EOTA

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European Assessment Document for

Kit for reinforced concrete members with high strength reinforcing steel but limited tensile utilisation

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

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

1.1.1 General description of the kit

The components of the product, "Kit for reinforced concrete members with high strength reinforcing steel but limited tensile utilisation", are put together to assemble anchorages and splices to be incorporated in the construction works. The components, see also Figure 1.1.1.1, are:

- A continuously threaded steel bar. The continuous thread is provided by ribs, hot rolled over the entire length of the bar – thread bar. The load bearing capacity of the Kit with high strength reinforcing steel is determined by the thread bar.
- Components for anchorages are steel plate for end bearing anchorage or anchor piece locked with one nut for torqued anchorage.
- Components for splices are contact coupler for end bearing splice, coupler with nuts for torqued splice, or turnbuckle with nuts for torqued splice with turnbuckle.

NOTE Within the document, “Kit for reinforced concrete members with high strength reinforcing steel but limited tensile utilisation” and “Kit with high strength reinforcing steel” are synonyms.

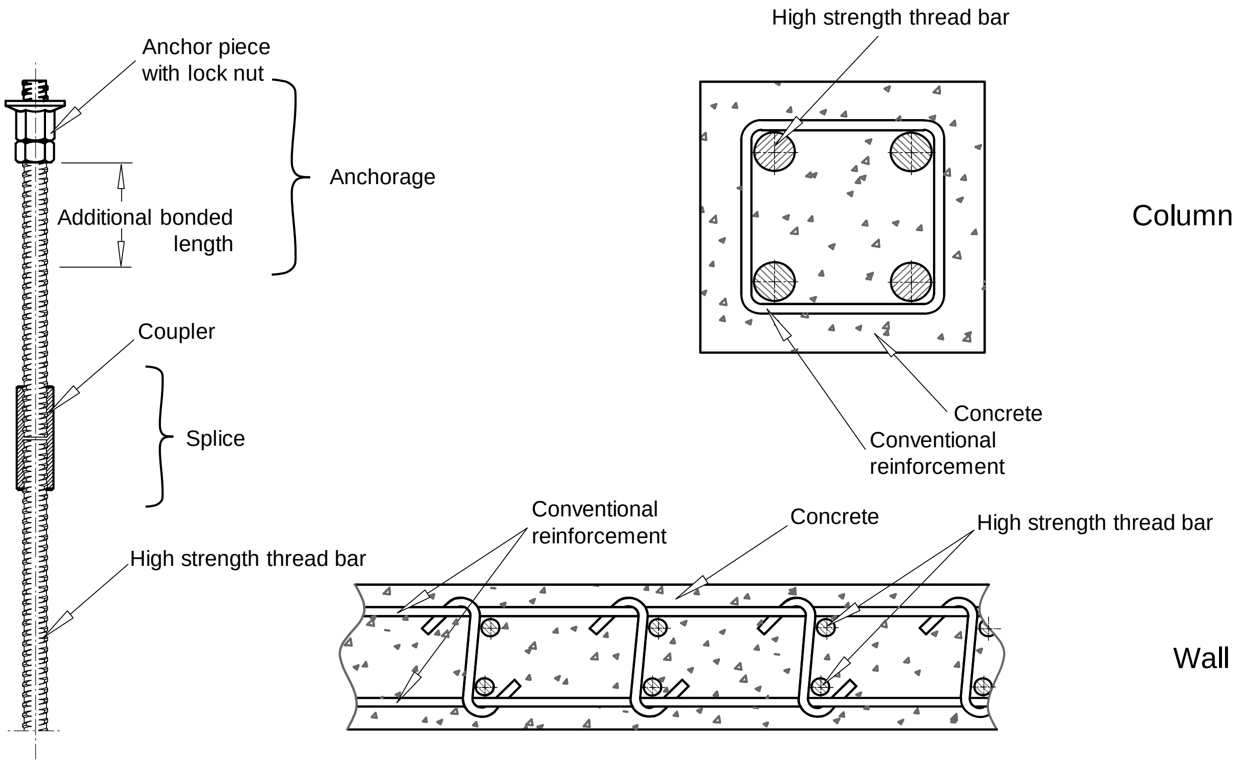

Figure 1.1.1.1 Thread bar with anchorage and splice – Cross sections of reinforced concrete members – Schematic examples

Limited slip at anchorage and splice is 0.10 mm to 0.20 mm at maximum, dependent on the length of anchorage or splice respectively, see Figure 1.1.1.3, whereby length of anchorage or splice is the dimension of anchorage and splice including all nuts, that is measured along the length of the thread bar, see example of Figure 1.1.1.2.

