EUROPEAN ASSESSMENT DOCUMENT

# EAD 330747-00-0601

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# FASTENERS FOR USE IN CONCRETE FOR REDUNDANT NON-STRUCTURAL SYSTEMS

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**Contents**

# 1 SCOPE OF THE EAD

## 1.1 Description of the construction product

This EAD covers post-installed metal fasteners placed into pre-drilled holes perpendicular to the surface (maximum deviation 5°) in concrete for redundant non-structural systems.

The metal parts of the fastener are made of carbon steel, stainless steel or malleable cast iron. The fasteners may include non-load bearing material, e.g. plastic parts, for rotation prevention. The fasteners are directly anchored in the concrete and transmit the applied loads.

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

The following operating principles of fasteners are covered by this EAD:

- torque-controlled expansion fasteners (TC)
- deformation-controlled expansion fasteners (DC)
- undercut fasteners (UC)
- concrete screws (CS)
- load-controlled expansion fasteners (LC); The construction of the load controlled fastener is the same as for TC type, but the expansion is not controlled by a specified torque. The fasteners expand when loaded.
- bonded fasteners (BF)

Examples of the different type of fasteners are given in EAD 330232 and EAD 330499.

If embedded parts of bonded fasteners are commercial standard rods supplied by a party other than the manufacturer of the bonding component (e.g. manufacturer of standard rods), the following conditions have to be fulfilled:

- Material, dimensions and mechanical properties of the metal parts according to the specifications given in an Annex of the ETA
- Confirmation of material and mechanical properties of the metal part by inspection certificate 3.1 according to EN 10204 [6]; the documents shall be stored
- Marking of the rod with the envisaged embedment depth. This may be done by the manufacturer of the rod or the person on job site.

This EAD applies to fasteners with the following dimensions:

- minimum diameter of 5 mm (thread size M5 or diameter of the shaft for CS).
- minimum fastening depth min $h_{ef}$ of 30 mm. In special cases, e.g. subject to internal exposure conditions only, min $h_{ef}$ may be reduced to 25 mm and these required restrictions have to be clearly stated in the ETA. For precast pre-stressed hollow core slabs the fastening depth is governed by the minimum wall thickness of 17 mm.

This EAD applies for concrete screws with a shaft diameter ≥ 5 mm and ($h_{nom}$ - $h_s$) ≥ 30 mm according to Figure 1.4.

Fasteners with internal thread are covered only if they have a thread length of at least d + 5 mm after taking account of possible tolerances.

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

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

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

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

## 1.2 Information on the intended use of the construction product

### 1.2.1 Intended use

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

The definition of redundant non-structural systems (see Figure 1.1) is given in terms of the number of fixing points $n_1$ to fasten the fixture and the number of fasteners per fixing point $n_2$. Furthermore $F_{Ed,lim}$ (kN) specifies the upper limit of the design value of actions on a fixing point up to which the strength and stiffness of the fixture are fulfilled and the load transfer in the case of excessive slip or failure of one fastener need not to be taken into account in the design of the fixture.

In this EAD it is assumed that the redistribution of loads in case of excessive slip or failure of one fastener according to FprEN 1992-4:2017 section 7.3 is considered in the static verification of the fastening.

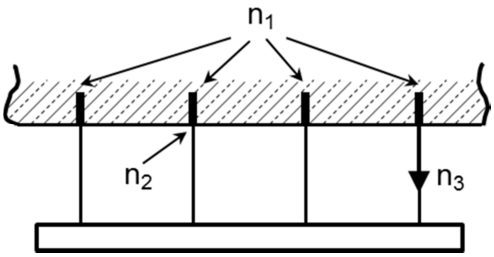



**Figure 1.1 Example of a redundant non-structural application**

The definition of the specific values for $n_1$, $n_2$ and $F_{Ed,lim}$ is given in CEN/TR 17079:2017 [18].

In this EAD the assessment is made to determine characteristic values of the fastener for design according to FprEN 1992-4 [5].

This EAD covers fasteners for installation in pre-drilled holes in compacted reinforced or unreinforced normal weight concrete without fibres and with strength classes in the range of C12/15 to C50/60 in accordance with EN 206 [4].

The fastener is intended to be used under the following conditions:

- tension, shear or combined tension and shear loading
- use in cracked or uncracked concrete
- under static or quasi-static actions
- with requirements related to resistance to fire (mechanical fasteners only)

*Note 1: The loading on the fastener resulting from actions on the fixture (e. g. tension, shear, bending or torsion moments or any combination thereof) will generally be axial tension and/or shear. When the shear force is applied with a lever arm, a bending moment on the fastener will arise. It is presumed, that compressive forces acting in the axis of the fastener are transmitted by the fixture directly to the concrete without acting on the fastener's load transfer mechanism.*

The hardened concrete is at least 21 days old.

**Mechanical fasteners**

The covered temperature range of the anchorage base material (concrete) for mechanical fasteners during the working life is within the range -40 °C to +80 °C.

The thickness of the concrete member in which the mechanical fastener is installed is $h \geq 2\ h_{ef}$ and $h \geq 80$ mm. For precast, pre-stressed hollow core elements the wall thickness shall be ≥ 17 mm.

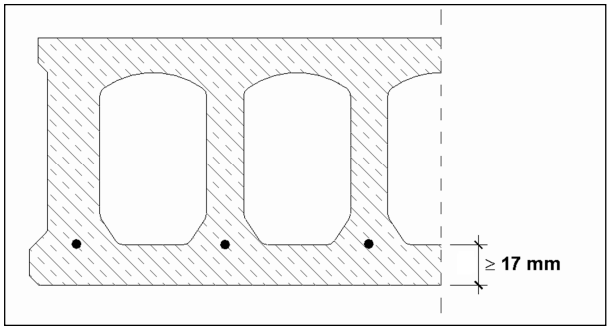



**Figure 1.2 Example of precast pre-stressed hollow core slabs**

**Bonded fasteners:**

The bonded fastener is suitable for

Concrete condition:

I1 = installation in dry or wet (water saturated) concrete and use in service in dry or wet concrete;

I2 = installation in water-filled drill holes (not sea water) and use in service in dry or wet concrete.

*Note 2: Water-filled holes are pre-drilled holes (with drilling and cleaning according to the MPII), which are afterwards filled with water (e.g. overnight rain in outdoor applications). Underwater installation is different to this condition as the water pressure has to be accounted for and is therefore not covered in this EAD.*

Concrete temperature at installation: $T_{i,min}$ to $T_{i,max}$

*Note 3: The minimum and maximum concrete temperatures at installation, $T_{i,min}$ and $T_{i,max}$, are specified by the manufacturer.*

Installation direction:

D1 = downward only,

D2 = downward and horizontal installation

D3 = downward and horizontal and upwards (e.g. overhead) installation

This EAD covers a range of temperature during installation and curing of the bonding material in the anchorage base material (concrete) between 0 °C and +40°C.

The covered service temperature ranges of anchorage base material (concrete) during the working life are

T1: 24°C/40°C = temperature range from -40°C to +40°C, with a maximum long term temperature of +24°C, and a maximum short term temperature of +40°C;

T2: 50°C/80°C = temperature range from -40°C to +80°C, with a maximum long term temperature of +50°C, and a maximum short term temperature of +80°C;

T3: $T_{lt}/T_{st}$ = temperature range from -40°C to $+T_{st}$, with a maximum long term temperature $T_{lt}$ = 0,6 to 1,0 $T_{st}$, and a maximum short term temperature of $T_{st} \geq 40$°C.

