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EAD 330499-02-0601-v01

August 2024

European Assessment Document for

Variant: Bonded fasteners and bonded expansion fasteners for use in concrete – Alternative drilling methods, seismic and fire resistance in steel fibre reinforced concrete, variable working life and time-to-failure assessment

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 Scope of the EAD

1.1 Description of the construction product

EAD 330499-02-0601 [1], clause 1.1 applies.

This EAD is a variant to EAD 330499-02-0601 [1] due to:

- Alternative drilling methods,
- Bonded fasteners and bonded expansion fasteners for use in steel fibre reinforced concrete (SFRC) under seismic action and under fire exposure,
- Reduced working life of zinc-based coated fasteners.
- Integration of an additional assessment method for a more realistic assessment of long-term bond resistance for bonded fasteners (factor ψ^0_{sus}) based on time to failure tests.

Drilling methods

1. Rotary hammer (electric drilling machine or driven by compressed air):

- Hammer drilling with standard drill bit and subsequent cleaning (cleaning procedure as defined by the manufacturer in the MPII)
- Hollow drilling (rotary hammer drilling using a hollow drill bit) with continuous vacuuming of the drilling dust with or without subsequent cleaning (cleaning procedure as defined by the manufacturer in the MPII)

2. Alternative drilling methods:

- Diamond core drilling (with or without rig, with or without water cooling, with or without roughening procedures) and subsequent cleaning (as defined by the manufacturer in the MPII).

As reference drilling and cleaning method only one method can be defined, for which the complete required test programme in accordance with EAD 330499-02-0601 [1], Table A.1.1 (BF) or Table B.2.1 (BEF) has been conducted. This also applies to extensions for fire or in accordance with Annexes C, E or F (working life 100 years, seismic action, and SFRC). Current practice is to take the rotary hammer drilling method with standard drill bit as reference method. If more than one drilling and cleaning method is used, Annex G describes the required supplementary test programme. It differentiates rotary hammer and alternative drilling methods. A reduced test programme can be executed (Table G.2.1 (BF) or Table G.2.2. (BEF)), if equivalence with the reference series can be shown in these series. If equivalence cannot be shown with Tables G.2.1 or G.2.2, additional test series are required (Table G.2.3 (BF), Table G.2.4 (BEF) and Table G.2.5 (BF and BEF for seismic action in accordance with Annex E)).

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use

EAD 330499-02-0601 [1], clause 1.2.1 applies.

In addition to EAD 330499-02-0601 [1], the following new assessments/essential characteristics are added:

- BF and BEF in steel fibre reinforced concrete (SFRC) C20/25 to maximum C90/105 under seismic action,
- BF and BEF in steel fibre reinforced concrete (SFRC) C20/25 to maximum C90/105 under fire exposure,
- Variable working life (durability of zinc based coated steel elements)

1.2.2 Working life/Durability

EAD 330499-02-0601 [1], clause 1.2.2 applies.

1.3 Specific terms used in this EAD

1.3.1 Abbreviations

EAD 330499-02-0601 [1], clause 1.3.1 applies with following addition:

Plain concrete	=	Compacted reinforced or unreinforced normal weight concrete without fibres in accordance with EN 206[1] [4]
SFRC	=	Steel fibre reinforced concrete

1.3.2 Notation

EAD 330499-02-0601 [1], clause 1.3.2 applies.

Notations of this variant and notation of EAD 330499-02-0601 [1], which were used in this variant.

b, c		parameter of the assessment curve [-]
cv_F	=	coefficient of variation of failure loads [-]
$c_{v\delta}$		coefficient of variation of displacements [-]
k_{sus}	=	factor for beneficial long-term effects [-]
n	=	number of tests [-]
N_{sust}	=	load applied on a fastener during sustained load test or freeze/thaw test or time to failure tests [kN]
$N_{sust,i}$	=	permanent load applied on a fastener during a single time to failure test, calculated as mean value of the load in the time period from $t_{start,i}$ to $t_{end,i}$ [kN]
$N_{sust,1}$	=	permanent load applied on a fastener during the first time to failure test [kN]
$N_{sust,1\text{-}10}$	=	permanent load applied on a fastener during the time to failure tests 1 to 10 [kN]

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

$N_{um,R6a-TTF}$	=	mean value of failure loads in test series R6a-TTF converted to the nominal concrete strength and accounting concrete batch influence [kN]
$N_{um,R6b-TTF}$	=	mean value of failure loads in test series R6b-TTF, converted to the nominal concrete strength and accounting concrete batch influence [kN]
$N_{5\%,R6a-TTF}$	=	5 % fractile of the failure loads $N_{5\%,R6a-TTF}$, converted to the nominal concrete strength and accounting concrete batch influence [kN]
$N_{5\%,R6b-TTF}$	=	5 % fractile of the failure loads $N_{5\%,R6b-TTF}$, converted to the nominal concrete strength and accounting concrete batch influence [kN]
S_x	=	squared deviation of the t values in the extrapolation sample [h]
$s_{y,x}$	=	root mean squared error of the tested points [N/mm²]
t	=	loading time [h]
t_f	=	time of failure in TTF tests [h]
$t_{f,i}$	=	calculated failure time for test i [h]
$t_{start,i}$	=	first find the time t_{start} where the load reaches the target load [h]
$t_{end,i}$	=	time when during failure the load drops at 0,95 of the target load and the load continues to drop [h]
$\overline{t_f}$	=	mean value of the failure times of the tests
α_{setup}	=	factor taking into account the influence of confined test setup [-]
α_1	=	reduction factor for loss of adhesion [-]
α_2	=	reduction factor for maximum long-term temperature [-]
α_3	=	reduction factor for maximum short-term temperature [-]
α_4	=	reduction factor for durability of the bonding material [-]
β_{cv}	=	reduction factor for large scatter of failure loads [-]
γ_{inst}	=	factor accounting for the sensitivity to installation [-]
$\delta_{0,5Num}$	=	displacements at 50 % of the mean failure load [mm]
$\sigma_{R6a-TTF}$	=	the standard deviation of the R6a-TTF tests [kN]
$\sigma_{R6b-TTF}$	=	the standard deviation of the R6b-TTF tests [kN]
$t_{crit,5\%}$	=	5% significance level of a t-student distribution [h]
$\tau_{5\%,extrapl}$	=	the extrapolated 5% prediction bound [N/mm²]
$\tau_{um,R6-TTF}$	=	mean reference bond strength (test series R6a-TTF or R6b-TTF), converted to the nominal concrete strength and accounting concrete batch influence [N/mm²]
τ_{suc}	=	bond strength corresponding to the sustained load applied in successful sustained load tests [N/mm²]
$\tau_{sust,i}$	=	bond resistance applied in tests for bond resistance at TTF tests [N/mm²]
$\hat{\tau}_{sust,i}$	=	prediction value of the bond strength [N/mm²]
τ_1	=	parameter of the assessment curve [N/mm²]

$\tau^{0}_{Rk,LT}$	=	basic characteristic long-term bond resistance at maximum long-term temperature [N/mm²]
$\tau_{Rk,LT}$	=	characteristic long-term bond resistance (LT) at maximum long-term temperature for the corresponding temperature range [N/mm²]
$\tau_{Rk,ucr}$	=	characteristic bond resistance for uncracked concrete C20/25 for working life of 50 years [N/mm²]
$\tau_{Rk,ucr,100}$	=	characteristic bond resistance for uncracked concrete C20/25 for working life of 100 years [N/mm²]
ψ^{0}_{sus}	=	reduction factor for long-term bond resistance at maximum long-term temperature for working life of 50 years [-]
$\psi^{0}_{sus,100}$	=	reduction factor for long-term bond resistance at maximum long-term temperature for working life of 100 years [-]

1.3.3 Indices

EAD 330499-02-0601 [1], clause 1.3.3 applies.

1.3.4 Definitions

EAD 330499-02-0601 [1], clause 1.3.4 applies with following additions:

TTF = Time to Failure

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 product 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 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 resistance to tension load (static and quasi-static loading)			
1	Resistance to steel failure	EAD 330499-02-0601 [1], 2.2.1	$N_{Rk,s}$ [kN]
2	Resistance to combined pull-out and concrete failure	2.2.1, C.4, C.5	τ_{Rk} or $\tau_{Rk,100}$ [N/mm^2], ψ_c, ψ^0_{sus}, $\psi^0_{sus,100}$ [-] (BF)
	Resistance to pull-out failure	EAD 330499-02-0601 [1], 2.2.2, C.5	$N_{Rk,p}$ or $N_{Rk,p,100}$ [kN], ψ_c [-] (BEF)
3	Resistance to concrete cone failure	EAD 330499-02-0601 [1], 2.2.3	$c_{cr,N}$ [mm], $k_{cr,N}$, $k_{ucr,N}$ [-]
4	Edge distance to prevent splitting under load	EAD 330499-02-0601 [1], 2.2.4	$c_{cr,sp}$ [mm]
5	Robustness	2.2.2	γ_{inst} [-]
6	Maximum installation torque	EAD 330499-02-0601 [1], 2.2.1.2	max T_{inst} [Nm] (BF)
	Installation torque	EAD 330499-02-0601 [1], 2.2.1.2	T_{inst} [Nm] (BEF)
7	Minimum edge distance, spacing and member thickness	EAD 330499-02-0601 [1], 2.2.6	c_{min}, s_{min}, h_{min} [mm]
Characteristic resistance to shear load (static and quasi-static loading)			
8	Resistance to steel failure	EAD 330499-02-0601 [1], 2.2.7	$V^0_{Rk,s}$ [kN], $M^0_{Rk,s}$ [Nm], k_7 [-]
9	Resistance to pry-out failure	EAD 330499-02-0601 [1], 2.2.8	k_8 [-]
10	Resistance to concrete edge failure	EAD 330499-02-0601 [1], 2.2.9	d_{nom}, ℓ_f [mm]
Displacements under short-term and long-term loading			
11	Displacement factors under short-term and long-term loading	EAD 330499-02-0601 [1], 2.2.10	δ_0, δ_∞ [mm/(N/mm^2)] or [mm/kN]
12	Resistance in steel fibre reinforced concrete	EAD 330499-02-0601 [1], 2.2.11	Description

Characteristic resistance and displacements for seismic performance categories C1 and C2			
12	Resistance to tension for seismic performance category C1	EAD 330499-02-0601 [1], 2.2.12	$N_{Rk,s,C1}$ [kN] (all) $\tau_{Rk,C1}$ [N/mm²] (BF) $N_{Rk,p,C1}$ [kN] (BEF)
13	Resistance to tension and displacements for seismic performance category C2	EAD 330499-02-0601 [1], 2.2.13	$N_{Rk,s,C2}$ [kN] (all) $\tau_{Rk,C2}$ [N/mm²] (BF) $N_{Rk,p,C2}$ [kN] (BEF) $\delta_{N,C2(50\%)}$, $\delta_{N,C2(100\%)}$ [mm] (all)
14	Resistance to shear load for seismic performance categories C1	EAD 330499-02-0601 [1], 2.2.14	$V_{Rk,s,C1}$ [kN] (all)
15	Resistance to shear load and displacements for seismic performance categories C2	EAD 330499-02-0601 [1], 2.2.15	$V_{Rk,s,C2}$ [kN] (all) $\delta_{V,C2(50\%)}$, $\delta_{V,C2(100\%)}$ [mm] (all)
Basic Works Requirement 2: Safety in case of fire			
16	Reaction to fire	EAD 330499-02-0601 [1], 2.2.16	Class
Resistance to fire			
17	Fire resistance to steel failure under tension loading	EAD 330499-02-0601 [1], 2.2.17	Level $N_{Rk,s,fi}$ [kN]
18	Fire resistance to bond failure under tension loading	2.2.3	Level $k_{fi,p}$ (θ) [-] $\tau_{Rk,fi}$ (θ) [N/mm²] (BF)
19	Fire resistance to steel failure under shear loading	EAD 330499-02-0601 [1], 2.2.19	Level $V_{Rk,s,fi}$ [kN], $M^0_{Rk,s,fi}$ [Nm]
Basic Works Requirement 3: Hygiene, health and the environment			
20	Content, emission and release of dangerous substances	EAD 330499-02-0601 [1], 2.2.20	Description/level
Aspects of durability			
21	Durability of zinc-based coatings in uncracked concrete only for variable working life	2.2.4	Description

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

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

2.2.1 Resistance to combined pull-out and concrete failure

EAD 330499-02-0601 [1], clause 2.2.2 applies with the following additions.

The assessment method of the sustained load factor ψ^0_{sus} is described in EAD 330499-02-0601 [1], 2.2.2.6. This method is based on sustained load tests, which were performed in the last years for many bonded fasteners. Therefore, this method is the reference method.

For more precise values of the sustained load factor ψ^0_{sus} the following assessment method shall be used. For these assessment additional tests are necessary, but more precise values save resources in the end application of the fasteners.

An overview regarding the different assessment steps is given in Table 2.2.1.1.