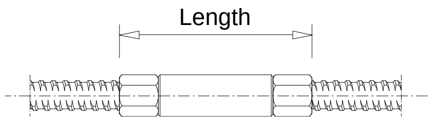

Figure 1.1.1.2 Length of splice – Example with torqued splice

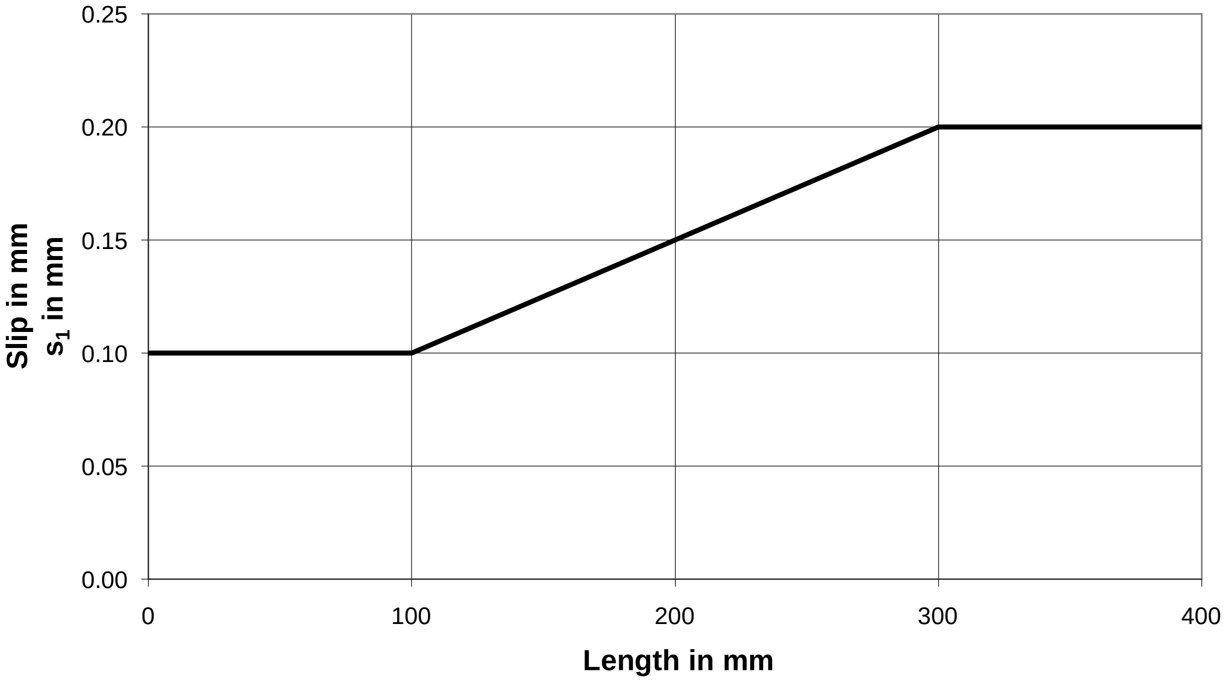

Figure 1.1.1.3 Maximum slip and s_1 versus length of splice or length of end anchorage

NOTE See Clause 2.2.2 for application of s_1.

1.1.2 Kit components

1.1.2.1 Thread bar

The thread bar is a hot rolled and continuously threaded steel bar. The thread is provided by hot rolled ribs. Nominal diameters shall be within 15 mm to 80 mm; within these limits, any series of nominal diameters are covered by this EAD; an example of typical series of nominal diameters is given in Table 1.1.2.1.1, together with nominal mechanical characteristics. The thread bar conforms to EN 1992-1-1[1], Annex C, except yield and tensile strength, which exceed the range in EN 1992-1-1, Annex C.

Nominal diameters, nominal yield strength, and nominal tensile strength of the thread bar are taken from the Manufacturer's Product Installation Instructions, MPII. If this information is not provided, then test specimens available shall be measured and tested according to Annex A to determine the nominal values.

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

Table 1.1.2.1.1 Thread bar – Diameters and mechanical characteristics

Example of nominal diameters of thread bar	Nominal yield strength	Nominal tensile strength
$\varnothing_{nom}$	$R_{e, nom}$	$R_{m, nom}$
mm	MPa	MPa
18 – 22 – 25 – 28 – 30 – 35 – 43 – 50 – 57.5 – 63.5 – 75	$\leq$ 670	$\leq$ 800

1.1.2.2 Components for anchorage

- Steel plate for end bearing anchorage.

  The end bearing anchorage transfers compression load to a steel plate by contact of the square cut end face of the thread bar.

- Anchor piece with one nut for torqued anchorage

  Torqued anchorage is used for tension, compression, or alternating loads comprising a torqued anchor piece with an additional bonded length. The torqued anchor piece is locked with one nut.