*Note 4: The maximum short term temperature $T_{st}$ and the maximum long term temperature $T_{lt}$ are specified by the manufacturer.*

The thickness of the concrete member in which the bonded fastener is installed is $h \geq h_{ef} + \Delta h$ and $h \geq 80$ mm, with $\Delta h \geq 2\ d_0$ and $\Delta h \geq 30$ mm.

### 1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the fastener for the intended use of 50 years when installed in the works (provided that the fastener is subject to appropriate installation (see 1.1)). These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[1].

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

## 1.3 Specific terms used in this EAD

### 1.3.1 Abbreviations

| | | |
|---|---|---|
| BF | = | Bonded fastener |
| CS | = | concrete screw |
| DC | = | deformation-controlled expansion fastener |
| LC | = | Load controlled fastener |
| MPII | = | manufacturer's product installation instructions |
| TC | = | torque-controlled expansion fastener |
| UC | = | undercut fastener |

### 1.3.2 Notation

| | | |
|---|---|---|
| $c_{cr}$ | = | edge distance for ensuring the transmission of the characteristic resistance of a single fastener |
| $c_{cr,N}$ | = | edge distance for ensuring the transmission of the characteristic resistance in tension of a single fastener without edge and spacing effects in case of concrete cone failure |
| $c_{cr,sp}$ | = | edge distance for ensuring the transmission of the characteristic resistance in tension of a single fastener without edge and spacing effects in case of splitting failure |
| $c_{min}$ | = | minimum allowable edge distance |
| $cv_F$ | = | coefficient of variation [%] related to loads |
| $d$ | = | fastener bolt / thread diameter |
| $d_0$ | = | nominal drill hole diameter |
| $d_{cut}$ | = | cutting diameter of drill bit |
| $d_{cut,m}$ | = | medium cutting diameter of drill bit (see Technical Report 048 [3] Figure 3.5) |
| $d_{cut,max}$ | = | cutting diameter at the upper tolerance limit (see Technical Report 048 [3] Figure 3.5) (maximum diameter bit) |

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

$d_{cut,min}$ = cutting diameter at the lower tolerance limit (see Technical Report 048 [3] Figure 3.5) (minimum diameter bit)

$d_{nom}$ = outside diameter of fastener

$E_s$ = modulus of elasticity

$f_c$ = concrete compressive strength measured on cylinders

$f_{c,t}$ = compressive strength of concrete at the time of testing

$f_{ck}$ = nominal characteristic concrete compressive strength (based on cylinder)

$f_{cm}$ = mean concrete compressive strength

$f_{uk}$ = nominal characteristic steel ultimate tensile strength

$f_{u,t}$ = steel ultimate tensile strength of the tested fastener

$F_{u,c}$ = mean value of failure load in a test series converted to nominal concrete strength

$F_{u,s}$ = mean value of failure load in a test series converted to nominal steel strength

$F_{u,t}$ = mean value of failure load in a test series

$F^{0}_{Rk}$ = characteristic resistance valid for all load directions and modes of failure for simplified design

$h$ = thickness of the concrete member

$h_{ef}$ = effective embedment depth

$h_{min}$ = minimum thickness of concrete member

$h_{nom}$ = overall fastener embedment depth in the concrete

$h_s$ = length of the tip of a concrete screw as defined in Figure 1.4

$h_t$ = height of the thread of a concrete screw as defined in Figure 1.4

$k_{cr,N}$ = indicative factor for concrete cone capacity under tension load in cracked concrete

$k_{ucr,N}$ = indicative factor for concrete cone capacity under tension load in uncracked concrete

$k_7$ = indicative factor accounting for ductility of a fastener

$k_8$ = indicative factor for pry-out failure

$l_f$ = effective length of fastener under shear loading(for calculation resistance for concrete edge failure)

m = normalisation exponent taking into account the effect of concrete strength on the resistance

$M^{0}_{Rk,s}$ = characteristic resistance for steel failure with lever arm

$M^{0}_{Rk,s,fi}$ = characteristic resistance for steel failure with lever arm under fire exposure

$N_{Rk,c}$ = characteristic tension resistance to concrete cone failure

$N_{Rk,p}$ = characteristic tension resistance to pull-out failure

$N_{Rk,p,fi}$ = characteristic tension resistance to concrete cone failure under fire exposure

$N_{Rk,s}$ = characteristic tension resistance to steel failure

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

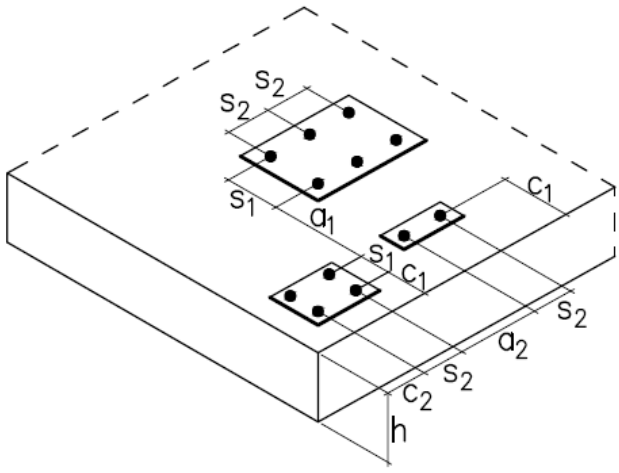
| | | |
|---|---|---|
| $N_{Rk,0}$ | = | initial value of the characteristic tensions resistance |
| $N_{u,m}$ | = | mean ultimate tensile load of the tests in concrete |
| $N_{u,m,A1}$ | = | mean ultimate tensile load of the test series A1 |
| $N_{u,m,A2}$ | = | mean ultimate tensile load of the test series A2 |
| $N_{u,5\%}$ | = | 5% fractile of failure loads in a test series |
| $N^0_{Rk,sp}$ | = | characteristic resistance to splitting failure |
| $n_1$ | = | number of fixing points for definition of redundant non-structural systems |
| $n_2$ | = | number of fasteners per fixing point for definition of redundant non-structural systems |
| $n_3$ | = | design value of actions for definition of redundant non-structural systems |
| $n_{min}$ | = | minimum number of tests for a test series |
| *rqd. α* | = | required value of α (see Table A.1) |
| $s_{cr}$ | = | spacing for ensuring the transmission of the characteristic resistance of a single fastener |
| $s_{cr,N}$ | = | spacing for ensuring the transmission of the characteristic resistance in tension of a single fastener without edge and spacing effects in case of concrete cone failure |
| $s_{min}$ | = | minimum spacing |
| $V_{Rk,s}$ | = | characteristic resistance to steel failure under shear load |
| $V_{Rk,s,fi}$ | = | characteristic resistance to steel failure under shear load under fire exposure |
| $V_{Rk,cp}$ | = | characteristic resistance to pry-out failure acc. to FprEN 1992-4:2017 |
| $\alpha$ | = | reduction factor for load according to A2.4 |
| $\alpha_1$ | = | reduction factor for uncontrolled slip according to A2.5 |
| $\alpha_p$ | = | reduction factor for applied load in sustained load tests, repeated load tests and freeze/thaw tests |
| $ß_{cv}$ | = | reduction factor for large scatter according to A2.2 |
| $\gamma_M$ | = | recommended material partial factor according to FprEN 1992-4 [5] of the corresponding failure mode |
| $\gamma_{Mc}$ | = | partial factor for resistance to concrete failure |
| $\gamma_{Mp}$ | = | partial factor for resistance to pull-out failure |
| $\gamma_{Ms}$ | = | partial factor for resistance to steel failure |
| $\gamma_{inst}$ | = | factor accounting for the sensitivity to installation of post-installed fasteners according to FprEN 1992-4 [5] |
| $\tau_{5\%}$ | = | initial characteristic bond resistance acc. to EAD 330499 |
| $\psi_c$ | = | increasing factor accounting for concrete strength |
| $\psi_{c,50}$ | = | increasing factor accounting for concrete strength class C50/60 |
| $\Delta w$ | = | required crack width, in addition to the initial hairline crack width as measured after the installation of the fastener |