Table 2.2.1.1 Assessment methods for ψ^0_{sus} and $\psi^0_{sus,100}$

Assessment in accordance with EAD 330499-02-0601 [1]: based on stabilisation of displacements				Assessment in accordance with this EAD-variant (330499-02-0601-v01): based on Time-to-failure Tests			
50 years [1]: Clause 2.2.2.6		100 years [1]: Clause C.4		50 years [1]: clause 2.2.1.1		100 years [1]: Clause C.4	
T1 [2] [3]	T2, T3 [2]	T1 [2] [3]	T2, T3 [2]	T1 [2] [3]	T2, T3 [2]	T1 [2] [3]	T2, T3 [2]
Tests: R6a, B14 (3 month)	Tests: R6b, B15 (3 month)	Tests: R6a, B14 (6 month)	Tests: R6b, B15 (6 month)	Tests: R6a-TTF, B14-TTF (≥ 28 d)	Tests: R6b-TTF, B15-TTF (≥ 28 d)	Tests: R6a-TTF, B14-TTF (≥ 28 d)	Tests: R6b-TTF, B15-TTF (≥ 28 d)
$\delta_{N,\infty,m}$ Extra-polation displace-ments B14 (3 month) to 50 years Equation (2.2.2.6.1.1)	$\delta_{N,\infty,m}$ Extra-polation displace-ments B15 (3 month) to 50 years Equation (2.2.2.6.1.1)	$\delta_{N,\infty,m}$ Extra-polation displace-ments B14 (6 month) to 100 years Equation (2.2.2.6.1.1)	$\delta_{N,\infty,m}$ Extra-polation displace-ments B15 (6 month) to 100 years Equation (2.2.2.6.1.1)	$\delta_{N,\infty,m}$ No performance assessed in accordance with this EAD-variant (based on time-to failure tests B14-TTF and B15-TTF), assessment shall be done in accordance with EAD 330499-02-0601 [1] (based on tests B14 and B15)			
τ_{suc} Equation (2.2.2.6.1.4) with N_{sust} from B14 (3 month) $\alpha_{p,B14}$ Equation (2.2.2.6.1.2) with $\tau_{Rk,0,ucr}$ for T1 and 50 years	τ_{suc} Equation (2.2.2.6.1.7) with N_{sust} from B15 (3 month) $\alpha_{p,B15}$ Equation (2.2.2.6.1.5) with $\tau_{Rk,0,ucr}$ for T2, T3 and 50 years	τ_{suc} Equation (2.2.2.6.1.4) with N_{sust} from B14 (6 month) $\alpha_{p,B14}$ Equation (2.2.2.6.1.2) with $\tau_{Rk,0,ucr}$ for T1 and 100 years	τ_{suc} Equation (2.2.2.6.1.7) with N_{sust} from B15 (6 month) $\alpha_{p,B15}$ Equation (2.2.2.6.1.5) with $\tau_{Rk,0,ucr}$ for T2, T3 and 100 years	τ_{suc} Equation (2.2.1.1.2.4) with $\tau_{5\%,extrpl}$ from B14-TTF $\alpha_{p,B14}$ See EAD 330499-02-0601 [1]	τ_{suc} Equation (2.2.1.1.2.4) with $\tau_{5\%,extrpl}$ from B15-TTF $\alpha_{p,B15}$ See EAD 330499-02-0601 [1]	τ_{suc} Equation (C.4.2) with $\tau_{5\%,extrpl,100}$ from B14-TTF $\alpha_{p,B14}$ See EAD 330499-02-0601 [1]	τ_{suc} Equation (C.4.2) with $\tau_{5\%,extrpl,100}$ from B15-TTF $\alpha_{p,B15}$ See EAD 330499-02-0601 [1]
ψ^0_{sus} Clause 2.2.2.6.4 with τ_{sust} in tests B14 (3 month) and with $\tau_{Rk,ucr}$ for T1 and 50 years	ψ^0_{sus} Clause 2.2.2.6.4 with τ_{sust} in tests B15 (3 month) and with $\tau_{Rk,ucr}$ for T2, T3 and 50 years	$\psi^0_{sus,100}$ Clause C.4 with τ_{sust} in tests B14 (6 month) and with $\tau_{Rk,ucr}$ for T1 and 100 years	$\psi^0_{sus,100}$ Clause C.4 with τ_{sust} in tests B15 (6 month) and with $\tau_{Rk,ucr}$ for T2, T3 and 100 years	ψ^0_{sus} Clause 2.2.1.1.3 with $\tau_{5\%,extrpl}$ from B14-TTF and with $\tau_{Rk,ucr}$ for T1 and 50 years	ψ^0_{sus} Clause 2.2.1.1.3 with $\tau_{5\%,extrpl}$ from B15-TTF and with $\tau_{Rk,ucr}$ for T2,T3 and 50 years	$\psi^0_{sus,100}$ Clause C.4 with $\tau_{5\%,extrp,100l}$ from B14-TTF and with $\tau_{Rk,ucr,100}$ for T1 and 100 years	$\psi^0_{sus,100}$ Clause C.4 with $\tau_{5\%,extrpl,100}$ from B15-TTF and with $\tau_{Rk,ucr,100}$ for T2,T3 and 100 years

1) working life in accordance with EAD 330499-02-0601 [1], clause 1.2.2

2) service temperature range in accordance with EAD 330499-02-0601 [1], clause 1.2.1

3) T1: maximum long-term temperature = normal ambient temperature

2.2.1.1 Sustained loads and factor ψ^0_{sus} (test series R6-TTF, B14-TTF, B15-TTF)

Purpose of the assessment

The tests shall be performed to check the creep behaviour of the loaded fasteners at normal ambient temperature (test series B14-TTF) and at maximum long-term temperature (test series B15-TTF). Based on these tests for each temperature range the factor ψ^0_{sus} (see EN 1992-4 [5], clause 7.2.1.6) accounting for the influence of sustained loads at maximum long-term temperature on the bond strength shall be determined.

Test conditions - general

The tests shall be carried out as confined tests in accordance with EAD 330499-02-0601 [1], Figure D.3.1.4.1, in uncracked concrete C20/25 and C12/15, both at normal ambient temperature and maximum long-term temperature with diameter 12 mm or smallest size if that is larger than 12 mm.

Note: It is recommended to test in concrete members of an age more than 90 days.

The age of concrete members shall be presented in the test report.

2.2.1.1.1 Reference tests R6a-TTF and R6b-TTF

The R6-TTF test series shall be performed in the same concrete batch and with the same curing time as the B14-TTF and the B15-TTF test series. The load shall be increased in such a way that the peak load occurs after 1 to 3 minutes from commencement in accordance with EAD 330499-02-0601 [1], D.3.2.

a) <u>at normal ambient temperature (= maximum long-term temperature for temperature range T1)</u>

Reference tests R6a-TTF shall be performed (n ≥ 5 tests, see also Table A.1.1).

Fasteners shall be installed at normal ambient temperature (+21°C ±3°C).

<u>b) at maximum long-term temperature</u>

Reference tests R6b-TTF shall be performed (n ≥ 5 tests, see also Table A.1.1).
Fasteners shall be installed at normal ambient temperature (+21°C ±3°C). The temperature of the test member shall be raised to reach the maximum long-term temperature at a rate of 5 K per hour on the concrete surface in the area of the fixing (less than 150 mm distance). The fastener shall be loaded to failure after the temperature has been.

Assessment of test series R6a-TTF and R6b-TTF:

<u>Failure loads</u>

- The mean value of failure loads $N_{um,R6a\text{-}TTF}$ and $N_{um,R6b\text{-}TTF}$ [kN] and bond strength $\tau_{um,R6a-TTF}$ and $\tau_{um,R6b-TTF}$, converted to the nominal concrete strength and accounting for concrete batch influence shall be determined in accordance with EAD 330499-02-0601 [1], clause A.2.1.2 and clause A.2.1.4.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20 % (cv_F > 20 %), then the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], clause A.2.1.5.

<u>Load displacement behaviour</u>

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], clause A.2.2.1.
- The displacements at 50 % of the mean failure load $\delta_{0,5Num}$ [mm] in each test shall be determined.
- The coefficient of variation of the displacements at 50 % of the mean failure load $c_{v\delta}$ [%] shall be determined. If the mean value of displacements at 50 % of the failure load are larger than 0,4 mm, then $c_{v\delta}$ shall not exceed 40 %. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur."

Expression of results:

$ß_{cv}$, α_1 to be used in EAD 330499-02-0601 [1], clause 2.2.2.14

2.2.1.1.2 Time-to-failure tests B14-TTF, B15-TTF

General test procedure and determination of sustained loads N_{sust}

The sustained load tests B14-TTF and B15-TTF in accordance with Table A.1.1 shall be performed.

The permanent load $N_{sust,i}$ shall be applied by a hydraulic jack or pneumatic cylinder or weight. The load shall be increased in the same way that the peak load occurs after 1 to 3 minutes from commencement in accordance with EAD 330499-02-0601 [1], D.3.2.

The load $N_{sust,i}$ shall be maintained and recorded. The temperature shall be maintained, at least for 3 fasteners for 28 days. Maximum temporary variation due to test setup shall be -5 % $N_{sust,i}$; no active permanent steering on lower load tolerance level is allowed. For assessment, the mean applied load during loading time shall be considered.

$N_{sust,1}$ shall be selected based on the scatter of the R6-TTF tests to avoid failure of the fastener during the loading but not lower than 0,85 $N_{um,R6\text{-}TTF}$ (Figure 2.2.1.1.2.1 (a)).

Minimum 10 failure loads shall be determined during the loading between $N_{sust,1}$ and the load level with no failure at a minimum testing time of 28 days shall be determined. It is possible to extend the test duration, until minimum 10 tests fail, or to restart additional tests by equally distributing the load levels between $N_{sust,1}$ and the load level with no failure at a minimum testing time of 28 days.

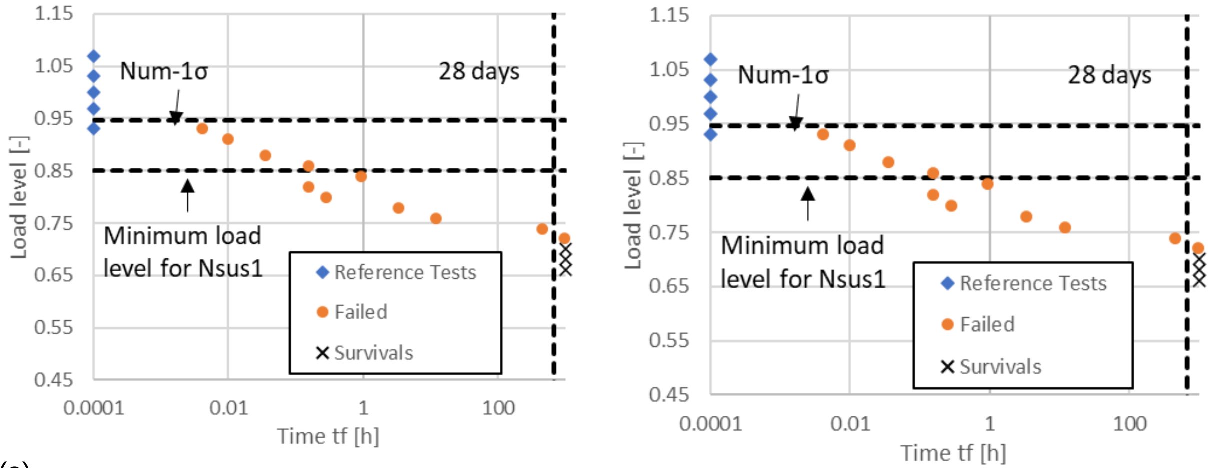
In addition, 3 sustained load tests shall be performed, where no failure occurs for a duration of the maximum of 28 days and the longest time, where failure had occurred.

The load levels shall be equally distributed with a maximum step of 3% $N_{um,R6\text{-}TTF}$. At least the 3 fasteners with the highest applied load $N_{sust,i}$, that has not failed and has been unloaded shall be considered as failed with a failure time corresponding to the unloading time.

The frequency of recording the load shall be chosen so that the mean load of the applied level during the test can be determined. As the failure time of a fastener will be short for high applied load the frequency shall be high for high applied constant loads and shall be decreased as $N_{sust,i}$ decreases. During the first 24 hours the frequency shall be 5 Hz, after 24 hours minimum 0,5 Hz.

When the fastener fails the failure time shall be defined by finding the drop of the measured load. The failure time shall be calculated as the time when the load drops by at least 5% subtracted the time when the load was applied on the fastener. The mean sustained load and the time from loading until failure t_f of the fastener shall be calculated for each test.

Figure 2.2.1.1.2.1 illustrates an example for the test requirements.



(a)

(b)

Figure 2.2.1.1.2.1 Examples of time-to-failure tests.