1.1.2.3 Components for splice

- Contact coupler
- Reducing contact coupler

  End bearing splice transfers compression loads by contact of the square cut end faces of the thread bars. The thread bars ends are hold in co-axial contact by a contact coupler. Thread bars with different nominal diameter are jointed with a reducing contact coupler.

- Coupler with nuts
- Reducing coupler with nuts
- Turnbuckle with nuts

  To transfer tensile, compression, or alternating loads, a torqued splice with nuts or a torqued splice with turnbuckle is used. Thread bars with different nominal diameter are jointed with a reducing coupler and two rigidly placed thread bars with ends in a given co-axial distance are jointed with a turnbuckle.

1.1.3 Further product related aspects

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(s) of the construction product

1.2.1 Intended use(s)

The Kit with high strength reinforcing steel is intended to be installed in buildings and civil engineering structures with following features:

- In-situ concrete and precast elements
- Concrete grades from C25/30 to C80/95
- Geometrical reinforcement percentages of up to 20 %, observing the required bar spacing and concrete cover
- Reinforced concrete members to transfer static, predominantly static, and accidental loads.
- Reinforced concrete compression members, e.g., columns and walls
- Reinforced concrete members to transfer tensile loads from static and predominantly static actions observing following constraints:
  - Either the yield strength is limited to ≤ 600 MPa
  - Or for bending with significant axial compression the serviceability limit states are verified
- Reinforced concrete members to transfer tensile loads from accidental actions and seismic actions
- Thread bars with nominal diameter > 57.5 mm are not intended to be bent.
- Corrosion protection of the Kit with high strength reinforcing steel is by concrete cover.
- Reinforced concrete members where decrease in load bearing capacity of concrete and steel under fire exposure is determined on basis of temperature field calculations.

The Kit with high strength reinforcing steel is intended for the uses of Table 1.2.1.1.

Table 1.2.1.1 Categories of intended use

№	Category of intended use
1	Building and civil engineering structure not subjected to low-cycle fatigue actions
2	Building and civil engineering structure subjected to low-cycle fatigue actions

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 Kit with high strength reinforcing steel for the intended use of 100 years when installed in the works, provided that the Kit with high strength reinforcing steel is subject to appropriate installation, see Clause 1.1.3. 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 defined by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

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

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

1.3 Specific terms used in this EAD

1.3.1 Splice

Assembly of a coupler (sleeve) and two thread bars to accomplish the jointing of the two thread bars.

Splice is either an end bearing splice, see Figure 1.3.2.1, a torqued splice, see Figure 1.3.3.1, or a torqued splice with turnbuckle, see Figure 1.3.4.1.

1.3.2 End bearing splice

Assembly of a contact coupler and two thread bars, see Figure 1.3.2.1, to accomplish a joint of the two thread bars to transfer compression loads. The compression loads are transferred directly from thread bar to thread bar via contact of the thread bars end faces.

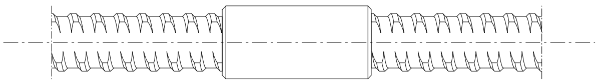

Figure 1.3.2.1 End bearing splice – Contact coupler and two thread bars – Schematic examples

1.3.3 Torqued splice

Assembly of a coupler and two thread bars, locked with nuts, see Figure 1.3.3.1, to accomplish a joint of the thread bars to transfer tension, compression, and alternating loads with limited slip.

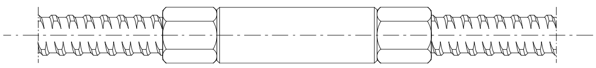

Figure 1.3.3.1 Torqued splice – Coupler, two nuts, and two thread bars – Schematic examples

1.3.4 Torqued splice with turnbuckle

Assembly of a turnbuckle (special sleeve) and two thread bars, locked with nuts, see Figure 1.3.4.1, to accomplish a joint of the thread bars with ends in a given co-axial distance to transfer tension, compression, and alternating loads with limited slip.

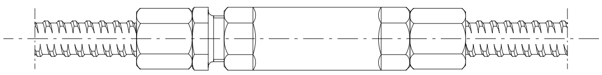

Figure 1.3.4.1 Torqued splice with turnbuckle – Turnbuckle, two nuts, and two thread bars – Schematic examples

1.3.5 Torqued anchorage

Assembly of a torqued anchor piece and a thread bar, locked with one nut, see Figure 1.1.1.1, to transfer tension, compression, and alternating loads with limited slip.

Torqued anchorage is installed with an additional bonded length.

1.3.6 End bearing anchorage

Assembly of thread bar and steel plate to transfer compression loads. The compression loads are transferred directly from the thread bar end face to the steel plate.