### 1.3.3 Indices

| | | |
|---|---|---|
| *cr* | = | cracked concrete |
| *fi* | = | under fire exposure |
| *r* | = | reference tests |
| *t* | = | tested result |

### 1.3.4 Definitions

| | | |
|---|---|---|
| fastener | = | a manufactured component for achieving fastening between the base material (concrete) and the fixture; it may consist of assembled components |
| fastener group | = | several fasteners (working together) |
| fastening | = | an assembly comprising base material (concrete), fastener or fastener group and component fixed to the concrete |
| fixture | = | component to be fixed to the concrete |
| full expansion | = | expansion achieved when setting the DC fastener according to the MPII; full expansion is used in the tests for determination of admissible service conditions |
| reference expansion | = | expansion achieved by applying specified expansion energy (see TR 048) to DC fastener; reference expansion is used in the suitability tests |
| test member | = | concrete member in which the fastener is tested |
| redundant non-structural system | = | application in which multiple fastener support elements that are capable to redistribute the load to neighbouring fasteners |




$a_1$, $a_2$ axial spacing between two fixing points in direction 1 and 2

$c_1$, $c_2$ edge distance of fastener in direction 1 and 2

h thickness of the concrete member

$s_1$, $s_2$ axial spacing of fasteners in one fixing point in direction 1 and 2

**Figure 1.3 Definitions - concrete member, fastener spacing and edge distance**

The effective fastening depth of concrete screws shall be determined according to Figure 1.4.

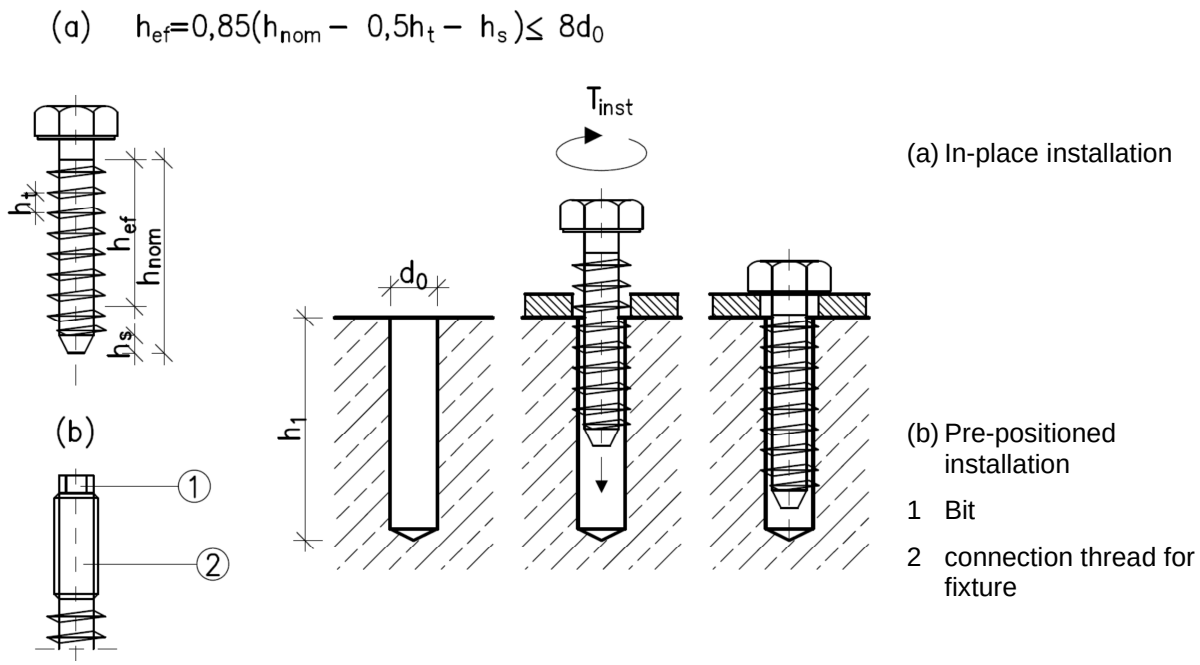



**Figure 1.4 Installation by driving the concrete screw with a self-cutting special thread with wrench or impact screw driver into a predrilled cylindrical hole.**

## 2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

### 2.1 Essential characteristics of the product

Table 2.1 shows how the performance of fasteners for use in concrete for redundant non-structural systems is assessed in relation to the essential characteristics.

**Table 2.1 Essential characteristics of the product assessment methods and criteria for the performance of the product in relation to those essential characteristics**

| No | Essential characteristic | Assessment methods | Type of expression of product performance *(level, class, description)* |
|---|---|---|---|
| Basic Works Requirement 2: Safety in case of fire[2] | | | |
| 1 | Reaction to fire | - | Class (A1) according to EN 13501-1 [7] |
| Resistance to fire (optional) | | | |
| 2 | Fire resistance to steel failure (tension load) | 2.2.12 | $N_{Rk,s,fi}$ [kN] |
| 3 | Fire resistance to pull-out failure (tension load) | | $N_{Rk,p,fi}$ [kN] |
| 4 | Fire resistance to steel failure (shear load) | | $V_{Rk,s,fi}$ [kN], $M^0_{Rk,s,fi}$ [Nm] |
| Basic Works Requirement 3: Hygiene, health and the environment[3] | | | |
| 5 | Content, emission and/or release of dangerous substances | acc. to EAD 330499 | Description |
| Basic Works Requirement 4: Safety and accessibility in use | | | |
| Characteristic resistance to tension load (static and quasi-static loading) | | | |
| 6 | Resistance to steel failure | 2.2.1 | $N_{Rk,s}$ [kN], $E_s$ [N/mm²] |
| 7 | Resistance to pull-out failure | 2.2.2 | $N_{Rk,p}$ [kN], $\psi_c$ ,$\tau_{Rk,p}$ [N/mm²] |
| 8 | Resistance to concrete cone failure | 2.2.3 | $k_{cr,N}$, $k_{ucr,N}$ [-], $h_{ef}$, $c_{cr,N}$ [mm] |
| 9 | Robustness | 2.2.4 | $\gamma_{inst}$ [-] |
| 10 | Minimum edge distance and spacing | 2.2.5 | $c_{min}$, $s_{min}$, $h_{min}$ [mm] |
| 11 | Edge distance to prevent splitting under load | 2.2.6 | $N^0_{Rk,sp}$ [kN], $c_{cr,sp}$ [mm] |
| Characteristic resistance to shear load (static and quasi-static loading) | | | |
| 12 | Resistance to steel failure under shear load | 2.2.7 | $V_{Rk,s}$ [kN], $M^0_{Rk,s}$ [Nm], $k_7$ [-] |
| 13 | Resistance to pry-out failure | 2.2.8 | $k_8$ [-] |
| 14 | Resistance to concrete edge failure | 2.2.9 | $d_{nom}$, $l_f$ |
| Characteristic resistance for all load directions and modes of failure for simplified design | | | |
| 15 | Characteristic resistance | 2.2.10 | $F^0_{Rk}$ [kN], $s_{cr}$, $c_{cr}$, [mm] |
| Durability | | | |
| 16 | Durability | 2.2.11 | Description |

[2] Relevant for mechanical fasteners only

[3] Relevant for bonding material of bonded fasteners only

## 2.2 Assessment methods and criteria for the performance of the product in relation to essential characteristics of the product

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

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

In the following text the relevant sections of EAD 330232 [1] and EAD 330499 [2] are referenced. In these chapters for fasteners for redundant non-structural systems the limitation of the scatter of displacements does not apply.