In Figure 2.2.1.1.2.1 (a):

- 10 fasteners loaded at load levels between $N_{um,R6\text{-}TTF}$ - 1 $\sigma_{R6\text{-}TTF}$ and 0,74 $N_{um,R6\text{-}TTF}$ have failed with a maximum t_f = 20 days loaded at load levels of a step of 0,02 $N_{um,R\text{-}TTF}$ and
- 3 fasteners loaded between 0,72 $N_{um,R6\text{-}TTF}$ and 0,68 $N_{um,R6\text{-}TTF}$ with a step of 0,02 $N_{um,R6\text{-}TTF}$ have reached a testing period of 28 days without failure.

In Figure 2.2.1.1.2.1 (b):

- 10 fasteners loaded at load levels between $N_{um,R6\text{-}TTF}$ – 1 $\sigma_{R6\text{-}TTF}$ and 0,74 $N_{um,R6\text{-}TTF}$ have failed with a maximum t_f = 20 days loaded at load levels of a step of 0,02 $N_{um,R6\text{-}TTF}$ and
- 1 fastener loaded at 0,72 $N_{um,R6\text{-}TTF}$ has failed after a loading period of 41 days.
- In that case 3 additional fasteners have been loaded at load levels between 0,70 $N_{um,R6\text{-}TTF}$ and 0,66 $N_{um,R6\text{-}TTF}$ with a step of 0,02 $N_{um,R6\text{-}TTF}$ and tested with no failure until a minimum loading period of 41 days. In that case the fasteners cannot be unloaded after 28 days since 28 days < 41 days (maximum observed failure).

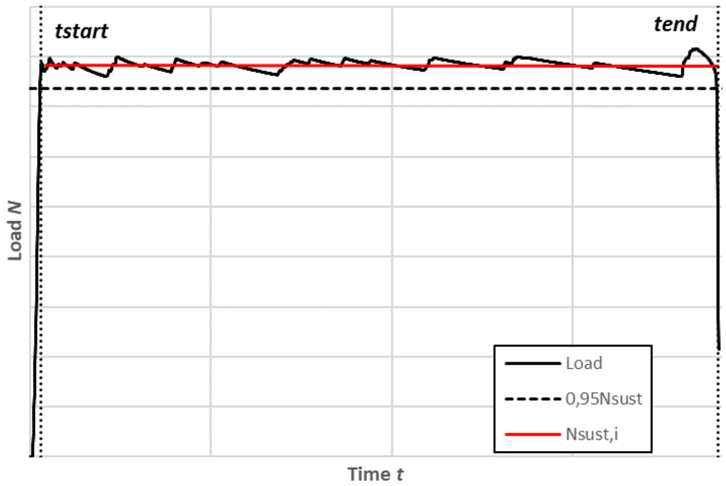


Figure 2.2.1.1.2.2 Calculation of t_f from TTF tests

Example of calculating failure time and load:

In Figure 2.2.1.1.2.2 the fastener shall be loaded to target load. The loading phase until the target load is reached lasts until *tstart*. Then the load remains constant, within the required tolerance, until the fastener fails and the load drops, or the test is stopped. The failure time $t_{f,i}$ and the $N_{sust,i}$ shall be calculated as following:

- First the time t_{start} where the load reaches the target load shall be found,
- the time t_{end} when during failure the load drops at 0,95 of the target load and the load continues to drop shall be found,
- the failure time $t_{f,i}$ = $t_{end,i}$ - $t_{start,I}$ shall be calculated,
- the $N_{sust,i}$ as the mean of the load in the time period from $t_{start,i}$ to $t_{end,I}$ shall be calculated.

<u>a) Tests at normal ambient temperature B14-TTF (= maximum long-term temperature for temperature range T1)</u>

The fasteners shall be installed at normal ambient temperature (+21°C ± 3°C).

For B14-TTF tests, the required load levels applied on the fastener, $N_{sust,i}$, shall be calculated based on the mean load of the reference tests $N_{um,R6a\text{-}TTF}$ not converted to the nominal concrete strength and without accounting for concrete batch influence.

The load levels steps shall be at maximum 0,03 $N_{um,R6a\text{-}TTF}$ between $N_{sus,1}$ and the load level that sustains the load for a minimum loading period of 28 days.

$N_{sus,1}$ shall be selected based on the scatter of the R6a-TTF tests, to avoid failure of the fastener during the loading but not lower than 0,85 $N_{um,R6a-TTF}$ (Figure 2.2.1.1.2.1 (a)).

For example, use a starting load level of $N_{sus,1} = N_{um,R6a-TTF}$ - 1 $\sigma_{R6a-TTF}$, where $\sigma_{R6a-TTF}$ is the standard deviation of the R6a-TTF tests.

A minimum of 10 tests with failure within a period of minimum 28 days (or longer) and minimum of 3 tests with no failure after a minimum loading time of 28 days, but longer than the longest time, where failure has occurred, are required for the assessment.

Temperatures in the room shall not vary more than ± 3 °C due to day/night and seasonal effects but the required temperature level of the test member shall be achieved as a mean over the test period.

b) Tests at maximum long-term temperature and B15-TTF)

The fasteners shall be installed at normal ambient temperature (+21°C ±3°C). The temperature of the test member shall be raised to reach the maximum long-term temperature at a rate of 5 K per hour on the concrete surface in the area of the fixing (less than 150 mm distance).

The fastener shall be loaded to the required load levels $N_{sust,i}$ after the temperature has been reached and the load shall be maintained until the fastener fails or a minimum loading period of 28 days has been reached.

The sustained loads applied on the fastener $N_{sust,i}$, shall be calculated based on the mean load of the reference tests $N_{um,R6b-TTF}$ not converted to the nominal concrete strength and without accounting for concrete batch influence.

The load levels steps shall be at maximum 0,03 $N_{um,R6b,TTF}$ between $N_{sus,1}$ and the load level that sustains the load for a minimum loading period of 28 days.

$N_{\mathrm{sus},1}$ shall be selected based on the scatter of the R6b-TTF tests to avoid failure of the fastener during the loading but not lower than 0,85 $N_{um,R6b-TTF}$.

For example, use a starting load level of $N_{sust,1} = N_{um,R6b-TTF}$ - 1 $\sigma_{R6b-TTF}$, where $\sigma_{R6a-TTF}$ is the standard deviation of the R6b-TTF tests.

A minimum of 10 test with failure within a period of minimum 28 days (or longer) and minimum of 3 tests with no failure after a minimum loading time of 28 days, but longer than the longest time, where failure has occurred, are required for the assessment.

Assessment for tests B14-TTF and B15-TTF:

After minimum 10 fasteners have failed and at least 3 fasteners have sustained the load for a required testing period, the data of $N_{sust,i}$ and $t_{f,i}$., convert the $N_{sust,i}$ to the nominal concrete strength and accounting for concrete batch influence shall be collected in accordance with EAD 330499-02-0601 [1], clause A.2.1.2 and A.2.1.4, respectively.

The corresponding bond stress of sustained load shall be calculated from equation (2.2.1.1.2.1).

$$\tau_{sust,i} = \frac{N_{sust,i}}{\pi \cdot d \cdot h_{ef}} \qquad (2.2.1.1.2.1)$$

with:

$N_{sust,i}$ = sustained load applied in each of n sustained load tests at normal ambient temperature and at maximum long-term temperature, which meet the criteria, normalized to C20/25 and C12/15 strength (in accordance with EAD 330499-02-0601 [1]) clause A.2.1.2

d = diameter of the steel element

h_{ef} = effective embedment depth

The stress vs time-to-failure diagram with the pairs of $t_{f,i}$ and $\tau_{sust,i}$ shall be created.

A non-linear regression of equation (2.2.1.1.2.2) to the data test with the least squares regression method shall be performed (iterative technique used to find the parameters that minimize the sum of the squared differences between observed data and a non-linear function.)

Depending on the targeted working life, the pairs of $t_{f,i}$ and $\hat{\tau}_{sust,i}$ shall be extrapolated in accordance with non-linear regression of equation (2.2.1.1.2.2) to 50 years.

$$\hat{\tau}_{sust,i} = \left(\tau_{um,R6-TTF} - \tau_1\right) + \tau_1 \cdot \left(\frac{\tau_{um,R6-TTF}}{\tau_{um,R6-TTF} + b \cdot t_{f,i}}\right)^c \qquad (2.2.1.1.2.2)$$

with:

$\tau_{um,R6-TTF}$ = mean reference bond strength (test series R6a-TTF or R6b-TTF)

τ_1, b, c = parameters determined by a non-linear regression analysis of the sustained load against the failure times measured at the sustained load test with the least squares regression method

Parameter τ_1 controls the asymptotic behaviour of the assessment curve ($\hat{\tau}_{sust,i}$ as $t_f \rightarrow \infty$). The non-linear regression fit shall be performed with

i. τ_1 fixed such as $\left(\tau_{u,m,R6-TTF} - \tau_1\right)$ = 0,4 $\tau_{um,R6-TTF}$ thus τ_1 = 0,6 $\tau_{um,R6-TTF}$ and

ii. τ_1 free to be fitted.

The final assessment shall be performed with the τ_1 that results in the lower value between the two fits (fixed and free to be fitted) at desired time (50 or 100 years). After the fit has been performed and the final assessment curve has been selected the extrapolated 5% prediction bound of the assessment equation (2.2.1.1.2.2) shall be calculated from equation (2.2.1.1.2.3).

$$\tau_{5\%,extrpl} = \hat{\tau}_{sust,i} - t_{crit,5\%} \cdot s_{y,x}\sqrt{1 + \frac{1}{n} + \frac{(t_i - \overline{t_f})^2}{Sx}} \qquad (2.2.1.1.2.3)$$

with:

$\hat{\tau}_{sust,i}$ = prediction value of the bond strength for a loading time t calculated in accordance with equation (2.2.1.1.2.2),

$t_{crit,5\%}$ = 5% significance level of a t-student distribution to be taken by the table of a t-distribution (see reference [11]) for one tailed a=0,05 and with degrees of freedom dof = n - 2 for fit with τ_1 = 0,6 $\tau_{um,R6-TTF}$ and dof = n - 3 for fitted τ_1,

Note: $t_{crit,5\%}$ to be taken by the table of a t-distribution (see reference [11])

$s_{y,x}$ = root mean squared error of the tested points given by $s_{y,x} = \sqrt{\frac{1}{n}\sum\left(\hat{\tau}_{sust,i} - \tau_{sust,i}\right)^2}$,

n = number of tests,

t_i = loading time with t_i from 0,01 sec. to 50 years, minimum 30 data points, equally distributed on the x-axis in Figure 2.2.1.1.2.3,

$\overline{t_f}$ = mean value of the failure times of the tests,

S_x = sum of squared deviation of the time values in the extrapolation curve given by $S_x = \sum(t - \bar{t})^2$. The calculation of S_x, shall be done considering the times $t_{f,i}$ and the time of the assessment, 50 years.

The bond strength corresponding to the sustained load applied in successful test series B14-TTF or B15-TTF shall be calculated in accordance with equation (2.2.1.1.2.4).

$$\tau_{suc} = \tau_{5\%,extrpl} \cdot 1,5 \cdot \gamma_{inst} \cdot (\alpha_2 \cdot \alpha_3 \cdot \alpha_4) / 1,1 \qquad (2.2.1.1.2.4)$$

with:

$\tau_{5\%,extrpl}$ = extrapolated 5% prediction bound in accordance with equation (2.2.1.1.2.3)

γ_{inst} = factor accounting for the sensitivity to installation under dry conditions (used in design in accordance with EN 1992-4 [5]), determined in accordance with clause 2.2.2.