1.3.7 Contact coupler

Steel sleeve (coupler) with internal thread and without nuts, see Figure 1.3.2.1. It is used in end bearing splices to hold the ends of the thread bars in concentric contact. Compression loads are transferred directly from one thread bar end face to the other end face.

1.3.8 Coupler

Steel sleeve (coupler) with internal thread, see Figure 1.3.3.1. It is used to transfer tensile, compression, or alternating loads with reduced slip in torqued splices, locked with nuts.

1.3.9 Reducing coupler

Steel sleeve (coupler) with internal threads. The internal threads are for two different nominal diameters at the two ends.

A reducing coupler can be a contact coupler or a coupler for torqued splice.

1.3.10 Turnbuckle

Steel sleeve (turnbuckle) in two pieces, see Figure 1.3.4.1, to allow for length compensation where two rigidly placed thread bars with ends in a given co-axial distance are to be jointed in a torqued splice with turnbuckle. The two ends of the turnbuckle may be provided for either the same nominal diameter or for two different nominal diameters of the thread bars.

It is used to transfer tensile, compression, or alternating loads with reduced slip in torqued splice with turnbuckle, locked with nuts.

1.3.11 Anchor piece

Steel part (anchor piece) with internal thread, see Figure 1.1.1.1. It is used for torqued anchorage with an additional bonded length to transfer tensile, compression, or alternating loads with limited slip. In torqued anchorage the anchor piece is locked with one nut.

1.3.12 Additional bonded length

The torqued anchor piece is installed with an additional bonded length extending along the thread bar adjacent to the torqued anchor piece, see Figure 2.2.1.2.1. Thereby, the load of the thread bar reduces along the additional bonded length and the torqued anchor piece only transfers a remaining part of that load.

NOTE The additional bonded length is considered in the design of the structure.

1.3.13 MPII

MPII are the Manufacturer’s Product Installation Instructions.

1.3.14 Symbols

1.3.14.1 Resistance to static load

$R_{e,\,nom}$ .... MPa .... Nominal yield strength of thread bar

$F_{u,\,s}$ .... N .... Maximum force in tensile test

$F_{e,\,nom}$ .... N .... Nominal force at yield of thread bar, $F_{e,\,nom} = S_n \cdot R_{e,\,nom}$

$F_{m,\,nom}$ .... N .... Nominal maximum force of thread bar, $F_{m,\,nom} = S_n \cdot R_{m,\,nom}$

S_n .... mm^2 .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

$R_{m,\,nom}$ .... MPa .... Nominal tensile strength of thread bar

r_t .... — .... Ratio for maximum force

a, b .... mm .... Side lengths of test specimen

h .... mm .... Height of specimen

c .... mm .... Concrete cover of reinforcement

1.3.14.2 Slip

$R_{e,\,nom}$ .... MPa .... Nominal yield strength of thread bar

S_n .... mm^2 .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

ΔL_s .... mm...................... Slip of splice according to ISO 15835-2
$s_{O,1}$ .... mm...................... Slip of Option 1
$s_{O,2}$ .... mm...................... Slip of Option 2
s_1............... mm...................... Value according to Figure 1.1.1.3
$r_{O,1}$, $r_{O,2}$ ....—....................... Ratios for Option 1 and Option 2

1.3.14.3 Resistance to fatigue

σ_{max} ....MPa..................... Upper stress level in fatigue test
$R_{e,nom}$ ....MPa..................... Nominal yield strength of the thread bar
S_n ....mm²..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1
$2 \cdot \sigma_a$ ....MPa..................... Stress range in fatigue test, i.e., two times the stress amplitude.

1.3.14.4 Low-cycle fatigue

$R_{eH,spec}$.......MPa..................... Test parameter in ISO 15835-2
$R_{e,nom}$ ....MPa..................... Nominal yield strength of thread bar
A_s ....mm²..................... Test parameter in ISO 15835-2
S_n ....mm²..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1
u_{20} .... mm...................... Residual elongation after first 20 cycles
$F_{u,lcf}$............. N .... Maximum force in low-cycle loading test
$F_{m,nom}$.......... N .... Nominal maximum force of thread bar, $F_{m,nom} = S_n \cdot R_{m,nom}$
$R_{m,nom}$ ....MPa..................... Nominal tensile strength of thread bar

1.3.14.5 Load transfer to the structure

F_u .... kN .... Maximum force in load transfer test
$F_{m,nom}$.......... kN .... Nominal maximum force of thread bar, $F_{m,nom} = R_{m,nom} \cdot S_n / 1\,000$
$f_{cm,e}$ ....MPa..................... Concrete compressive strength at time of end of load transfer test
$f_{cm,0}$ ....MPa..................... Nominal concrete compressive strength for load transfer test
$R_{m,nom}$ ....MPa ....Nominal tensile strength of thread bar
R_m...............MPa ....Actual tensile strength of thread bar
S_n ....mm²..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