### 2.2.1 Resistance to steel failure under tension load

#### 2.2.1.1 Steel capacity (test series N1)

**Purpose of the test**

The characteristic resistance to steel failure may be calculated for steel elements with constant strength over the length of the element as given in Equation (2.1). The smallest cross section in the area of load transfer applies.

$$N_{Rk,s} = A_s \cdot f_{uk} \quad [N] \tag{2.1}$$

If the steel strength differs along the length of the element, calculate the design steel capacity for the specified steel strengths and the corresponding nominal stressed cross sections according to Equation (2.1) taking into account the recommended partial factor for steel resistance $\gamma_{M,s}$ according to prEN 1992-4 [5], Table 4.1. Take the minimum of these design steel capacities and determine the characteristic resistance to steel failure. The characteristic resistance and the corresponding partial factor $\gamma_{M,s}$ shall be stated in the ETA.

In this context for internal threaded fasteners both the steel resistance of the sleeve and the screw have to be taken into account.

Tests are needed only if calculation of the characteristic resistance to steel failure is not reasonable because the distribution of the steel strength of the finished product along the length of the fastener is not known or cannot easily be determined.

The modulus of elasticity for steel can be taken as $E_s$ = 210 000 N/mm².

**Test conditions and assessment**

The steel capacity is assessed in accordance with EAD 330232 [1] section 2.2.1.1 for mechanical fasteners and EAD 330499 section 2.2.1.1 [2] for bonded fasteners.

#### 2.2.1.2 Hydrogen embrittlement (CS, test series N3)

**Purpose of the test:**

The tests are only required for concrete screws (see Figure 1.4).

Screws of high strength may be sensitive to brittle fracture due to hydrogen embrittlement caused by the production process or by corrosion during (even short-time) exposure to moisture. The test is designed to detect fasteners with a high susceptibility to hydrogen induced brittle fracture and will be performed under conditions of constant mechanical load and hydrogen evolution on the surface of the screw.

This test for concrete screws may be omitted if

- concrete screws are made of stainless steel
- it is ensured by factory production control, that the strength of the steel in the area of load transfer is less than 1000 N/mm² and hardness is smaller than 350 HV referring to the total cross section for both surface and core hardness according to EN ISO 6507; < 36 HRC according to EN ISO 6508.

**Test conditions and assessment**

Testing and assessment of hydrogen embrittlement for concrete screws (CS) shall be carried out in accordance with EAD 330232 [1] section 2.2.1.3. If no separate reference test series is carried out for this test, test series A2 shall be used as the corresponding reference test series.

### 2.2.2 Resistance to pull-out failure

The resistance to pull-out failure is influenced by various aspects. These aspects are assessed for the different types of fasteners in 2.2.2.1 to 2.2.2.15 and accounted for in the determination of the characteristic resistances $N_{Rk,p}$ and $\tau_{Rk}$ as given in 2.2.2.16 and 2.2.2.17

#### 2.2.2.1 Reference tension tests (test series A1 to A4)

**Purpose of the test**

These tests are performed to determine the tension capacity of a single fastener without edge influence and thereby establishing the baseline values for the assessment of the performance under tension load $N_{Rk,0}$.

**Test conditions**

The tests shall be performed according to Technical Report 048 [3].

The tests are performed in concrete C20/25 and C50/60 as given in Annex A, Table A.1, lines A1 to A4.

If the manufacturer applies for one tension resistance for all concrete strength classes, then the tests in high strength concrete according to Table A.1 line A4 may be omitted.

The holes shall be drilled with a cutting diameter $d_{cut,m}$ of the drill bit according to Technical Report TR 048 [3], Figure 3.5. Deformation controlled expansion fasteners (DC) shall be set with full expansion according to TR 048.

**Assessment**

The following assessment shall be made for each fastener size and for each embedment depth:

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength.
- Determine $N_{Rk,0}$ from the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal concrete strength according to Annex A, A2.1.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 15% ($cv_F$ > 15%), determine the reduction factor for large scatter $ß_{cv}$ according to A2.2.
- Verify the criteria for uncontrolled slip and determine the reduction factor $\alpha_1$ according to Annex A, A2.5.
- Use the reduction factor $\alpha_1$ together with rqd. $\alpha_1$ = 0,4.

#### 2.2.2.2 Degree of expansion for DC fasteners (test series F1)

**Purpose of the test**

In order to achieve reproducible results for deformation controlled expansion fasteners, defined conditions for the expansion shall be achieved.

**Test conditions and assessment**

The test conditions and the definition of the various conditions for the expansion (i.e. full expansion, reference expansion and installation expansion) are given in the Technical Report TR 048 section 3.7 [3].

#### 2.2.2.3 Maximum crack width and large hole diameter (test series F2)

**Purpose of the test**

These tests are performed to evaluate the sensitivity to maximum crack width and, for mechanical fasteners also sensitivity to large hole diameter in low strength concrete.

**Test conditions**

The tests shall be performed according to Technical Report TR 048 [3].

The influence of increased crack width $\Delta w$ = 0,35 mm in combination with drill bits at the upper limit of tolerances (large hole diameter) is checked for mechanical fasteners. For bonded fasteners the influence of an increased crack width $\Delta w$ = 0,35 mm is assessed. The tests are performed in minimum concrete strength class as applied for by the manufacturer.

For mechanical fasteners the holes shall be drilled with a cutting diameter $d_{cut,max}$ of the drill bit according to Technical Report 048 [3], Figure 3.5. Deformation controlled expansion fasteners (DC) shall be set with reference expansion according to TR 048.

**Assessment**

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength.
- Determine the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal concrete strength according to Annex A, A2.1.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 20% ($cv_F$ > 20%), determine the reduction factor for large scatter $ß_{cv}$ according to A2.2.
- Determine the reduction factors $\alpha$ and $\alpha_1$ (uncontrolled slip) according to Annex A, sections A2.4 and A2.5, respectively.
- For the determination of α the test results are compared with reference test series according to Table A.1 line A3. The corresponding value for rqd. α is given as rqd. α = 0,75.

#### 2.2.2.4 Maximum crack width and small hole diameter (test series F3)

**Purpose of the test**

These tests are performed to evaluate the sensitivity to maximum crack width and, for mechanical fasteners also sensitivity to small hole diameter in high strength concrete.

**Test conditions**

The tests shall be performed according to Technical Report 048 [3], 3.3.1.

The influence of increased crack width $\Delta w$ = 0,35 mm in combination with drill bits at the lower limit of tolerances (small hole diameter) is checked for mechanical fasteners. For bonded fasteners the influence of an increased crack width $\Delta w$ = 0,35 mm is assessed. The tests are performed in concrete C50/60.