α_2 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.9.1), tests at maximum long-term temperature

α_3 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.9.2), tests at maximum short-term temperature

α_4 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.12.1), tests for checking durability of bonding material

Example of assessment:

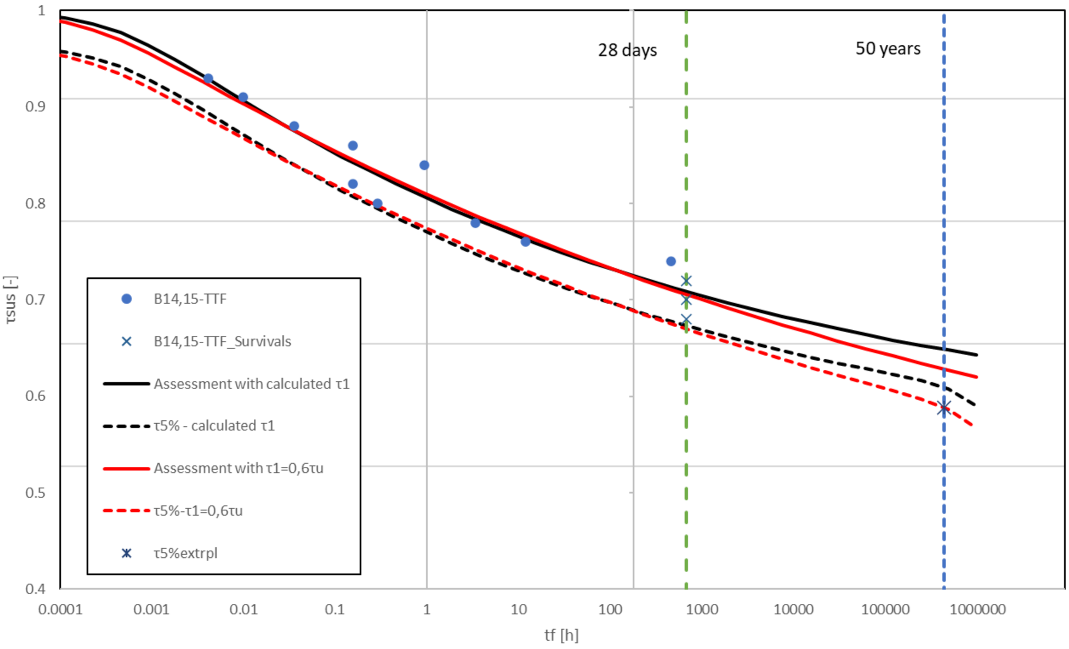


Figure 2.2.1.1.2.3 Calculation of $\tau_{5\%,extrpl}$ from B14-TTF and B15-TTF

In Figure 2.2.1.1.2.3 the calculation of $\tau_{5\%,extrpl}$ is given by the following steps:

- the data $\tau_{sust,i}$ shall be calculated from equation (2.2.1.1.2.1) and t_{fi},
- a non-linear regression of equation (2.2.1.1.2.2) shall be performed twice to the data,
  - with τ_1 = 0,6 $\tau_{um,R6-TTF}$
  - with τ_1 obtained by the regression
- the 5% fractile prediction bound for the two fits shall be calculated from equation (2.2.1.1.2.3),
- the 5% fractile prediction bounds shall be extrapolated to t=50 years,
- the $\tau_{5\%,extrpl}$ shall be calculated by taking the minimum value of the two extrapolated curves at 50 years.

Expression of results:

τ_{suc} to be used in EAD 330499-02-0601 [1], equation (2.2.2.6.1.2) and (2.2.2.6.1.5) for calculation of α_p.

2.2.1.1.3 Factor ψ^0_{sus} for combined pull-out and concrete failure

The factor ψ^0_{sus} accounting for the influence of sustained tension load on the bond strength for combined pull-out and concrete failure shall be assessed for working life of 50 years based on test series B14-TTF and B15-TTF.

The factor ψ^0_{sus} shall be determined for every temperature range requested by the manufacturer in accordance with equation (2.2.1.1.3.3) for the maximum long-term temperature. Please note that normal ambient temperature corresponds to maximum long-term temperature of temperature range T1.

The basic characteristic long-term bond resistance at maximum long-term temperature shall be determined in accordance with equation (2.2.1.1.3.1).

$$\tau^0_{Rk,LT} = \tau_{5\%,extrpl} \tag{2.2.1.1.3.1}$$

with:

$\tau^0_{Rk,LT}$ = basic characteristic long-term bond resistance at maximum long-term temperature

$\tau_{5\%,extrpl}$= extrapolated 5% prediction bound of the assessment equation (2.2.1.1.2.2) calculated from equation (2.2.1.1.2.3)

The characteristic long-term bond resistance shall be determined accounting for the relevant (reduction) factors as follows:

$$\tau_{Rk,LT} = \tau^0_{Rk,LT} \cdot a_3 \cdot a_4 \cdot k_{sus} \cdot a_{setup} \cdot min\beta_{cv} \tag{2.2.1.1.3.2}$$

with:

$\tau_{Rk,LT}$ = characteristic long-term bond resistance (LT) at maximum long-term temperature for the corresponding temperature range

α_3 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.9.2)

α_4 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.12.1)

α_{setup} = 0,75, reduction factor for uncracked concrete in accordance with EAD 330499-02-0601 [1], clause 2.2.2.14.

k_{sus} = 1,135

Note: The factor k_{sus} takes account of beneficial effects under long-term loading. The influence of the confinement on the pull-out resistance decreases under long-term loading and an increase of 13,5% of the reduction factor α_{setup} has been evaluated from tests.

min β_{cv} = minimum of reduction factors β_{cv} in accordance with EAD 330499-02-0601 [1], equation (A.2.1.5.2)

The factor ψ^0_{sus}, accounting for the influence of sustained tension load on the bond strength for combined pull-out and concrete failure, shall be determined as given in equation (2.2.1.1.3.3).

$$\psi^0_{sus} = \frac{\tau_{Rk,LT}}{\tau_{Rk,ucr}} \cdot 1,15 \leq 1,0 \tag{2.2.1.1.3.3}$$

with:

ψ^0_{sus} = reduction factor of long-term bond resistance at maximum long-term temperature.

$\tau_{Rk,ucr}$ = characteristic value of short-term bond resistance at maximum long-term temperature, as given in the ETA for uncracked concrete.

Expression of results:

Factors ψ^0_{sus} for temperature ranges according to the intended use.

2.2.2 Robustness

Purpose of the assessment

These tests shall be performed to assess the sensitivity of the fastener tension capacity to installation conditions. In this context the sensitivity to the degree of hole cleaning in dry and water saturated concrete, to hole cleaning for applications where the hole contains standing water at the time of installation of the fastener and to mixing effort are considered. The reference tests (R5 or A3) and the robustness tests B6 to B9 (BF) or E2 to E5 (BEF) shall be performed with the reference drilling and cleaning method used in the full test programme.

For each alternative drilling and cleaning method specified by the manufacturer, the test series B6 to B8 (BF) or E2 to E4 (BEF) shall be performed in addition, e.g., hammer drilling with additional cleaning procedure (blowing – brushing – blowing), hollow drilling without additional cleaning procedure (each type of hollow drill bit) and other alternative drilling and cleaning methods, e.g., diamond core drilling (roughening and flushing).

Test conditions - general

The tests shall be carried out as confined tension tests for BF and unconfined tension tests for BEF in uncracked concrete.

The fasteners shall be installed with the maximum embedment depth $h_{ef,max}$ = 20 d or as defined by the manufacturer. To avoid steel failure, but still account properly for the installation aspects for $h_{ef,max}$ the procedure given in section A.2 (see also EAD 330499-02-0601 [1], Figure A.2.1) shall be applied.

Additional test conditions for the specific test series B6 to B9 (BF) and E2 to E5 (BEF) are given in the following subsections. The following test conditions are defined for drilling the hole with a hammer drilling method producing drilling dust that has to be removed from the bore hole by blowing (sucking) and brushing or by hollow drilling with continuous vacuuming. Other drilling methods require different methods of reduced bore hole cleaning (e.g., reduced flushing for diamond drilled holes).

Assessment

The assessment for the test series B6 to B9 (BF) and E2 to E5 (BEF) shall be carried out accounting for the normalization to the nominal concrete strength in accordance with EAD 330499-02-0601 [1], clause A.2.1.2. The reduction factor for each test series is calculated using the corresponding reference test series R5 or A3.

Based on the results of these tests the factor γ_{inst} accounting for the sensitivity to installation shall be determined in accordance with 2.2.2.6.

The factor γ_{inst} accounting for the sensitivity to installation for all sizes of the fastener shall follow a regular curve.

2.2.2.1 Reference test series (test series R5, A3)

Purpose of the assessment

The test series is needed as reference for comparison of test results in test series B6 to B9 (BF) or E2 to E5 (BEF). It is required for the reference drilling and cleaning method.

Test conditions

The tests shall be performed with fastener sizes s/m/l (see EAD 330499-02-0601 [1], Table A.1.2). The tests shall be performed in dry concrete (equilibrium moisture content).

The test conditions as concrete batch, temperature, steel element, embedment depth, curing time and setting torque shall be the same as for test series B6 to B9 (BF) or E2 to E5 (BEF).

The drill holes shall be drilled downwards to the maximum embedment depth. The drill hole shall be cleaned according to the MPII. The bonding material shall be placed and the steel element shall be inserted according to the MPII.

> *Note: In the assessment, the results of series B6 to B8 (BF) or E2 to E4 (BEF) with alternative drilling and cleaning methods shall be compared to the reference test R5 (BF) or A3 (BEF) with the reference drilling and cleaning method, respectively. The assessment may result in different installation factors γ_{inst} for different cleaning methods.*

Assessment

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.

Load displacement behaviour

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50 % of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load is larger than 0,4 mm, cv_δ shall not exceed 25%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

Expression of results:

$N_{u,m}$,, $N_{5\%}$ [kN] to be used as reference in 2.2.2.2, 2.2.2.3, 2.2.2.4, 2.2.2.5,

$ß_{cv}$, α_1 to be used in EAD 330499-02-0601 [1], clause 2.2.2.14 / 2.2.2.15.

2.2.2.2 Robustness in dry concrete (test series B6, E2)

Purpose of the assessment

The test series shall be performed to assess the influence of reduced cleaning effort in dry concrete. The tests shall be performed with each drilling and cleaning method of the MPII. The different drilling and cleaning methods shall be assessed, using as reference, the test series R5 (BF) or A3 (BEF) performed with the reference drilling and cleaning method. Each type/brand of hollow drill bit or alternative drilling and cleaning method (e.g., diamond coring bit, roughening procedure) listed in the MPII shall be tested and assessed.

Test conditions

The tests shall be performed with fastener sizes in accordance with EAD 330499-02-0601 [1], Table A.1.2 or Table B.2.1. The tests shall be performed in dry concrete (equilibrium moisture content).

The drill holes shall be drilled downwards to the maximum embedment depth.

The following cleaning process of the hole shall be carried out in the tests.

Hammer drilling with standard drill bit or hollow drilling and subsequent cleaning (cleaning procedure as defined by the manufacturer):

The hole shall be cleaned as defined by the manufacturer using two blowing operations by hand pump or compressed air and one brushing operation, i.e., either blow-brush-blow or blow-blow-brush or brush-blow-blow. The type of blowing and the order of brushing/blowing shall be done as prescribed in the MPII. This test procedure is valid only if the MPII specify hole cleaning with at least four blowing and two brushing operations, meaning twice the operations given above. If the MPII specify less than this, the above requirement (2 blows + 1 brush) shall be reduced proportionately and the number of blows/brushes shall be lowered to the next whole number. Therefore, where the MPII recommend two blowing and one brushing operations, the tests shall be carried out without the brushing operation and one blowing only.

If the MPII recommends a vacuum cleaning instead of a blowing operation, the same procedure (including requirements and corresponding reduced operations) applies.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Hollow drilling (rotary hammer drilling using a hollow drill bit) with continuous vacuuming of the drilling dust without subsequent cleaning:

If the vacuum cleaning is part of the drilling process, the drilling shall be done without venting (meaning, airing out the dust by periodically moving the drill bit out of the hole) during the drilling process. If the cleaning is performed with suction bit or a hollow drill bit, then the vacuum with the smallest maximum flow rate and suction pressure specified in the MPII shall be used during the drilling process.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Diamond core drilling (with or without rig, with or without water cooling, with or without roughening procedures) and subsequent cleaning (as defined by the manufacturer in the MPII):

The hole shall be cleaned and roughened as defined by the manufacturer. The roughening and cleaning procedure shall be reduced 50% (duration or number of repetitions), but not more than 3 cleaning operations, compared to the procedure specified in the MPII.

The bonding material shall be placed and the steel element shall be installed according to the MPII. Use the same type of steel element for tests with different drilling and cleaning methods.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Assessment of reference drilling and cleaning method

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with EAD 330499-02-0601 [1], Annex A, comparing the test results with reference test series in accordance with Table A.1.1, lines R5 (BF) or A3 (BEF).
- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.
- If α < 0,70, the reduction (α/rqd. α) shall be determined by using rqd. α = 0,7 and γ_{inst} = 1,4.

Load displacement behaviour

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load is larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

Assessment of additional cleaning methods

Rotary hammer drilling (Hammer drilling and Hollow drilling):

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.

- $N_{u,m}$ [kN] and / or bond strength $\tau_{u,m}$ [N/mm²] and the 5% fractile of the failure loads $N_{5\%}$ [kN] and/or bond strength $\tau_{5\%}$ [N/mm²] of test series B6 or E2 shall be at least 95% of the corresponding parameters of the tests with the reference cleaning method (i.e., take minimum values of series B6 and R5 or E2 and A3). The comparison of the 5 %-fractile may be omitted for any number of tests in a test series if 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 %.
- Each type/brand of hollow drill bit listed in the MPII shall be assessed. To show equivalence, each type/brand shall show the same or a better γ_{inst} as the reference drilling and cleaning method.
- If no equivalence to the reference drilling/cleaning method can be assessed due to lower resistances, the additional cleaning method shall be either:
    - taken as new reference drilling and cleaning method in the complete test programme and other drilling and cleaning methods can be assumed equivalent compared to the new reference drilling/cleaning method and the reduced programme in accordance with Table G.2.1 (BF) or G.2.2 (BEF) applies.
    - assessed separately in accordance with Table G.2.3 (BF) or G.2.4 (BEF), and G.2.5 (for seismic application) (no equivalence)."