1.3.14.6 Mass per metre

S_n ....mm²..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1
m_n ....kg/m..................... Nominal mass per metre of thread bar
m................kg/m..................... Actual mass per metre of thread bar
ρ................kg/m³.................... Density, 7 850 kg/m³, for hot rolled thread bar

1.3.14.7 Weldability

a................ mm...................... Throat thickness
b................ mm...................... Length of bar protrusion
t................. mm...................... Steel plate thickness
$\varnothing_{nom}$ .... mm...................... Nominal diameter of thread bar
$F_{u,w}$ .... N .... Maximum force in tensile test on set-through bar transverse end plate joint
$F_{m,act}$ .... N .... Actual maximum force of thread bar
$F_{m,nom}$........... N .... Nominal maximum force of thread bar, $F_{m,nom} = S_n \cdot R_{m,nom}$

S_n .... mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1
$R_{m, nom}$ .... MPa .... Nominal tensile strength of thread bar
r_1, r_2 .... — .... Ratios

1.3.14.8 Strength characteristics of thread bar

S_n .... mm² .... Nominal cross-sectional area of thread bar
$\varnothing_{nom}$ .... mm .... Nominal diameter
R_m/R_e .... — .... Ratio tensile strength to yield strength
A_{gt} .... % .... Elongation at maximum force in tensile test
E .... MPa .... Modulus of elasticity
$(R_m/R_e)_k$ .... — .... Characteristic value of the ratio tensile strength to yield strength
R_e .... MPa .... Yield strength in tensile test
$R_{e, k}$ .... MPa .... Characteristic value of yield strength
$R_{e, nom}$ .... MPa .... Nominal yield strength
R_m .... MPa .... Tensile strength in tensile test
$R_{m, k}$ .... MPa .... Characteristic value of tensile strength
$R_{m, nom}$ .... MPa .... Nominal tensile strength
r_{Rm}, r_{Re} .... — .... Ratios
S_n .... mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

1.3.14.9 Compression

$\varnothing_{nom}$ .... mm .... Nominal diameter

1.3.14.10 Modulus of elasticity

E .... MPa .... Modulus of elasticity
$R_{m, nom}$ .... MPa .... Nominal tensile strength
ε_{50} .... % .... Extension at 0.50 · $R_{m, nom}$ in force-extension diagram
ε_{20} .... % .... Extension at 0.20 · $R_{m, nom}$ in force-extension diagram
S_n .... mm² .... Nominal cross-sectional area of thread bar, see Clause 2.2.9.1

1.3.14.11 Elongation at maximum force

$A_{gt, k}$ .... % .... Characteristic value of elongation at maximum force

1.3.14.12 Bond characteristics

$F_{mean, d}$ .... N .... Mean value of all F_{mean} of a nominal diameter, $\varnothing_{nom}$ = d
$F_{0.01}$ .... N .... Force in pull-out test at a slip of 0.01 mm
$F_{0.1}$ .... N .... Force in pull-out test at a slip of 0.1 mm
F_1 .... N .... Force in pull-out test at a slip of 1 mm
τ_{dk} .... MPa .... Characteristic bond strength for diameter, $\varnothing_{nom}$ = d
$\varnothing_{nom}$ .... mm .... Nominal diameter of thread bar
l .... mm .... Length of bonded section in pull-out test
$f_{cm, 0}$ .... MPa .... Nominal compressive strength of concrete
$f_{cm, e}$ .... MPa .... Actual mean compressive strength of concrete at end of test

1.3.14.13 Determination of nominal values

d_{act} .... mm .... Actual diameter of specimen

m_{act}............kg/m.................... Actual mass per metre of specimen

ρ................kg/m³.................... Density, 7 850 kg/m³, for hot rolled thread bar

$\varnothing_{nom}$ .... mm...................... Nominal diameter of the group

S_n ....mm²..................... Nominal cross-sectional area of the group

$R_{e, act}$ ....MPa..................... Actual yield strength of specimen

$R_{e, mean}$........MPa..................... Arithmetic mean of actual yield strengths of all specimens of the group

$R_{e, nom}$.........MPa..................... Nominal yield strength of the group

$R_{m, act}$.........MPa..................... Actual tensile strength of specimen

$R_{m, mean}$.......MPa..................... Arithmetic mean of actual tensile strengths of all specimens of the group