For mechanical fasteners the holes shall be drilled with a cutting diameter $d_{cut,min}$ of the drill bit according to Technical Report TR 048 [3], Figure 3.5. Deformation controlled expansion fasteners (DC) shall be set with reference expansion according to TR 048.

**Assessment**

- Determine the mean value of failure loads $N_{u,m}$ [kN], converted to the nominal concrete strength.
- Determine the 5% fractile of the failure loads $N_{u,5\%}$ [kN], converted to the nominal concrete strength according to Annex A, A2.1.
- Verify the coefficient of variation of failure loads. If the coefficient of variation exceeds 20% ($cv_F$ > 20%), determine the reduction factor for large scatter $ß_{cv}$ according to A2.2.
- Determine the reduction factors $\alpha$ and $\alpha_1$ (uncontrolled slip) according to Annex A, sections A2.4 and A2.5, respectively.
- For the determination of α the test results are compared with reference test series according to Table A.1 line A4. The corresponding value for rqd. α is given as rqd. α = 0,75.

#### 2.2.2.5 Repeated loads (test series F4)

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

Testing and assessment of repeated loads for mechanical fasteners (TC, DC, UC, LC, CS) shall be carried out in accordance with EAD 330232 [1] section 2.2.2.5. The determination of $\alpha_1$ (uncontrolled slip) is addressed in A2.5 of this EAD.

Testing and assessment of repeated loads for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.2.4. If no separate reference test series is carried out for this test, test series A1 shall be used as the corresponding reference test series.

#### 2.2.2.6 Torqueing in low strength concrete (CS test series F6)

The tests are only required for concrete screws. The tests are performed to check if failure occurs during setting (turn-through of the concrete screw), which would then reduce the performance of the fastener.

Testing and assessment of torqueing in low strength concrete shall be carried out in accordance with EAD 330232 [1] section 2.2.2.7.

The test series is required in the minimum concrete strength class as applied for by the manufacturer.

#### 2.2.2.7 Torqueing in high strength concrete (CS, test series F7)

The tests are only required for concrete screws. The tests are performed to check if steel failure occurs due to the torsion during setting.

Testing and assessment of torqueing in high strength concrete shall be carried out in accordance with EAD 330232 [1] section 2.2.2.8.

#### 2.2.2.8 Impact screw driver (CS, test series F8)

The tests are only required for concrete screws. The tests are performed to check if failure occurs while setting with impact screw drivers.

Testing and assessment of concrete screws set with impact screw driver shall be carried out in accordance with EAD 330232 [1] section 2.2.2.9.

#### 2.2.2.9 Increased temperature (BF, test series B2 and B3)

The test conditions and the assessment of bonded fasteners for maximum long term temperature and maximum short term temperature shall be carried out in accordance with EAD 330499 [2] section 2.2.2.9.

#### 2.2.2.10 Minimum installation temperature (BF, test series B4)

The test conditions and the assessment of bonded fasteners for minimum installation temperature follow EAD 330499 [2] section 2.2.2.10.

#### 2.2.2.11 Minimum curing time (BF, test series B5)

The test conditions and the assessment of bonded fasteners for minimum curing time follow EAD 330499 [2] section 2.2.2.11.

#### 2.2.2.12 Sustained loads (BF, test series B14 and B15)

The tests are performed to check the creep behaviour of the loaded fastener at normal ambient temperature (Test series B14) and at maximum long term temperature (test series B15).

The test series is required in the minimum concrete strength class as applied for by the manufacturer.

Testing and assessment of sustained load for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.2.6.

If no separate reference test series is carried out for this test, in tests at normal ambient temperature (test series B14) test series A1 shall be used as the corresponding reference test series.

#### 2.2.2.13 Freeze/thaw conditions (BF, test series B16)

These tests are performed to determine the performance of the fastener under freeze/thaw conditions simulating varying life conditions.

Testing and assessment of Freeze/thaw conditions for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.2.7. If no separate reference test series is carried out for this test, test series A2 shall be used as the corresponding reference test series.

#### 2.2.2.14 Installation direction (BF, test series B17)

The tests are performed to check the performance under unfavourable installation directions. The test series may be omitted for downward installation only.

Testing and assessment of installation direction for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.2.8. If no separate reference test series is carried out for this test, test series A1 shall be used as the corresponding reference test series.

#### 2.2.2.15 Sensitivity to sulphurous atmosphere and high alkalinity (BF, test series R8, B18 and B19)

These tests are performed to determine the performance of the fastener under sulphurous atmosphere and high alkalinity.

Testing and assessment of high alkalinity for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.2.12. If no separate reference test series is carried out for this test, test series R8 shall be used as the corresponding reference test series.

#### 2.2.2.16 Characteristic resistance to pull-out failure

The initial value $N_{Rk,0}$ is taken as the 5% fractile of failure loads in the reference tension test series according to Table A.1 line A3 and A4.

The characteristic tension resistance shall be reduced if certain requirements are not met as described in the following:

(1) Load/displacement behaviour, tension loading
If the requirements on uncontrolled slip according to A2.5 are not fulfilled by the tension tests, the characteristic resistance shall be reduced according to Equation (2.2). The smallest value for $\alpha_1$ applies.

(2) Repeated load tests
If, in the repeated load tests the criteria on the displacement behaviour given in 2.2.2.5 are not fulfilled, the characteristic resistance shall be reduced by applying the reduction factor $\alpha_p$ according to Equation (2.2).

(3) Ultimate load in any other tests
If the requirements on the ultimate load in test series according to Table A.1 line N3, F2 to F4 and B17, are not fulfilled in one or more test series, the characteristic resistance shall be reduced according to Equation (2.2). The smallest value of the ratio α/(rqd α) applies. If not all sizes of fasteners have been tested, the smallest reduction factor for the size of fasteners shall be applied for all neighbour sizes which were not tested.

$$N_{Rk,p} = N_{Rk,0} \cdot \min \beta_{cv} \cdot min\left\{min\alpha_p; min\ \alpha_1; min\left(\frac{\alpha}{rqd.\ \alpha}\right)\right\} \quad (2.2)$$

The characteristic resistance shall be rounded down accounting for increments as given in Table 2.2.

**Table 2.2 Values of characteristic resistance $N_{Rk,p}$**

| Range of $N_{Rk,p}$ [kN] | Increment [kN] | Values |
|---|---|---|
| < 1,5 | | 0,75 / 0,9 / 1,2 |
| 1,5 to 10 | 0,5 | 1,5 / 2,0 … 9,5 / 10,0 |

The characteristic resistance of a fastener in case of pull-out failure in concrete of strength > C20/25 is determined by multiplying the characteristic value for concrete C20/25 by a factor $\psi_c$ according to A2.1.

#### 2.2.2.17 Characteristic bond resistance

The characteristic bond resistance for bonded fasteners shall be determined according to EAD 330499, section 2.2.2.13 and Equation (2.3).

$$\tau_{Rk} = \tau_{5\%} \cdot \alpha_{setup} \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot min\ \beta_{cv} \cdot min\left\{min\alpha_p; min\alpha_1; min\left(\frac{\alpha}{rqd.\ \alpha}\right)\right\} \quad (2.3)$$

### 2.2.3 Resistance to concrete cone failure

The assessment of concrete cone capacity for mechanical fasteners shall be carried out in accordance with EAD 330232 [1] section 2.2.3. The assessment of concrete cone capacity for bonded fasteners shall be carried out in accordance with EAD 330499 [2] section 2.2.3.