<u>Load displacement behaviour</u>

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load is larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

Assessment of alternative drilling and cleaning methods

<u>Failure loads</u>

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% ($cv_F > 20\%$), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with EAD 330499-02-0601 [1], Annex A, comparing the test results with reference test series in accordance with Table A.1.1, lines R5 (BF) or A3 (BEF) (reference method).
- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.

<u>Load displacement behaviour</u>

- The reduction factor α_1 in accordance with EAD 330499-02-0601 [1], A.2.2.1 shall be determined.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] in each test shall be determined.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load is larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

  Note: For different rotary hammer drilling methods (Hammer drilling and hollow drilling) equivalent or better performance and robustness are required. For alternative drilling and cleaning methods (e.g., diamond core drilling) no equivalency in this test series is required, but additional tests in accordance with Table G.2.1 (BF) or G.2.2 (BEF) (reduced programme for equivalent performance *in series B6 to B8 (BF) or E2 to E4 (BEF)) or Table G.2.3 (BF) or G.2.4 (BEF) (reduced programme for lower performance in series B6 to B8 (BF) or E2 to E4 (BEF)) shall be performed in any case.*

Expression of results (may differ for different drilling and cleaning methods)

$ß_{cv,}$ (α/rqd. α), α_1 to be used in EAD 330499-02-0601 [1], clause 2.2.2.14 / 2.2.2.15.

α resulting from test series B6 or E2 to be used in 2.2.2.6.

Assessed types/brands of hollow drill bits, diamond core bits or other drilling/cleaning equipment (e.g., flow rate and suction pressure of vacuum cleaner) shall be given in the ETA.

2.2.2.3 Robustness in water saturated (wet) concrete (test series B7, E3)

Purpose of the assessment

The test series shall be performed to assess the influence of reduced cleaning effort in water saturated concrete. The tests shall be performed with each cleaning and drilling method of the MPII. The different drilling and cleaning methods shall be assessed using as reference the test series R5 (BF) or A3 (BEF) performed with the reference drilling and cleaning method. Each type/brand of hollow drill bit or alternative drilling and cleaning method (e.g., diamond core bit, roughening procedure) listed in the MPII shall be tested and assessed.

Test conditions

The tests shall be performed with fastener sizes in accordance with EAD 330499-02-0601 [1], Table A.1.2, or Table B.2.1.

The concrete in the area of anchorage shall be water saturated when the hole is drilled, cleaned and the embedded steel element is installed and tested.

The following procedure may be applied to ensure a water saturated concrete in the area of the anchorage:

1. A pilot hole shall be drilled in the concrete substrate to the recommended depth.
2. The pilot hole shall be filled with water and remains flooded for 8 days until water has percolated into the concrete.
3. The water shall be removed from the pilot hole.
4. The final hole shall be drilled at the recommended diameter d_0.

Note: The diameter of the pilot hole shall be chosen such that sufficient penetration of water into the concrete is achieved. Therefore, the diameter of the pilot hole of 0,5 d_0 to 0,8 d_0 is recommended.

If methods other than those described above are used it shall be shown by methods that the concrete in the area of the anchorage is water saturated (e.g., concrete is stored under water immediately after stripping the formwork).

<u>Hammer drilling with standard drill bit or hollow drilling and subsequent cleaning (cleaning procedure as defined by the manufacturer):</u>

The hole shall be cleaned as defined by the manufacturer using two blowing operations by hand pump or compressed air and one brushing operation, i.e., either blow-brush-blow or blow-blow-brush or brush-blow-blow. The type of blowing and the order of brushing/blowing shall be done as prescribed in the MPII. This test procedure is valid only if the MPII specify hole cleaning with at least four blowing and two brushing operations, meaning twice the operations given above. If the MPII specify less than this, the above requirement (2 blows + 1 brush) shall be reduced proportionately and the number of blows/brushes shall be lowered to the next whole number. Therefore, where the MPII recommend two blowing and one brushing operation, the tests shall be carried out without the brushing operation and one blowing only.

If the MPII recommends a vacuum cleaning instead of a blowing operation, the same procedure (including requirements and corresponding reduced operations) applies.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

<u>Hollow drilling (rotary hammer drilling using a hollow drill bit) with continuous vacuuming of the drilling dust without subsequent cleaning:</u>

If the vacuum cleaning is part of the drilling process, the drilling shall be done without venting (meaning, airing out the dust by periodically moving the drill bit out of the hole) during the drilling process. If the cleaning is performed with suction bit or a hollow drill bit, then the vacuum with the smallest specified maximum flow rate shall be used during the drilling process.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Diamond core drilling (with or without rig, with or without water cooling, with or without roughening procedures) and subsequent cleaning (as defined by the manufacturer in the MPII):

The hole shall be cleaned and roughened as defined by the manufacturer. The roughening and cleaning procedure shall be reduced by 50% (duration or number of repetitions), but not more than 3 cleaning operations, compared to the procedure specified in the MPII.

The bonding material shall be placed and the steel element shall be inserted according to the MPII. The same type of steel element for tests with different cleaning methods shall be used.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Assessment of reference drilling and cleaning method

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with Annex A comparing the test results with reference test series in accordance with EAD 330499-02-0601 [1], Table A.1.1, line R5 (BF) or A3 (BEF).
- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.
- If $\alpha < 0,65$ determine the reduction (α/rqd. α) by using rqd. $\alpha = 0,65$ and $\gamma_{inst} = 1,4$.

Load displacement behaviour

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

Assessment of alternative drilling and cleaning methods

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined .
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), determine the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with EAD 330499-02-0601 [1] Annex A comparing the test results with reference test series in accordance with EAD 330499-02-0601 [1], Table A.1.1, lines R5 (BF) or A3 (BEF) (reference method).

- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.

Load displacement behaviour

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

  Note: Each type/brand of hollow drill bit or alternative drilling and cleaning method (e.g., diamond core bit, roughening procedure, flow rate and suction pressure of vacuum cleaner) listed in the MPII shall be assessed.

Expression of results (may differ for different drilling and cleaning methods):

$ß_{cv,}$ (α/rqd. α), α_1 to be used in EAD 330499-02-0601 [1], clause 2.2.2.14 / 2.2.2.15.

α resulting from test series B7 or E3 to be used in 2.2.2.6.

Assessed types/brands of hollow drill bits, diamond core bits or other drilling equipment (e.g., flow rate and suction pressure of vacuum cleaner) shall be given in the ETA.

2.2.2.4 Robustness in water-filled hole (test series B8, E4)

Purpose of the assessment

The test series shall be performed to assess the influence of reduced cleaning effort in water filled holes.

These tests are not required for fasteners where the MPII state that water shall be completely removed before the capsule is inserted or the injection mortar is injected.

The tests shall be performed with each cleaning or drilling method of the MPII. The different cleaning or drilling methods shall be assessed using as reference the test series R5 (BF) or A3 (BEF) performed with the reference drilling and cleaning method. Each type/brand of hollow drill bit or alternative drilling method bit (e.g., diamond coring bit, roughening procedure) listed in the MPII shall be tested.

Test conditions

The tests shall be performed with fastener sizes in accordance with EAD 330499-02-0601 [1], Table A.1.2 or Table B.2.1.

The tests shall be made in concrete which is water saturated in the area of the anchorage. To ensure a water saturated concrete in the area of the anchorage the procedure of 2.2.2.3 shall be applied.

Hammer drilling with standard drill bit or hollow drilling and subsequent cleaning (cleaning procedure as defined by the manufacturer):

The hole shall be cleaned as defined by the manufacturer using two blowing operations by hand pump or compressed air and one brushing operation, i.e., either blow-brush-blow or blow-blow-brush or brush-blow-blow. The type of blowing and the order of brushing/blowing shall be done as prescribed in the MPII. This test procedure is valid only if the MPII specify hole cleaning with at least four blowing and two brushing operations, meaning twice the operations given above. If the MPII specify less than this, the above requirement (2 blows + 1 brush) shall be reduced proportionately and the number of blows/brushes shall be lowered to the next whole number. Therefore, where the MPII recommend two blowing and one brushing operations, the tests shall be carried out without the brushing operation and one blowing only.

If the MPII recommends a vacuum cleaning instead of a blowing operation, the same procedure (including requirements and corresponding reduced operations) applies.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Hollow drilling (rotary hammer drilling using a hollow drill bit) with continuous vacuuming of the drilling dust without subsequent cleaning:

If B7/E3 was tested and show same performance than the reference method, the B8/E4 tests with hollow drilling can be omitted and the results of the standard drilling method apply.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Diamond core drilling (with or without rig, with or without water cooling, with or without roughening procedures) and subsequent cleaning (as defined by the manufacturer in the MPII):

The hole shall be cleaned and roughened as defined by the manufacturer. The roughening and cleaning procedure shall be reduced by 50% (duration or number of repetitions), but not more than 3 cleaning operations, compared to the procedure specified in the MPII.

After cleaning the hole, the hole shall be filled with water. Without removing the water from the hole, the bonding material shall be placed and the embedded metal part shall be inserted as described in the MPII. Use the same type of steel element for tests with different cleaning methods.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning (see also clause A.2).

Assessment of reference drilling and cleaning method

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with EAD 330499-02-0601 [1], Annex A, comparing the test results with reference test series in accordance with EAD 330499-02-0601 [1], Table A.1.1, line R5 (BF), or A3 (BEF).
- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.
- If $\alpha < 0{,}65$ the reduction (α/rqd. α) shall be determined by using rqd. $\alpha = 0{,}65$ and $\gamma_{inst} = 1{,}4$.

Load displacement behaviour

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

Assessment of alternative drilling and cleaning methods

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5% fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20% (cv_F > 20%), the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with EAD 330499-02-0601 [1], Annex A, comparing the test results with reference test series in accordance with EAD 330499-02-0601 [1], Table A.1.1, lines R5 (BF) or A3 (BEF) (reference method).
- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.

Load displacement behaviour

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50% of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50% of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50% of the failure load are larger than 0,4 mm, cv_δ shall not exceed 40%. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur".

Expression of results (may differ for different drilling and cleaning methods):

$ß_{cv,}$ (α/rqd. α), α_1 to be used in EAD 330499-02-0601 [1], clause 2.2.2.14 / 2.2.2.15.

α resulting from test series B8 or E4 to be used in 2.2.2.6.

Assessed types/brands of hollow drill bits, diamond core bits or other drilling equipment (e.g., flow rate and suction pressure of vacuum cleaner) shall be given in the ETA.

2.2.2.5 Robustness of mixing technique (test series B9, E5)

Purpose of the assessment

The test series shall be performed to assess the influence of the mixing technique.

Tests are only required for those fastener types where the mixing technique is ensured by the installer, such techniques include:

a) mixing components until a colour change is achieved throughout the material.

b) mixing with recommended equipment for a specified time.

c) carrying out a repetitive mixing operation for a specified number of times.

The test may be omitted if the mixing of the mortar is ensured by use of capsule type systems in accordance with EAD 330499-02-0601 [1], Figure 1.1.1, or static mixers of injection type systems in accordance with EAD 330499-02-0601 [1], Figure 1.1.2.

Test conditions

The test with diameter size 12 mm or smallest size if that is larger than 12 mm shall be performed.

Tests shall be carried out on incomplete mixes, i.e., by reducing the specified process by 25 %. For example, in the case of missing technique a) mentioned above, the test shall be carried out after mixing for 75 % of the time taken to achieve an even colour throughout the material.

Assessment

Failure loads

- The mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength shall be determined.
- The 5 % fractile of the failure loads $N_{5\%}$ [kN], converted to the nominal concrete strength shall be determined.
- The coefficient of variation of failure loads shall be determined. If the coefficient of variation exceeds 20 % (cv_F > 20 %), then the reduction factor for large scatter $ß_{cv}$ shall be determined in accordance with EAD 330499-02-0601 [1], A.2.1.5.
- The reduction factor α shall be determined in accordance with EAD 330499-02-0601 [1] Annex A comparing the test results with reference test series in accordance with EAD 330499-02-0601 [1], Table A.1.1, line R5 (BF), and A3 (BEF).
- The robustness factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1.
- If α < 0,70, then the reduction (α/rqd. α) shall be determined by using rqd. α = 0,7 and γ_{inst} = 1,4.

<u>Load displacement behaviour</u>

- The reduction factor α_1 shall be determined in accordance with EAD 330499-02-0601 [1], A.2.2.1.
- The displacements at 50 % of the mean failure load $\delta_{0,5Nu,m}$ [mm] shall be determined in each test.
- The coefficient of variation of the displacements at 50 % of the mean failure load cv_δ [%] shall be determined. If the mean value of displacements at 50 % of the failure load are larger than 0,4 mm, then cv_δ shall not exceed 40 %. Otherwise, the ETA shall include a sentence: "The displacements of the fasteners are not similar. Significant decrease of resistance to tension load in groups of fasteners may occur."