$R_{m, nom}$ ....MPa..................... Nominal tensile strength of the group

S_n ....mm²..................... Nominal cross-sectional area of specimen

1.3.14.14 Load transfer to the structure test

a, b .... mm...................... Side lengths of test specimen

x, y .... mm...................... Minimum specified centre spacing in x- and y-direction

A_c ....mm²..................... Gross cross-sectional concrete area of specimen

e_x, e_y .... mm...................... Edge distance in x- and y-direction respectively

c................ mm...................... Concrete cover of reinforcement

h................ mm...................... Height of specimen

F .... N .... Force in load transfer test

F_u .... N .... Maximum force in load transfer test

$F_{m, nom}$........... N .... Nominal maximum force of thread bar, $F_{m, nom} = R_{m, nom} \cdot S_n$

$R_{m, nom}$ ....MPa..................... Nominal tensile strength of thread bar

S_n ....mm²..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

$f_{cm, e}$ ....MPa..................... Concrete compressive strength at time of end of load transfer test

$f_{cm, 0}$ ....MPa..................... Nominal concrete compressive strength for load transfer test

m.................—....................... Number of load cycles

n..................—....................... Number of load points for measurements

w .... mm...................... Crack width

w_{max}........... mm...................... Maximum crack width

ε_5, ε_7, ε_9, ε_{n-8}, ε_{n-6}, ε_{n-4}, ε_{n-2}, ε_n .... mm/m.................... Strain, measured at specific load points.

w_5
w_7
w_9
w_{n-8}
w_{n-6}
w_{n-4}
w_{n-2}
w_n
} .... mm...................... Crack width, measured at specific load points.

ε .... mm/m.................... Strain

ε_t .... mm/m.................... Strain, measured perpendicular to loading direction – transversal strain

ε_v .... mm/m.................... Strain, measured parallel to loading direction – longitudinal strain

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 Kit with high strength reinforcing steel is assessed in relation to the essential characteristics. In Table B.1 the essential characteristics relevant for the categories of intended use of Table 1.2.1.1 are listed.

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

№	Essential characteristic	Assessment method	Type of expression of product performance
Basic requirement for construction works 1: Mechanical resistance and stability			
1	Resistance to static load	2.2.1	Level
2	Slip	2.2.2	Level
3	Resistance to fatigue	2.2.3	Level
4	Low-cycle fatigue	2.2.4	Level and description
5	Load transfer to the structure	2.2.5	Level and description
6	Reinforcement corrosion protection and detailing	2.2.6	Level and description
7	Mass per metre	2.2.7	Level
8	Weldability	2.2.8	Level
9	Strength characteristics of thread bar	2.2.9	Level
10	Compression	2.2.10	Description
11	Modulus of elasticity	2.2.11	Level
12	Elongation at maximum force	2.2.12	Level
13	Bendability	2.2.13	Description
14	Bond characteristics	2.2.14	Level and description
Basic requirement for construction works 2: Safety in case of fire			
15	Reaction to fire	2.2.15	Class

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

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

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

The assessment of the Kit with high strength reinforcing steel shall be carried out by means of the assessment of anchorages, splices, and thread bars that are representative for the performance of the Kit with high strength reinforcing steel.

2.2.1 Resistance to static load

2.2.1.1 Torqued splice

Resistance to static load including measurement of displacement of the torqued splice, torqued splice with reducing coupler, and torqued splice with turnbuckle shall be tested in tensile test following ISO 15835-1, clause 4, and ISO 15835-2, clauses 5.2 and 5.3, and clause 5.4 for displacement measurement. The following parameters and procedures apply in relation to ISO 15835-2, clauses 5.3 and 5.4:

- Test equipment shall be according to EN ISO 15630-1, clause 5.2.
- Tensile test shall be performed at room temperature.
- EN ISO 6892-1, clauses 10.1 and 10.2 apply.
- Force-displacement-plots shall be recorded throughout the test.
- The specimen, see Figure 2.2.2.2.1, shall be loaded in three load cycles according to Figure 2.2.2.2.2, between $0.02 \cdot R_{e,\,nom}$ and $0.65 \cdot R_{e,\,nom}$. Stresses shall be calculated with the nominal cross-sectional area of the thread bar, S_n.
- Testing rate for load cycles shall be according to EN ISO 6892-1, clauses 10.3.3.1, 10.3.3.2.4, and 10.3.3.2.5 whereby the crosshead separation rate applies.
- After the third load cycle the extensometer may be removed and loading shall be continued until failure of the specimen.
- Testing rate shall be according to EN ISO 6892-1, clause 10.3.3.3, whereby the crosshead separation rate applies.
- Maximum force, $F_{u,\,s}$, and location and mode of failure shall be determined.

NOTE Determination of A_{gt} according to ISO 15835-2 is not required.