### 2.2.4 Robustness

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

#### 2.2.4.1 Robustness to variation in use conditions (test series F9) mechanical fasteners

Test are carried out in the concrete strength given in Table A.1, line F9. The test conditions are given in EAD 330232, 2.2.4.1.

The assessment of robustness for mechanical fasteners (TC, DC, UC, LC and CS) shall be carried out in accordance with EAD 330232 [1]. Therefore, the factor $\gamma_{inst}$ shall be determined in accordance with EAD 330232, section 2.2.4. However, deviating from EAD 330232, for mechanical fasteners the tests in

cracked concrete are performed with a crack width of 0,2 mm and test series A3 shall be used as reference test series.

Load controlled fasteners shall be installed with 50% of the load as specified in the MPII.

#### 2.2.4.2 Robustness to variation in use conditions (test series F9) bonded fasteners

The test conditions and the assessment for robustness to variation in use conditions of bonded fasteners shall be carried out in accordance with EAD 330499 [2]. Therefore, the factor $\gamma_{inst}$ shall be determined in accordance with EAD 330499, section 2.2.5.

### 2.2.5 Minimum edge distance and spacing (test series F10)

The tests are performed to check that splitting of the concrete does not occur during the installation of the fastener.

Testing and assessment of minimum edge distance for mechanical fasteners (TC, DC, UC, LC and CS) shall be carried out in accordance with EAD 330232 [1]. Therefore, $c_{min}$ and $s_{min}$ shall be determined in accordance with EAD 330232, section 2.2.5.

Testing and assessment of minimum edge distance for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2]. Therefore, $c_{min}$ and $s_{min}$ shall be determined in accordance with EAD 330499, section 2.2.6.

The tests may be omitted if the spacing and edge distances given in Table 2.3 are kept.

### 2.2.6 Edge distance to prevent splitting under load (test series F11)

The tests are performed to check determine the characteristic edge distance at which splitting is not decisive.

Testing and assessment of edge distance for mechanical fasteners (TC, DC, UC, LC and CS) shall be carried out in accordance with EAD 330232 [1]. Therefore, $N^0_{RK,sp}$, $c_{cr,N}$ and $s_{cr,N}$ shall be determined in accordance with EAD 330232, section 2.2.6.

Testing and assessment of edge distance for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2].

The tests may be omitted if the spacing and edge distances given in Table 2.3 are taken as $s_{min}$ and $c_{min}$, respectively.

**Table 2.3 Default values for edge distance and spacing**

| | Deformation-controlled expansion fasteners (DC) | All other fasteners |
|---|---|---|
| spacing $s_{cr}$ | ≥ 200 mm and ≥ 4 $h_{ef}$ | ≥ 200 mm and ≥ 4 $h_{ef}$ |
| edge distance $c_{cr}$ | ≥ 150 mm and ≥ 3 $h_{ef}$ | ≥ 100 mm and ≥ 3 $h_{ef}$ |

### 2.2.7 Characteristic resistance to shear load (test series V1)

Testing and assessment of the characteristic resistance to shear load for mechanical fasteners (TC, DC, UC, LC and CS) shall be carried out in accordance with EAD 330232 [1]. Therefore, $V^0_{RK,s}$, $M^0_{RK,s,}$ $k_7$ shall be determined in accordance with EAD 330232, section 2.2.7.

Testing and assessment of the characteristic resistance to shear load for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.7.

### 2.2.8 Concrete pry-out failure (test series V2)

The assessment of concrete pry-out failure for mechanical fasteners (TC, DC, UC, CS, LF) and the factor $k_8$ shall be carried out in accordance with EAD 330232 [1] section 2.2.8.

The assessment of concrete pry-out failure for bonded fasteners (BF) and the factor $k_8$ shall be carried out in accordance with EAD 330499 [2] section 2.2.8.

### 2.2.9 Concrete edge failure

Geometrical data $d_{nom}$ and $l_f$ used for design are given as follows:

$d_{nom}$ outside diameter of the fastener relevant for shear loading

$l_f$ effective length of the fastener for transfer of shear load

### 2.2.10 Characteristic resistance for simplified design methods

$F^0_{Rk}$ for all load directions taking into account the decisive failure mode and the corresponding partial factor $\gamma_M$ is given as follows:

$$F^0_{Rk} / \gamma_M = \min (N_{Rk,S} / \gamma_{Ms}; N_{Rk,c} / \gamma_{Mc}; N_{Rk,p} / \gamma_{Mp}; V_{Rk,S} / \gamma_{Ms}; V_{RK,cp}/\gamma_{Mc}; V_{Rk,c}/\gamma_{Mc}) \quad (2.4)$$

$$c_{cr} = c_{cr,N} \quad (2.5)$$

$$s_{cr} = s_{cr,N} \quad (2.6)$$

With
$V_{Rk,c}$ calculated with the minimum edge distance cmin

In absence of National regulations recommended values for $\gamma_{Ms}$, $\gamma_{Mc}$, $\gamma_{Mp}$ are given in FprEN 1992-4 Table 4.1.

### 2.2.11 Durability

Testing and assessment of durability for mechanical fasteners (TC, DC, UC, CS, LF) shall be carried out in accordance with EAD 330232 [1] section 2.2.12.

Testing and assessment of durability for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section 2.2.11.

### 2.2.12 Fire resistance

Testing and assessment of resistance to fire for mechanical fasteners (TC, DC, UC, LC and CS) shall be carried out in accordance with EAD 330232 section 2.2.13 to 2.2.15.

## 3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

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

For the products covered in this EAD the applicable European legal act is: Decision 97/161/EC.

The system is: 2+

### 3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the fastener in the procedure of assessment and verification of constancy of performance are laid down in Table 3.1.

Table 3.1 gives guidance; the control plan depends on the individual manufacturing process and has to be established between TAB and manufacturer for each product.

**Table 3.1 Control plan for the manufacturer; cornerstones**

| No | Subject/type of control | Test or control method | Criteria, if any | Minimum number of samples | Minimum frequency of control |
|---|---|---|---|---|---|
| **Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]** | | | | | |
| **Metal Parts** | | | | | |
| 1 | Dimensions (outer diameter, inner diameter, thread length, etc.) | Caliper and/or gauge | Laid down in control plan | 3 | Every manu-facturing batch or 100.000 elements or when raw material batch has been changed *) |
| 2 | Tensile Load or tensile strength | EN ISO 6892-1 [11], EN ISO 898-1 [10], EN ISO 3506-1 [8] | | 3 | |
| 3 | Yield strength | EN ISO 6892-1 [11], EN ISO 898-1 [10], EN ISO 3506-1 [8] | | 3 | |
| 4 | Core hardness and Surface hardness (at specified functioning relevant points of the product) – where relevant | Tests acc. to EN ISO 6507 [19]or EN ISO 6508 [20] | | 3 | |
| 5 | Roughness of cone - where relevant | profile method: EN ISO 12085 [17]<br>Software measurement standards:<br>EN ISO 5436 [15]<br>EN ISO 1302 [16] | | 3 | |
| 6 | Zinc plating - where relevant | x-ray measurement according to EN ISO 3497 [12], magnetic method according to EN ISO 2178 [13], Phase-sensitive eddy-current method according to EN ISO 21968 [14] | | 3 | |
| 7 | Fracture elongation - where relevant | EN ISO 6892-1 [11] EN ISO 898-1 [10] | | 3 | |
| 8 | Hard metal tip of fastener made of stainless steel - where relevant | Check of material, geometry, position and fixing to stainless steel | | 3 | |
| **Bonding material** | | | | | |
| 9 | Batch number and expiry date | visual check | Laid down in control plan | 1 | each batch |
| 10 | Components | check material and the mass of components acc. to recipe | | | |
| 11 | Specific gravity / Density | Standardized method proposed by the manufacturer | | | Every shift or 8 hours of production per machine |
| 12 | Viscosity | | | | |
| 13 | Reactivity (gel time, where relevant: max. reaction temperature, time to max reaction temperature) | | | | Each batch |

| No | Subject/type of control | Test or control method | Criteria, if any | Minimum number of samples | Minimum frequency of control |
|---|---|---|---|---|---|
| **Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]** | | | | | |
| 14 | Properties of raw material | (e.g. by infrared analysis) | | | initial testing and each change of batch |
| 15 | Performance of the cured bonding material | (e.g. tension test to failure) | | 3 | Each batch |