Expression of results:

$ß_{cv,}$ (α/rqd. α), α_1 to be used in EAD 330499-02-0601 [1], clause 2.2.2.14 / 2.2.2.15.

α resulting from test series B9 or E5 to be used in 2.2.2.6.

2.2.2.6 Assessment of the factor for sensitivity to installation

The factor γ_{inst} accounting for the sensitivity to installation shall be evaluated from the results of the tests for robustness i.e., test series B6 to B9 (BF) and test series E2 to E5 (BEF).

For each test series B6 to B9 or E2 to E5 as applied by the manufacturer the factor γ_{inst} shall be determined in accordance with Table 2.2.2.6.1 by comparing the factor α with the value of rqd α for the specific test. The largest resulting factor γ_{inst} applies.

Table 2.2.2.6.1 Values of rqd.α in the sensitivity to robustness tests for bonded fasteners

factor γ_{inst}	rqd.α for tests in accordance with EAD 330499-02-0601 [1], Table A.1.1	
	Table A.1.1, lines B6, B9, or Table B.2.1, lines E1, E2	Table A.1.1, lines B7, B8, or or Table B.2.1, lines E3, E4
1,0	rqd. $\alpha \geq$ 0,95	rqd. $\alpha \geq$ 0,90
1,2	0,95 > rqd. $\alpha \geq$ 0,80	0,90 > rqd. $\alpha \geq$ 0,75
1,4	0,80 > rqd. $\alpha \geq$ 0,70	0,75 > rqd. $\alpha \geq$ 0,65

Expression of results (may differ for different drilling and cleaning methods):

Robustness, factor for installation: γ_{inst} for each drilling and cleaning method as applied by the manufacturer

Assessed types/brands of hollow drill bits, diamond core bits or other drilling equipment (e.g., flow rate and suction pressure of vacuum cleaner) shall be given in the ETA.

2.2.3 Fire resistance to bond failure under tension loading (test series R10, F2)

EAD 330499-02-0601 [1], clause 2.2.18 applies with the following additions.

Installation

The tests shall be performed using each drilling method applied for by the manufacturer. If the equivalence of two different drilling methods has been shown (Table G.2.1 (BF) or Table G.2.3 (BEF)), the factor $k_{fi,p}(\theta)$ shall be transferred to the equivalent drilling method for assessment in EAD 330499-02-0601 [1], clause 2.2.18.

2.2.4 Durability of zinc-based coatings in uncracked concrete only for variable working life

Purpose of the assessment

If fasteners with zinc-based coating (minimum thickness of 40 μm and mean thickness of 50 μm) are intended to be used in other environmental conditions than given in 1.2.1, Environmental conditions, (1), the durability (corrosion resistance) in accordance with EN ISO 10684 [3] shall be assessed for a reduced working live (less than or equal to 50 years) for corrosivity categories as given in EN ISO 9223 [2], Table C.1.

Assessment method

A reduced working life of a zinc based coated fastener, e.g., hot dipped galvanized fasteners in accordance with EN ISO 10684 [3] shall be calculated based on the minimum thickness of the zinc-based coating according to the technical specification of the fastener using the corrosion rate r_{corr} for a given corrosivity category in accordance with EN ISO 9223 [2].

Often fasteners with a thickness of the zinc-based coating of 50 μm are used. Therefore, an example is given in Table 2.2.4.1.

Table 2.2.4.1 Corrosion rates for zinc-based coated coatings for different corrosivity categories

Corrosivity category in accordance with EN ISO 9223 [2], Table C.1	Corrosion rate r_{corr} in μm/a (based on EN ISO 9223 [2], Table 2)	Example of reduced working life for a zinc-based coating of minimum 50 μm in years
C1	0,1	500 a 1)
C2	0,7	75 a 1)
C3	2,0	25 a
C4	4,0	12,5 a
C5	8,4	5 a
CX	25	2 a

1) Limited by the working life in accordance with Clause 1.2.2

Expression of results

The working life shall be stated in the ETA depending on the thickness of the coating and the corrosivity category in accordance with EN ISO 9223 [2].

3 Assessment and verification of constancy of performance

3.1 System of assessment and verification of constancy of performance to be applied

EAD 330499-02-0601 [1], clause 3.1 applies.

3.2 Tasks of the manufacturer

EAD 330499-02-0601 [1], clause 3.2 applies.

3.3 Tasks of the notified body

EAD 330499-02-0601 [1], clause 3.3 applies.

4 Reference documents

EAD 330499-02-0601 [1], clause 4 applies.

[1]	EAD 330499-02-0601	Bonded fasteners and bonded expansion fasteners for use in concrete
[2]	EN ISO 9223:2012	Corrosion of metals and alloys - Corrosivity of atmospheres - Classification, determination and estimation (ISO 9223:2012)
[3]	EN ISO 10684:2004 + AC:2009	Fasteners - Hot dip galvanized coatings (ISO 10684:2004 + Cor. 1:2008)
[4]	EN 206:2013 + A2:2021	Concrete - Specification, performance, production and conformity
[5]	EN 1992-4:2018	Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete

ANNEX A TEST PROGRAMME FOR BF AND GENERAL ASPECTS OF ASSESSMENT

A.1 Test programme for BF

EAD 330499-02-0601 [1], clause A.1 with the following additions applies.

In case of assessment in accordance with 2.2.1.1, the following test series shall be performed.

Table A.1.1 Test programme for BF

N°	Purpose of test	concrete	crack width [mm]	Size	h_{ef}	n_{min}	rqd. α	Clause
Reference tests (with confined test setup)								
R6a-TTF	Reference for sustained load at normal ambient temperature	C12/15	0	m	7d [1)]	5	-	2.2.1.1.1
		C20/25				5		
R6b-TTF	Reference for sustained load at maximum long-term temperature	C12/15	0	m	7d [1)]	5		
		C20/25				5		
Resistance to combined pull-out and concrete failure								
B14-TTF	Sustained loads at normal ambient temperature	C12/15	0	m	7d [1)]	13[2)]	- [3)]	2.2.1.1.2
		C20/25				13[2)]		
B15-TTF	Sustained loads at maximum long-term temperature	C12/15	0	m	7d [1)]	13[2)]	- [3)]	2.2.1.1.2
		C20/25				13[2)]		

1) This value is valid for injection type and bulk type BF. For capsule type BF, the specified embedment depth associated with the capsule size shall be used. To avoid steel failure, the embedment depth modifications may be necessary (see EAD 330499-02-0601 [1], clause A.2).

2) ≥ 10 tests with failure, ≥ 3 with no failure during loading.

3) No residual load tests required for TTF tests.

A.2 Provisions for all test series

EAD 330499-02-0601 [1], clause A.2 applies. In the case of an assessment in accordance with 2.2.2, the following additions apply.

If the manufacturer applies for steel elements of bonded fasteners which are geometrically identical but of different material, all tests shall be made with one material. For the other material, only the tests in accordance with Table A.1.1, lines N1, N2 and V1 shall be carried out.

If the assessment covers more than one drilling method, Annex G applies. If different sizes of packages, types of nozzles and dispensers will be used for one system, equal mixing of the bonding material components shall be proven for all sizes of the packages and with all types of nozzles and dispensers both for coaxial and shuttle cartridges.

If instructions for hole cleaning are not provided by the MPII, the tests shall be carried out without hole cleaning.

The curing time before commencement of the test in test series in accordance with EAD 330499-02-0601 [1], Table A.1.1, lines B1 to B19, shall be comparable to the curing time in the corresponding reference test series.

ANNEX B BONDED EXPANSION FASTENERS

EAD 330499-02-0601 [1], Annex B applies.

ANNEX C ADDITIONAL PROVISIONS FOR WORKING LIFE OF 100 YEARS

C.1 General

EAD 330499-02-0601 [1], clause C.1 applies.

C.2 Repeated loads (test series B12)

EAD 330499-02-0601 [1], clause C.2 applies.

C.3 Crack cycling under load (test series B13, E8)

EAD 330499-02-0601 [1], clause C.3 applies.

C.4 Sustained loads (test series R6, R6-TTF, B14, B14-TTF, B15, B15-TTF E9, E10)

EAD 330499-02-0601 [1], clause C.4 applies with the following additions.

The assessment method of the sustained load factor $\psi^0_{sus,100}$ is described in EAD 330499-02-0601 [1], C.4. This method is based on sustained load tests, which were performed in the last years for many bonded fasteners. Therefore, this method is the reference method.

For more precise values of the sustained load factor $\psi^0_{sus,100}$ the assessment method in accordance with 2.2.1.1 shall be used and the Factor $\psi^0_{sus,100}$ for combined pull-out and concrete failure shall be assessed as follows.

The factor $\psi^0_{sus,100}$ accounting for the influence of sustained tension load on the bond strength for combined pull-out and concrete failure shall be assessed for working life of 100 years based on test series B14-TTF and B15-TTF.

After the fit in accordance with equation (2.2.1.1.2.2) has been performed and the final assessment curve has been selected the extrapolated 5% prediction bound of the assessment equation (2.2.1.1.2.2) shall be calculated from equation (C.4.1) for a working life of 100 years.

$$\tau_{5\%,extrpl,100} = \hat{\tau}_{sust,i} - t_{crit,5\%} \cdot s_{y,x}\sqrt{1 + \frac{1}{n} + \frac{(t_i - \overline{t_f})^2}{Sx}} \qquad \text{(C.4.1)}$$

with:

$\hat{\tau}_{sust,i}$ value of the load for a loading time t calculated in accordance with equation (2.2.1.1.2.2),

$t_{crit,5\%}$ 5% significance level of a t-student distribution for one tailed a = 0,05 and with degrees of freedom dof = n - 2 for fit with $\tau_1 = 0{,}6\ \tau_{Ru,m,R6-TTF}$ and dof = n - 3 for fitted τ_1,

Note: $t_{crit,5\%}$ to be taken by the table of a t-distribution (see reference [11])

$s_{y,x}$ root mean squared error of the tested points given by $s_{y,x} = \sqrt{\frac{1}{n}\sum\left(\hat{\tau}_{sust,i} - \tau_{sust,i}\right)^2}$,

n number of tests,

t_i loading time with t_i from 0,01 sec. to 100 years, minimum 30 data points, equally distributed on the x-axis in Figure C.4.1,

$\overline{t_f}$ mean value of the failure times of the tests,

S_x sum of squared deviation of the time values in the extrapolation curve given by $S_x = \sum(t - \bar{t})^2$. The calculation of S_x, shall be done considering the times $t_{f,i}$ and the time of the assessment, 100 years.

The bond strength shall be calculated corresponding to the sustained load applied in successful test series B14-TTF or B15-TTF in accordance with equation (C.4.2).

$$\tau_{suc} = \tau_{5\%,extrpl,100} \cdot 1{,}5 \cdot \gamma_{inst} \cdot (\alpha_2 \cdot \alpha_3 \cdot \alpha_4) / 1{,}1 \qquad \text{(C.4.2)}$$

with:

$\tau_{5\%,extrpl,100}$ = extrapolated 5% prediction bound in accordance with equation (C.4.1)

γ_{inst} = factor accounting for the sensitivity to installation under dry conditions (used in design in accordance with EN 1992-4 [5]), determined in accordance with clause 2.2.2

α_2 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.9.1), tests at maximum long-term temperature

α_3 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.9.2), tests at maximum short-term temperature

α_4 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.12.1), tests for checking durability of bonding material

Example of assessment:

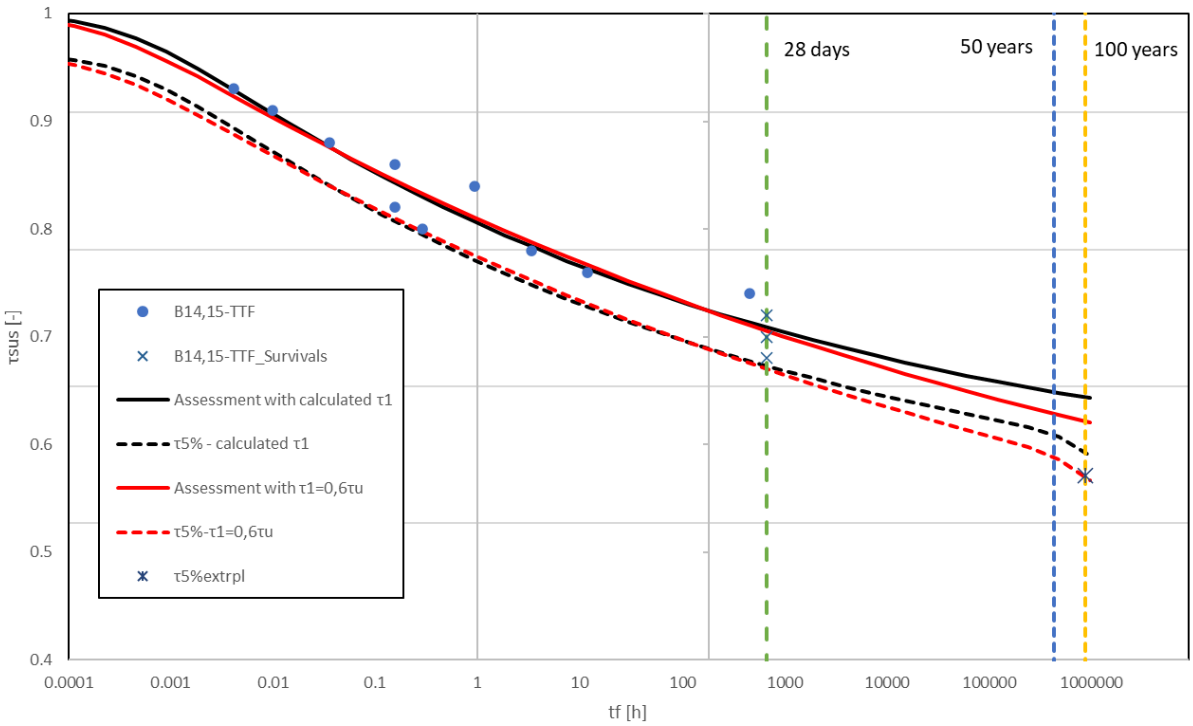


Figure C.4.1 Calculation of $\tau_{5\%,100,extrpl}$ from B14-TTF and B15-TTF

In Figure C.4.1 the calculation of $\tau_{5\%,extrpl}$ shall be given by the following steps:

- the data $\tau_{sust,i}$ calculated from equation (2.2.1.1.2.1) and $t_{f,I}$ shall be collected,
- a non-linear regression of equation (2.2.1.1.2.2) shall be performed twice to the data,
  - with $\tau_1 = 0{,}6\tau_{um,R6\text{-}TTF}$
  - with τ_1 obtained by the regression
- the 5% fractile prediction bound for the two fits shall be calculated from equation (C.4.1),
- the 5% fractile prediction bounds shall be extrapolated to t =100 years,

- the $\tau_{5\%,100,extrpl}$ shall be calculated by taking the minimum value of the two extrapolated curves at 100 years.

The basic characteristic long-term bond resistance at maximum long-term temperature shall be determined in accordance with equation (C.4.3).

$$\tau^0_{Rk,LT,100} = \tau_{5\%,extrpl,100} \tag{C.4.3}$$

with:

$\tau^0_{Rk,LT,100}$ = basic characteristic long-term bond resistance at maximum long-term temperature

$\tau_{5\%,extrpl,100}$ = extrapolated 5% prediction bound of the assessment equation (2.2.1.1.2.2) calculated from equation (C.4.1)

The characteristic long-term bond resistance shall be determined accounting for the relevant (reduction) factors as follows:

$$\tau_{Rk,LT,100} = \tau^0_{Rk,LT,100} \cdot a_3 \cdot a_4 \cdot k_{sus} \cdot a_{setup} \cdot min\beta_{cv} \tag{C.4.4}$$

with:

$\tau_{Rk,LT,100}$ = characteristic long-term bond resistance (LT) at maximum long-term temperature for the corresponding temperature range

α_3 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.9.2)

α_4 = reduction factor in accordance with EAD 330499-02-0601 [1], equation (2.2.2.12.1)

α_{setup} = 0,75, reduction factor for uncracked concrete in accordance with EAD 330499-02-0601 [1], clause 2.2.2.2.

k_{sus} = 1,135

Note: The factor k_{sus} takes account of beneficial effects under long-term loading. The influence of the confinement on the pull-out resistance decreases under long-term loading and an increase of 13,5% of the reduction factor α_{setup} has been evaluated from tests.

min β_{cv} = minimum of reduction factors β_{cv} in accordance with EAD 330499-02-0601 [1], equation (A.2.1.5.2)

The factor $\psi^0_{sus,100}$, accounting for the influence of sustained tension load on the bond strength for combined pull-out and concrete failure, shall be determined as given in equation (C.4.5).

$$\psi^0_{sus,100} = \frac{\tau_{Rk,LT,100}}{\tau_{Rk,ucr,100}} \cdot 1{,}15 \leq 1{,}0 \tag{C.4.5}$$

With:

$\psi^0_{sus,100}$ = reduction factor of long-term bond resistance at maximum long-term temperature.

$\tau_{Rk,ucr,100}$ = characteristic value of short-term bond resistance at maximum long-term temperature, as given in the ETA for uncracked concrete.

Note: The factor 1,15 applies also for intended working life of 100 years

Expression of results:

τ_{suc} to be used in EAD 330499-02-0601 [1], equations (2.2.2.6.1.2) and (2.2.2.6.1.5), for calculation of α_p.

Factors $\psi^0_{sus,100}$ for temperature ranges according to the intended use.

C.5 Determination of the characteristic bond resistance

EAD 330499-02-0601 [1], clause C.5 applies.

ANNEX D DETAILS OF TESTS FOR BF AND BEF IN CONCRETE

EAD 330499-02-0601 [1], Annex D, applies.

D.1 Scope

EAD 330499-02-0601 [1], Annex D.1, applies.

D.2 Abbreviation and Notation

EAD 330499-02-0601 [1], Annex D.2, applies.

D.3 Details of Tests

EAD 330499-02-0601 [1], Annex D.3, applies.

D.4 Tests for fire resistance

EAD 330499-02-0601 [1], Annex D.4, applies.

D.5 Test Report

EAD 330499-02-0601 [1], Annex D.5 applies with the following additions.

The test report shall include at least:
- Rig or handheld.
- Turning speed.
- Cutting head geometry (e.g., 2-, 3- or 4- cutter).
- Impact energy of the tool (hammer driller).
- Frequency of the impact strike.
- Depth of borehole.

ANNEX E BF AND BEF IN CONCRETE UNDER SEISMIC ACTION

EAD 330499-02-0601 [1], Annex E applies.

ANNEX F ASSESSMENT FOR BF AND BEF IN STEEL FIBRE REINFORCED CONCRETE

F.1 Scope

EAD 330499-02-0601 [1], Annex F.1, applies.

F.2 Test programme and details of tests

EAD 330499-02-0601 [1], Annex F.2, applies with the following additions.

Table F.2.1 Test programme for BF in steel fibre reinforced concrete

N°	Purpose of test	Concrete Steel fibre content	crack width [mm]	Size 2)	h_{ef}	n_{min}	clause
R1F	Bond strength with confined test setup	C20/25 20 kg/m³	0	All	7d 1)	5	[1], 2.2.2.1
R2F		C50/60 80 kg/m³	0	s/m/l	7d 1)	5	
B6F	Robustness in dry concrete	C20/25 20 kg/m³	0	s/m/l	max	5	2.2.2.2
B7F	Robustness in water saturated concrete	C20/25 20 kg/m³	0	s/m/l	max	5	2.2.2.3
B8F	Robustness in water filled holes (clean water)	C20/25 20 kg/m³	0	s/m/l	max	5	2.2.2.4
B10F	Increased crack width	C20/25 20 kg/m³	0,5	s/m/l	7d 1)	5	[1], 2.2.2.3
B11F	Increased crack width	C50/60 80 kg/m³	0,5	s/m/l	7d 1)	5	[1], 2.2.2.3
Seismic performance category C2							
C2.1aF	Reference tension tests in low strength concrete	C20/25 20 kg/m³	0,8	s/m/l	7d 1)	5	E.3.4.2, E.4.2.1, E.4.2.2
C2.1bF	Tension tests in high strength concrete	max 80 kg/m³	0,8	s/m/l	7d 1)	5	

1) This value is valid for injection type and bulk type BF. For capsule type BF, the specified embedment depth associated with the capsule size shall be used. To avoid steel failure, the embedment depth modifications may be necessary (see clause A.2).

3) The reduced range of tested sizes s/m/l depends on the number of requested sizes and is given in EAD 330499-02-0601 [1], Table A.1.2.

Table F.2.2: Test programme for BEF in steel fibre reinforced concrete

N°	Purpose of test	concrete	crack width [mm]	T/T_{inst}	size 1) 2)	n_{min}	EAD 330499-02-0601 [1], clause
E1F	Reduced installation torque in dry concrete	C20/25 20 kg/m³	0,3	0,5	all	10	B.2.3
E3F	Robustness in water saturated concrete	C20/25 20 kg/m³	0,3	1/0,5	all	10	
E4F	Robustness in water filled holes (clean water)	C20/25 20 kg/m³	0,3	1/0,5	all	10	
E6F	Increased crack width	C20/25 20 kg/m³	0,5	1/0,5	s/m/l	10	2.2.2.3
E7F	Increased crack width	C50/60 80 kg/m³	0,5	1/0,5	s/m/l	10	2.2.2.3
Seismic performance category C2							
C2.1aF	Reference tension tests in low strength concrete	C20/25 20 kg/m³	0,8	1/0,5	s/m/l	5	E.3.4.2, E.4.2.1, E.4.2.2
C2.1bF	Tension tests in high strength concrete	max 80 kg/m³	0,8	1/0,5	s/m/l	5	

1) See EAD 330499-02-0601 [1], Table A.1.2; m: medium size (12 mm) or smallest size which is larger than 12 mm;

2) The reduced range of tested sizes s/m/l depends on the number of requested sizes and is given in EAD 330499-02-0601 [1], Table A.1.2.

Assessment of seismic performance category C1

The resistance for category C1 in accordance with Annex E in plain concrete covers application in SFRC for category C1 if tests in accordance with Table F.2.1 lines R1F to B11F for BF and Table F.2.2 lines E1F to E7F shall be performed and the assessment shows equivalency.

Assessment for seismic performance category C2 test series C2.1aF and C2.1bF

Equivalence of performance accounting for the sensitivity of fibres in the concrete shall be evaluated by comparison of the results of the test series C2.1aF and C2.1bF to the corresponding series in plain concrete.

Failure loads

- Assessment in accordance with EAD 330499-02-0601 [1], clause E.4.2.2.
- The $t_{u,m}$ [N/mm²] or $N_{u,m}$ [kN] shall be at least 95% of the corresponding test series in normal weight concrete of the same strength in accordance with EAD 330499-02-0601 [1], clause E.4.2.2.

Assessment under fire exposure

The resistance under fire conditions in plain concrete covers application in SFRC.

ANNEX G ALTERNATIVE DRILLING METHODS

G.1 Scope

This Annex provides information for the assessment of bonded fasteners (BF) and bonded expansion fasteners (BEF) for use with alternative drilling methods. The provided tests are required for every method being different in drilling and borehole cleaning and/or roughening.

The assessment shall be made to show the validity of the performance of the bonded fasteners system combined with alternative drilling and cleaning methods as assessed for use in compacted normal weight concrete with or without fibres of different strength classes and loading.

Alternative drilling methods:

- Diamond core drilling (with or without rig, with or without water cooling, with or without roughening procedures) and subsequent cleaning (as specified by the manufacturer in the MPII).

The surface roughness of the drilled hole is regarded equivalent for hammer drilling and hollow drilling. Therefore, hollow drilling is not defined as an alternative drilling method if equivalence is shown based on test series B6 to B8 (BF) or test series E2 to E4 (BEF).

Note: The surface roughness of the drilled hole is lower with diamond core drilling compared to the reference hammer drilling. Depending on the type of diamond drill bit, the diameter of drilled holes may be smaller or larger and shall be specified by the manufacturer.

The essential characteristics of bonded fasteners or bonded expansion fasteners combined with alternative drilling methods assessed in accordance with this Annex may be used for design in accordance with EN 1992-4 [5].

For the assessment of alternative drilling methods, one of the following approaches shall be used:

1. Same performances for reference and alternative drilling methods shall be given in ETA:

a) Statistical equivalence of the mean values and 5%-fractile values of the ultimate loads shall be shown. $N_{u,m}$ [kN] and / or bond strength $\tau_{u,m}$ [N/mm²] and the 5% fractile of the failure loads $N_{5\%}$ [kN] and / or bond strength $\tau_{5\%}$ [N/mm²] of test series shall be equivalent to or higher than 95% of the corresponding parameters in the reference test programme with the reference drilling and cleaning method.

b) The results of tests carried out using alternative drilling methods shall show higher mean values or 5%-fractile values (item a) not fulfilled) for the ultimate loads in one or more series; also in this case, the values of the reference drilling and cleaning method remain decisive.

c) The applicable test programme is given in Table G.2.1 (bonded fasteners) or in Table G.2.2 (bonded expansion fasteners). The proof in accordance with item a) or b) shall apply to all series with alternative methods given in these tables.

Note: For the cleaning procedure in test series B6 to B8 (BF) or E2 to E4 (BEF), the provisions given in section 2.2.2, apply.

If SFRC is assessed in accordance with Annex F and equivalence with plain concrete (without fibres) is shown, no additional tests for SFRC with alternative drilling method are required.