With maximum force of the test, $F_{u,\,s}$, a ratio shall be calculated:

- Ratio according to Equation 2.2.1.1.1 for failure in free length of thread bar
- Ratio according to Equation 2.2.1.1.2 for failure of coupler, pull-out of thread bar, or other failure within the splice.

$$r_t = \frac{F_{u,\,s}}{F_{m,\,nom}}$$ Equation 2.2.1.1.1

$$r_t = \frac{F_{u,\,s}}{1.30 \cdot F_{e,\,nom}}$$ Equation 2.2.1.1.2

Record measurements and observations in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

$R_{e, nom}$ .... MPa .... Nominal yield strength of thread bar

$F_{u, s}$ .... N .... Maximum force in tensile test

$F_{e, nom}$ .... N .... Nominal force at yield of thread bar, $F_{e, nom} = S_n \cdot R_{e, nom}$

$F_{m, nom}$ .... N .... Nominal maximum force of thread bar, $F_{m, nom} = S_n \cdot R_{m, nom}$

S_n .... mm^2 .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

$R_{m, nom}$ .... MPa .... Nominal tensile strength of thread bar

r_t .... — .... Ratio for maximum force

Minimum value of ratio r_t shall be given in the ETA.

2.2.1.2 Torqued anchorage with torqued anchor piece

Resistance to static load, including measurement of displacement of torqued anchorage with torqued anchor piece, shall be tested in tensile test according to Clause 2.2.1.1. The following steps shall be taken:

- Testing of torqued anchor piece according to Figure 2.2.1.2.2.
- Ratio r_t according to Equation 2.2.1.1.1 or Equation 2.2.1.1.2 for failures according to Clause 2.2.1.1 shall be calculated.

Record measurements and observations in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

r_t .... — .... Ratio for maximum force

Minimum value of ratio r_t shall be given in the ETA.

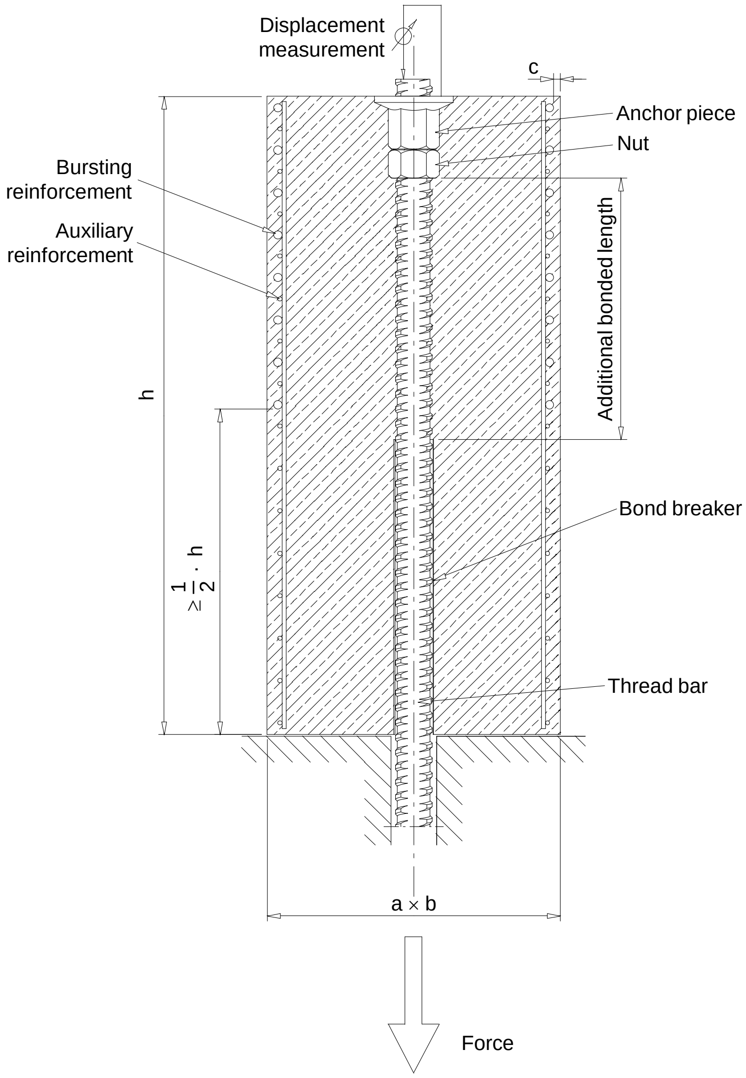

Figure 2.2.1.2.1 Torqued anchorage with torqued anchor piece – Load transfer test – Schematic examples