*) The lower control interval is decisive

### 3.3 Tasks of the notified body

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

**Table 3.2 Control plan for the notified body; cornerstones**

| No | Subject/type of control | Test or control method | Criteria, if any | Minimum number of samples | Minimum frequency of control |
|---|---|---|---|---|---|
| **Initial inspection of the manufacturing plant and of factory production control** | | | | | |
| 1 | Ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the mechanical fastener or bonding material for bonded fastener. In particular it shall be checked if all tasks given in Table 3.1 were performed. | - | Laid down in control plan | - | 1 |
| **Continuous surveillance, assessment and evaluation of factory production control** | | | | | |
| 2 | Verifying that the system of factory production control and the specified automated manufacturing process are maintained taking account of the control plan. | - | Laid down in control plan | - | 1/year |

## 4 REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment is of relevance.


| | | |
|---|---|---|
| [1] | EAD 330232-00-0601 | Mechanical fasteners for use in concrete |
| [2] | EAD 330499-00-0601 | Bonded fasteners for use in concrete |
| [3] | TR 048:2016-08 | Details of tests for post-installed fasteners in concrete |
| [4] | EN 206 | Concrete: Specification, performance, production and conformity |
| [5] | FprEN 1992-4:2017 | Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete |
| [6] | EN 10204: 2004 | Metallic products – Types of inspection documents |
| [7] | EN 13501 | Fire classification of construction products and building elements; Part 1: Classification using data from reaction to fire tests; Part 2: Classification using data from fire resistance tests, excluding ventilation services |
| [8] | EN ISO 3506 | Mechanical properties of corrosion-resistant stainless steel fasteners, Part 1: Bolts, screws and studs; Part 2: Nuts |
| [9] | EN ISO/IEC 17025 | General requirements for the competence of testing and calibration laboratories. |
| [10] | ISO 898 | Mechanical properties of fasteners made of carbon steel and alloy steel. Part 1: Bolts, screws and studs with specified property classes – Coarse thread and fine pitch thread<br>Part 2: Nuts with specified property classes – Coarse thread and fine pitch thread |
| [11] | EN ISO 6892-1 | Metallic materials – Tensile testing – Part 1: Method of test at room temperature |
| [12] | ISO 3497 | Metallic coatings - Measurement of coating thickness - X-ray spectrometric methods |
| [13] | ISO 2178 | Non-magnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method |
| [14] | ISO 21968 | Non-magnetic metallic coatings on metallic and non-metallic basis materials - Measurement of coating thickness - Phase-sensitive eddy-current method |
| [15] | ISO 5436-1 | Geometrical Product Specifications (GPS) - Surface texture: Profile method; Measurement standards - Part 1: Material measures |
| [16] | EN ISO 1302 | Geometrical Product Specifications (GPS) - Indication of surface texture in technical product |
| [17] | EN ISO 12085:1997 | Geometrical Product Specifications (GPS) - Surface texture: Profile method - Motif parameters (ISO 12085:1996); |
| [18] | CEN/TR 17079:2017 | Design of fastenings for use in concrete – Redundant non-structural systems |
| [19] | EN ISO 6507:2016 | Metallic materials - Vickers hardness test - Part 1: Test method (ISO/DIS 6507-1:2016) |
| [20] | EN ISO 6508:2016 | Metallic materials - Rockwell hardness test - Part 1: Test method (ISO 6508-1:2016) |

# A ANNEX TEST PROGRAM AND GENERAL ASPECTS OF ASSESSMENT

## A1 Test program

The test program for the assessment consists of

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

The tests in low strength concrete shall be performed with the minimum concrete strength class applied for by the manufacturer. For concrete strength class C12/15 the tests are required in concrete with a compressive strength $f_{cm} \leq 20$ MPa (measured on cylinders) or $f_{cm} \leq 25$ MPa (measured on cubes).

Tests with bonded fasteners may be performed with confined test set-up according to Technical Report TR 048 [3] and EAD 330499 [2].

Bonded Fasteners

Bonded fasteners shall be installed in bore holes of the largest possible hole diameter as specified by the manufacturer for the considered size of the fastener. For bonded fasteners the requirements on the tolerances of cutting diameter of drill bit do not apply.

Fasteners for use in prestressed hollow core slabs

Fasteners which are intended to be used in hollow core slabs may be tested in flat concrete slabs with thickness as specified by the manufacturer as the minimum bottom flange thickness (≥ 17 mm acc. to Figure 1.2).

If the fastener is only intended for use in prestressed hollow core slabs, test series F2, F3 and F9 may be performed in uncracked concrete.

**Table A.1 Test program**

| N° | Purpose of test | Concrete | Crack width | Size | $d_{cut}$ | $n_{min}$ | rqd. α | Required for | Section |
|---|---|---|---|---|---|---|---|---|---|
| **Resistance to steel failure under tension load** | | | | | | | | | |
| N1 | Steel capacity | - | 0 | All | - | 5 | - | All | 2.2.1.1 |
| N3 | Hydrogen induced embrittlement | C50/60 | 0 | All | $d_{cut,m}$ | 5 | 0,90 | CS | 2.2.1.2 |
| **Basic tension tests** | | | | | | | | | |
| A1 | Reference tension tests | C20/25 | 0,00 | m | $d_{cut,m}$ | 5 | - | DC, TC, UC, LC, BF | 2.2.2.1 |
| | | | | All | | | | CS | |
| A2 | | C50/60 | | m | | 5 | | BF, CS | |
| A3 | | C20/25 | 0,20 | All | | 5 | | All | |
| A4 | | C50/60 | | All | | 5 | | All[1)] | |
| **Resistance to pull-out failure** | | | | | | | | | |
| F1 | Degree of expansion | C50/60 | 0 | All | $d_{cut,m}$ | 5 | | DC | TR 048 |
| F2 | Maximum crack width and large hole diameter | min | 0,35 | All | $d_{cut,max}$ | 5 | 0,75 | DC, TC, UC, LC, CS | 2.2.2.3 |
| | | | | s/m/l | - | 5 | | BF | |
| F3 | Maximum crack width and small hole diameter | C50/60 | 0,35 | All | $d_{cut,min}$ | 5 | 0,75 | DC, TC, UC, LC, CS | 2.2.2.4 |
| | | | | s/m/l | - | | | BF | |
| F4 | Repeated loads | min | 0 | m [2)] | $d_{cut,m}$ | 3 | 1,00 | DC, TC, UC, LC | 2.2.2.5 |
| | | | | m | - | 5 | | BF | |
| | | | | All | $d_{cut,m}$ | 5 | | CS | |
| F6 | Torqueing in low strength concrete | min | 0 | All | $d_{cut,max}$ | 10 | | CS | 2.2.2.6 |