2. Differentiation of performance in the ETA for alternative methods:

   a) If the validation for equivalence or higher performance in accordance with items 1. a) or b) cannot be fulfilled for all test series with the alternative drilling and cleaning method, the test programme in accordance with Table G.2.3 (BF) or Table G.2.4. (BEF) shall apply.

   b) The assessment of the performance with alternative drilling and cleaning methods shall be performed separately. For the series given in Table G.2.3 (BF) or Table G.2.4. (BEF), the assessment shall be performed as given in the corresponding sections. For series not required as per Table G.2.3 or Table G.2.4 that are only performed with the reference drilling and cleaning method (see Annex A, Table A.1 or Annex B.2.1 and Table B.1), the reduction factors applicable for the reference drilling and cleaning method shall be adopted.

   c) If seismic performance in accordance with Annex E is sought for alternative drilling and cleaning methods, Table G.2.5 applies.

G.2 Test programme

Test conditions

For bonded fasteners, the test programme to show the same performance using alternative drilling methods, in comparison with the reference drilling method, is given in Table G.2.1. Robustness tests for bonded fasteners shall be performed in accordance with EAD 330499-02-0601 [1], Table A.1, lines B6 - B8.

For bonded expansion fasteners, the test programme to show the same performance using alternative drilling methods, in comparison with the reference drilling method, is given in Table G.2.2. Robustness tests for bonded expansion fasteners shall be performed in accordance with EAD 330499-02-0601 [1], Table B.2.1, lines E2 - E4.

The test programme for determination of the performance using alternative drilling and cleaning methods, differently from the reference drilling and cleaning method, is given in Table G.2.3 for bonded fasteners, Table G.2.4 for bonded expansion fasteners and Table G.2.5 for seismic performance.

For further details on the test conditions, see Annex A and Annex B.

Table G.2.1 Reduced test programme for bonded fasteners using alternative drilling methods for equivalent performance in the ETA as the reference drilling method

N°	Purpose of test	Concrete	Crack width Δw [mm]	Size 3)	n_{min}	EAD 330499-02-0601 [1], clause
R1	Bond strength with confined test setup	C20/25	0	All	5	2.2.2.1
R2		C50/60	0	s/m/l	5	
B10 2)	Increased crack width	C20/25	0,5	s/m/l	5	2.2.2.3
B11 2)	Increased crack width	C50/60 max 1)	0,5	s/m/l	5	2.2.2.3
C2.1a	Seismic C2 reference tension tests in low strength concrete	C20/25	0,8	s/m/l	5	E.3.4.2, E.4.2.1, E.4.2.2
C2.1b	Seismic C2 reference tension tests in high strength concrete	C50/60	0,8	s/m/l	5	E.3.4.2, E.4.2.1, E.4.2.2

1) Highest concrete strength class (not larger than C90/105) for which the assessment is requested by the manufacturer

2) Tests sufficient to also show equivalence of seismic category C1.

Table G.2.2 Reduced test programme for bonded expansion fasteners using alternative drilling methods for equivalent performance in the ETA as the reference drilling method

N°	Purpose of test	Concrete	crack width Δw [mm]	T/T_{inst}	Size 1) 2)	n_{min}	EAD 330499-02-0601 [1], clause
E6 3)	Increased crack width	C20/25	0,5	1/0,5	s/m/l	5	2.2.2.3
E7 3)	Increased crack width	C50/60 max 4)	0,5	1/0,5	s/m/l	5	2.2.2.3
C2.1 a	Seismic C2 reference tension tests in low strength concrete	C20/25	0,8	1/0,5	s/m/l	5	E.4.2.1 E.4.2.2
C2.1 b	Seismic C2 reference tension tests in high strength concrete	C50/60	0,8	1/0,5	s/m/l	5	E.3.4.2, E.4.2.1, E.4.2.2

1) See Table A.3; m: medium size (12 mm) or smallest size which is larger than 12 mm;
2) The reduced range of tested sizes s/m/l depends on the number of requested sizes and is given in Table A.3.
3) Tests sufficient to also show equivalence of seismic category C1.
4) Highest concrete strength class (not larger than C90/105) for which the assessment is requested by the manufacturer

Table G.2.3 Test programme for bonded fasteners using alternative drilling methods in case of lower performance compared to the reference drilling method (no equivalence in one of the series R1, R2, B10, B11)

N°	Purpose of test	concrete	crack width [mm]	Size 2)	h_{ef}	n_{min}	rqd. α	clause
Reference tests (with confined test setup)								
R1	Bond strength with confined test setup	C12/15	0	All	7d 1)	5	-	[1], 2.2.2.1
		C20/25				5		
R2		C50/60	0	s/m/l	7d 1)	5	-	
		max 3)				5		
R3		C12/15	0,3	s/m/l	7d 1)	5	-	
		C20/25				5		
R4		C50/60	0,3	s/m/l	7d 1)	5	-	
		max 3)				5		
R5	Reference for robustness test series B6 to B9	C12/15	0	s/m/l	max	5	-	2.2.2
		C20/25				5		
R6	Reference for sustained load a) at normal ambient temperature and b) at maximum long-term temperature	C12/15	0	m	7d 1)	a) 5 b) 5	-	[1], 2.2.2.6
		C20/25				a) 5 b) 5		

N°	Purpose of test	concrete	crack width [mm]	Size 2)	h_{ef}	n_{min}	rqd. α	clause
Basic tension tests (with unconfined test setup)								
A1	Characteristic resistance for tension loading not influenced by edge and spacing effects	C12/15 C20/25	0	s/m/l	min	5 5	-	[1], 2.2.2.2
A2		C50/60	0	s/m/l	min	5	-	
A3		C12/15 C20/25	0,3	s/m/l	min	5 5	-	
A4		C50/60	0,3	s/m/l	min	5	-	
A6	Minimum embedment depth	C12/15 C20/25	0	small	min	20 20	0,90	[1], 2.2.3.2
Resistance to combined pull-out and concrete failure								
B6	Robustness in dry concrete	C12/15 C20/25	0	s/m/l	max 2)	5 5	see Table 2.2.2.6.1	2.2.2.2
B7	Robustness in water saturated concrete	C12/15 C20/25	0	s/m/l	max 2)	5 5		2.2.2.3
B8	Robustness in water filled holes (clean water)	C12/15 C20/25	0	s/m/l	max 2)	5 5		2.2.2.4
B10	Increased crack width	C12/15 C20/25	0,5	s/m/l	7d 1)	5 5	0,80	[1], 2.2.2.3
B11	Increased crack width	C50/60 max 3)	0,5	s/m/l	7d 1)	5 5	0,80	[1], 2.2.2.3
B12	Repeated loads	C12/15 C20/25	0	m	7d 1)	5 5	1,00	[1], 2.2.2.4
B13	Crack cycling under load	C12/15 C20/25	0,1 - 0,3	All	7d 1)	5 5	0,90	[1], 2.2.2.5
B14	Sustained loads (normal ambient temperature)	C12/15 C20/25	0	m	7d 1)	5 5	0,90	[1], 2.2.2.6
B15	Sustained loads (maximum long-term temperature)	C12/15 C20/25	0	m	7d 1)	5 5	0,90	[1], 2.2.2.6

1) This value is valid for injection type and bulk type BF. For capsule type BF, the specified embedment depth associated with the capsule size shall be used. To avoid steel failure, the embedment depth modifications may be necessary (see clause A.2).

2) Pull-out test such that steel failure will be avoided. To avoid steel failure, the embedment depth modifications may be necessary (see clause A.2).

3) Highest concrete strength class (not larger than C90/105) for which the assessment is requested by the manufacturer.

Table G.2.4. Test programme for bonded expansion fasteners using alternative drilling methods in case of lower performance in the ETA compared to the reference drilling method (no equivalence in one of the series E6, E7)

N°	Purpose of test	Concrete	Crack width Δw [mm]	T/T_{inst}	Size 1) 2)	n_{min}	rqd. α	EAD 330499-02-0601 [1], clause
E1	Reduced installation torque in dry concrete	C12/15	0,3	0,5	all	5	see Table 2.2.2.6.1	B.2.3
		C20/25				5		
E2	Robustness in dry concrete	C12/15	0,3	1/0,5	all	5		
		C20/25				5		
E3	Robustness in water saturated concrete	C12/15	0,3	1/0,5	all	5		
		C20/25				5		
E4	Robustness in water filled holes (clean water)	C12/15	0,3	1/0,5	all	5		
		C20/25				5		
E5	Robustness to mixing technique	C12/15	0,3	1/0,5	m	5		
		C20/25				5		
E6	Increased crack width	C12/15	0,5	1/0,5	s/m/l	5	0,80	2.2.2.3
		C20/25				5		
E7	Increased crack width	C50/60	0,5	1/0,5	s/m/l	5	0,80	2.2.2.3
		maximum				5		
E8	Crack cycling under load	C12/15	0,1–0,3	1/0,5	s/m/l	5	0,90	2.2.2.5
		C20/25				5		
		C12/15			intermediate	5		
		C20/25				5		
E9	Sustained loads (normal ambient temperature)	C12/15	0	1/0,5	m	5	0,90	2.2.2.6
		C20/25				5		
E10	Sustained loads (maximum long-term temperature)	C12/15	0	1/0,5	m	5	0,90	2.2.2.6
		C20/25				5		
E13	Slip force test	C12/15	0,3	0	All	5	-	B.2.5
		C20/25				5		
E14	Bond force test	C12/15	0,3	0	All	5	-	B.2.6
		C20/25				5		

1) m: size 12 mm or smallest size which is larger than 12 mm;
2) The reduced range of tested sizes s/m/l depends on the number of requested sizes and is given in EAD 330499-02-0601 [1], Table A.1.2.

Table G.2.5 Additional tests for fasteners (BF and BEF) under seismic category C1 and/or C2 using alternative drilling methods in case of lower performance compared to the reference drilling method (no equivalence in one of the series R1, R2, B10, B11, C2.1a, C2.1b)

N°	Purpose of test	Concrete	Crack width Δw [1] [mm]	n_{min} [2]	EAD 330499-02-0601 [1], clause
	Category C1				
C1.1	Functioning under pulsating tension load	C20/25	0,5	5	E.3.3.2
	Category C2				
C2.1a	Reference tension tests in low strength concrete	C20/25	0,8	5	E.3.4.2
C2.1b	Reference tension tests in high strength concrete	C50/60	0,8	5	E.3.4.2
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	E.3.4.3
C2.5	Functioning with tension load under varying crack width	C20/25	$\Delta w_1 = 0{,}0$ [4] $\Delta w_2 = 0{,}8$	5	E.3.4.5

1) Crack width Δ*w* added to the width of hairline crack after fastener installation but before loading of fastener.

2) Test all fastener diameters for which the fastener is to be assessed for use in seismic applications. For fasteners with different steel types, steel grades, production methods, types of steel elements (bonded fasteners), multiple embedment depths see EAD 330499-02-0601 [1], E.3.2.

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

4) Δw_1 = 0,0 mm is defined in E.3.4.5.

ANNEX H FURTHER INFORMATION AND BACKGROUND FOR ASSESSMENT

Further information and background for assessment programme is given in the following documents:

[6]	Sustained Load Performance of Bonded Anchors Embedded in Concrete, Andrea Carolina Oña Vera, Krešimir Ninčević, Ioannis Boumakis, Wouter Botte, Sahand Sartipi, Roman Wan-Wendner, Bond in Concrete 2022, Stuttgart 25th-27th July 2022
[7]	Long term assessment of bonded anchors with two different methods, Findley extrapolation vs. time-to-failure approach, Krešimir Ninčević, Roberto Piccinin, Ioannis Boumakis, Thilo Pregartner, Roman Wan-Wendner, Konrad Bergmeister, Life-Cycle of Structures and Infrastructure Systems – Biondini & Frangopol (Eds)© 2023 The Author(s), ISBN 978-1-003-32302-0 Open Access: www.taylorfrancis.com, CC BY-NC-ND 4.0 license
[8]	Creep rate based time-to-failure prediction of adhesive anchor systems under sustained load, Ioannis Boumakis, Kresimir Nincevic, Jan Vorel, Roman Wan-Wendner, Elsevier, Composites Part B 178 (2019), https://doi.org/10.1016/j.compositesb.2019.107389
[9]	Discrete element framework for modeling tertiary creep of concrete in tension and compression, Ioannis Boumakis, Giovanni Di Luzio, Marco Marcon, Jan Vorel, Roman Wan-Wendner, Elsevier, Engineering Fractue Mechanics 200 (2018), journal homepage: https://doi.org/10.1016/j.engfracmech.2018.07.006
[10]	Consistent Time-to-Failure Tests and Analyses of Adhesive Anchor Systems, Kresimir Nincevic, Ioannis Boumakis, Stefan Meissel, Roman Wan-Wendner, applied science, MDPI, Received: 17 January 2020; Accepted: 18 February 2020; Published: 24 February 2020
[11]	Statistical Tables and Formulae, Stephen Kokoska, Christopher Nevison. Springer-Verlag New York Inc. 1989.