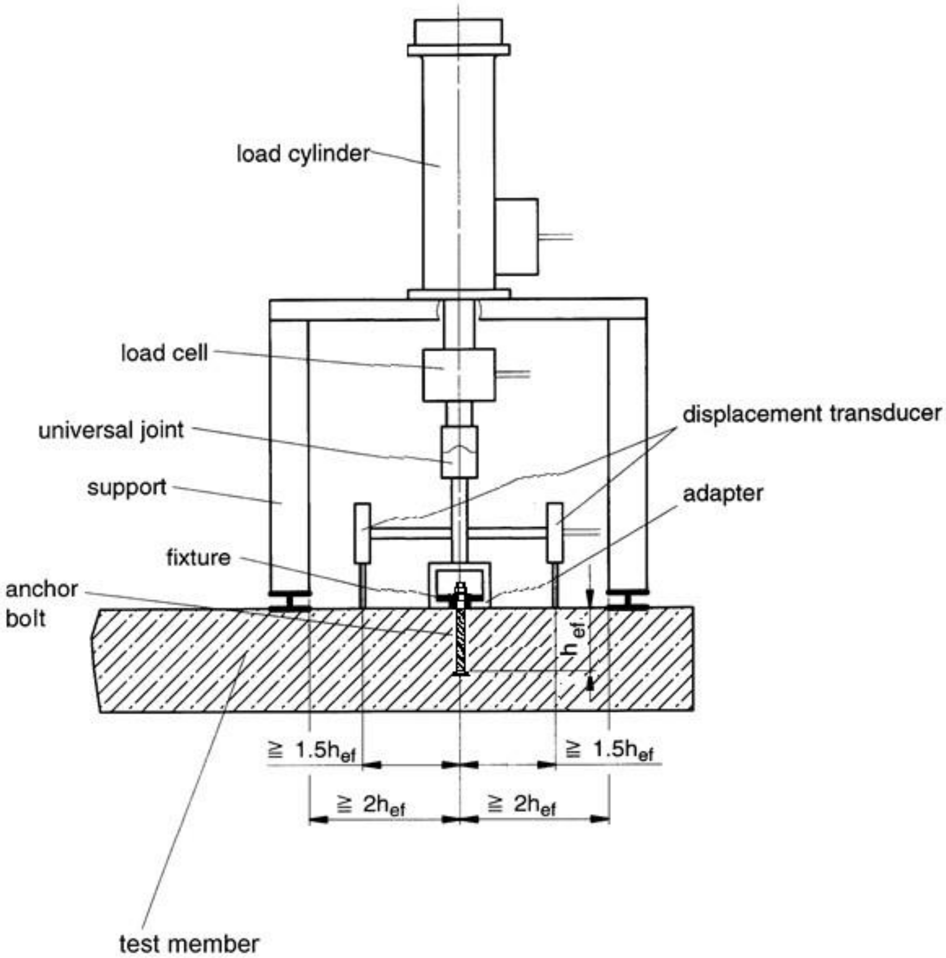


Figure A.5.1: Example of a tension test rig for unconfined tests

ANNEX B GENERAL ASSESSMENT METHODS

B.1 Conversion of failure loads to nominal strength

The conversion of failure loads shall be done according to equation B.1.1 to B.1.2 depending on the failure mode.

Concrete failure	$F_{u,c} = F_{u,test} \cdot \left(\frac{f_c}{f_{c,test}} \right)^{0,5}$	with $\frac{f_c}{f_{c,test}} \leq 1,0$	(B.1.1)
Steel failure	$F_{u,s} = F_{u,test} \frac{f_u}{f_{u,test}}$		(B.1.2)

B.2 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.

$$F_{u,5\%} = F_{u,m}(1 - k_s \cdot cv_F) \quad \text{(B.2.1)}$$

$$F_{u,95\%} = F_{u,m}(1 + k_s \cdot cv_F) \quad \text{(B.2.2)}$$

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

n = 10 tests: k_s = 2,57

Note 1: The confidence level of 90% is defined for characteristic resistance of fasteners in EN 1992-4 [1] and is therefore used for the assessment in this EAD.