| N° | Purpose of test | Concrete | Crack width | Size | $d_{cut}$ | $n_{min}$ | rqd. α | Required for | Section |
|---|---|---|---|---|---|---|---|---|---|
| F7 | Torqueing in high strength concrete | C50/60 | 0 | All | $d_{cut,min}$ | 10 | | CS | 2.2.2.7 |
| F8 | Impact screw driver | min | 0 | All | $d_{cut,max}$ | 15 | | CS | 2.2.2.8 |
| F9 | Robustness to variation in use conditions | min | 0,20 | All | $d_{cut,max}$ | 5 | 0,95<br>0,80<br>0,70 | CS, UC | 2.2.4 |
| | | | 0 | s/m/l | - | | | BF | |
| | | min | 0,20 | All | $d_{cut,m}$ | | | DC | |
| | | C50/60 | | | | | | TC, LC | |
| F10 | Minimum edge distance and spacing | C20/25 | 0 | All | $d_{cut,m}$ | 5 | - | Design method A and B only | 2.2.5 |
| F11 | Edge distance to prevent splitting under load | C20/25 | 0 | All | $d_{cut,m}$ | 4 | - | optional | 2.2.6 |
| **Characteristic Resistance to shear load** | | | | | | | | | |
| V1 | Characteristic resistance to steel failure-under shear load | C20/25 | 0 | All | $d_{cut,m}$ | 5 | - | All | 2.2.7 |
| V2 | Characteristic resistance to pry-out failure | C20/25 | 0 | All | - | 5 | | Optional test | 2.2.8 |
| **Reference test for bonded fasteners** | | | | | | | | | |
| R8 | Reference for slice tests | min | 0 | m | - | 10 | - | BF | 2.2.2.15 |
| **Tests for bonded fasteners only** | | | | | | | | | |
| B2 | Maximum long term temperature | C20/25 | 0 | m | - | 5 | | BF | 2.2.2.9 |
| B3 | Maximum short term temperature | C20/25 | 0 | m | - | 5 | | BF | 2.2.2.9 |
| B4 | Minimum installation temperature | C20/25 | 0 | m | - | 5 | | BF | 2.2.2.10 |
| B5 | Minimum curing time at normal ambient temperature | C20/25 | 0 | m | - | 5 | | BF | 2.2.2.11 |
| B14 | Sustained loads (normal ambient temperature) | min | 0 | m | - | 5 | 0,90 | BF | 2.2.2.12 |
| B15 | Sustained loads (maximum long term temperature) | min | 0 | m | - | 5 | 0,90 | BF | 2.2.2.12 |
| B16 | Freeze/thaw conditions | C50/60 | 0 | m | - | 5 | 0,90 | BF | 2.2.2.13 |
| B17 | Installation direction | min | 0 | max | - | 5 | 0,90 | BF | 2.2.2.14 |
| B18 | High alkalinity | min | 0 | m | - | 10 | 1,00 | BF | 2.2.2.15 |
| B19 | Sulphurous atmosphere | min | 0 | m | - | 10 | 0,90 | BF | |

1) The tests may be omitted, if in the reference tension tests in concrete strength class C20/25 the failure is caused by rupture of steel or if the manufacturer applies for one tension resistance for all concrete strength classes.

2) Other sizes shall also be tested if the fastener sizes are not similar in in respect to geometry and friction (not relevant for BF)

3) For minimum concrete strength C12/15: the results for C12/15 may be achieved by conversion according to section A2.1.

For certain test series according to Table A.1 a reduced range of tested sizes, indicated by “s/m/l”, may be used. The number of diameters to be tested in this case depends on the number of requested sizes and is given in Table A.2.

**Table A.2 Reduced range of tested sizes s/m/l**

| Number of requested sizes | Number of diameters to be tested |
|---|---|
| ≤ 5 | 3 |
| ≤ 8 | 4 |
| ≤ 11 | 5 |
| > 11 | 6 |

**Provisions for all test series**

As far as applicable the Technical Report 048 [3] shall be followed for the test members, test setup and performance of the tests. Modifications are addressed in the following sections, which overrule conflicting provisions in the Technical Report 048 [3]. For fasteners other than bonded fasteners the tension tests are performed with unconfined test setup.

It is recommended that handling of tests and calibration items are performed in accordance with EN ISO/IEC 17025 [9].

If the mechanical fasteners are intended to be installed with more than one embedment depth, in general, the tests have to be carried out with all embedment depths. In special cases, e.g. when steel failure occurs, the number of tests may be reduced. For bonded fasteners the embedment depth shall follow EAD 330499.

## A2 General assessment methods

### A2.1 Conversion of failure loads to nominal strength

For mechanical fasteners the conversion of failure loads shall be done according to Equation (A.1) to (A.6) depending on the failure mode.

| | | |
|---|---|---|
| **Concrete failure** | $F_{u,c} = F_{u,t} \cdot \left( \frac{f_c}{f_{c,t}} \right)^{0,5}$ with $\frac{f_c}{f_{c,t}} \le 1,0$ | (A.1) |
| **Pull-out failure** | $F_{u,c} = F_{u,t} \cdot \left( \frac{f_c}{f_{c,t}} \right)^{m}$ with $\frac{f_c}{f_{c,t}} \le 1,0$ | (A.2) |
| | $\psi_{c,50} = \frac{N_{u,m,A2}}{N_{u,m,A1}} \le \sqrt{\frac{50}{\min f_{ck}}}$ | (A.3) |
| | $m = \log(\psi_{c,50}) / \log(50 / \min f_{ck})$ | (A.4) |
| | $\psi_{c,xx} = \left( \frac{f_{ck,xx}}{\min f_{ck}} \right)^{m}$ | (A.5) |
| **Steel failure** | $F_{u,s} = F_{u,t} \frac{f_{uk}}{f_{u,t}}$ | (A.6) |

For bonded fasteners the conversion of failure loads shall be done in accordance with EAD 330499, section A2.3.2.

### A2.2 Criteria regarding scatter of failure loads

The criteria regarding scatter of failure loads for mechanical fasteners (TC, DC, UC, LC, CS) are given in EAD 330232 [2] section A2.2.

The criteria regarding scatter of failure loads for bonded faster fasteners (BF) are given in EAD 330499 [2] section A2.3.5.

### A2.3 Establishing 5 % fractile

Establishing 5 % fractile for mechanical fasteners (TC, DC, UC, LC, CS) shall be carried out in accordance with EAD 330232 [2] section A2. 3.

Establishing 5 % fractile for bonded fasteners (BF) follow in EAD 330499 [2] section A2.3.6.

### A2.4 Determination of reduction factors $\alpha$

The determination of reduction factors $\alpha$ for mechanical fasteners (TC, DC, UC, LC, CS) shall be carried out in accordance with EAD 330232 [2] section A2.4.

The determination of reduction factors $\alpha$ for bonded fasteners (BF) shall be carried out in accordance with EAD 330499 [2] section A2.3.8.

### A2.5 Criteria for uncontrolled slip under tension loading

The assessment for uncontrolled slip under tension loading for mechanical fasteners (TC, DC, UC, LC, CS) are the same as given in EAD 330232 [2] section A2.5. However, the level for uncontrolled slip is 0,4 $N_{Ru}$ instead of 0,7 $N_{Ru}$.

The assessment for uncontrolled slip under tension loading for bonded fasteners (BF) shall be carried out in accordance with "loss of adhesion" in EAD 330499 [2] section A2.4.