Where

a, b .... mm...................... Side lengths of test specimen

h................. mm...................... Height of specimen

c................. mm...................... Concrete cover of reinforcement

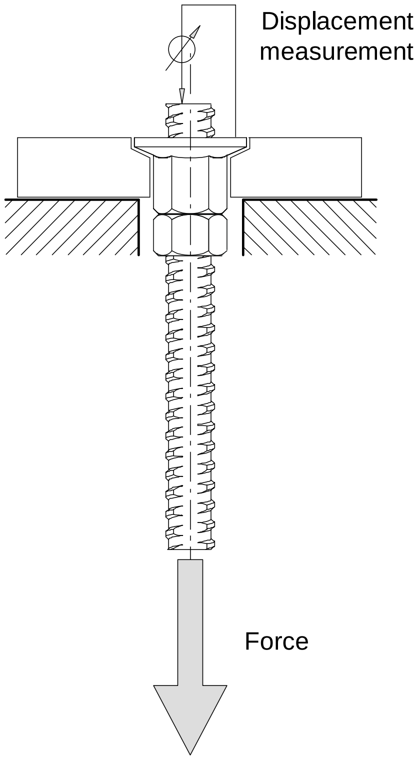

Figure 2.2.1.2.2 Torqued anchorage with torqued anchor piece – Measurement of displacement – Schematic

2.2.2 Slip

2.2.2.1 End bearing splice

Slip of end bearing splice shall be tested according to Clause 2.2.1.1, but in a compression test with the following deviations:

- For compression test, the end faces of the specimen shall be machined to flat and parallel load transfer planes, perpendicular to the thread bar axis.
- Length of specimen shall be length of contact coupler plus ≥ 50 mm protruding thread bar on both ends of the contact coupler.
- Testing shall be performed with a compression testing machine according to EN 12390-4. Hardened load transfer steel platens shall be inserted between testing machine and specimen.
- Force-displacement-plots shall be recorded throughout the test.
- The specimen shall be loaded in three load cycles according to Figure 2.2.2.2.2, between $0.02 \cdot R_{e,\,nom}$ and $0.65 \cdot R_{e,\,nom}$. Stresses shall be calculated with the nominal cross-sectional area of the thread bar, S_n.
- Compressive loading by the testing machine shall be continued after the third load cycle up to ≥ 5 ‰ strain in compression.
- Testing rate throughout the compression test shall be according to EN ISO 6892-1, clauses 10.3.3.1, 10.3.3.2.4, and 10.3.3.2.5 whereby the crosshead separation rate applies.
- Where buckling of the specimen occurs, the test shall be considered as invalid.

Slip according to Option 1 and Option 2 according to ISO 15835-1, clause 5.4.1, and ISO 15835-2, clauses 5.4.4 and 5.4.5, shall be determined with the force-displacement-plots at $0.65 \cdot R_{e,\,nom}$ of the third load cycle and at $0.02 \cdot R_{e,\,nom}$ after the third load cycle, see Figure 2.2.2.2.2.

With slip according to Option 1, see Equation 2.2.2.1.1, Option 2, see Equation 2.2.2.1.2, and with s_1 according to Figure 1.1.1.3, ratios according to Equation 2.2.2.1.3 and Equation 2.2.2.1.4 shall be calculated. As length in Figure 1.1.1.3, the length of the coupler of the end bearing splice shall be taken.

$s_{O,1} = \Delta L_s$ Equation 2.2.2.1.1

For Option 1, ΔL_s according to ISO 15835-2, clause 5.4.4 shall be taken

$s_{O,1} = \Delta L_s$ Equation 2.2.2.1.2

For Option 2, ΔL_s according to ISO 15835-2, clause 5.4.5 shall be taken

$r_{O,1} = \frac{s_{O,1}}{s_1}$ Equation 2.2.2.1.3

$r_{O,2} = \frac{s_{O,2}}{s_1}$ Equation 2.2.2.1.4

Record measurements and observations in accordance with Annex E.

The test results shall be also adopted for end bearing anchorage with steel plate.

Number of tests and test configurations shall be performed according to Annex D.

Where

$R_{e,nom}$ .... MPa .... Nominal yield strength of thread bar

S_n .... mm^2 .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

ΔL_s .... mm .... Slip of splice according to ISO 15835-2

$s_{O,1}$ .... mm .... Slip of Option 1

$s_{O,2}$ .... mm .... Slip of Option 2

s_1 .... mm .... Value according to Figure 1.1.1.3

$r_{O,1}$, $r_{O,2}$ .... — .... Ratios for Option 1 and Option 2

- Maximum value of ratio $r_{O.1}$ and
- Maximum value of ratio $r_{O.2}$

shall be given in the ETA.

2.2.2.2 Torqued splice

Measurement of displacement of the torqued splice, torqued splice with reducing coupler, and torqued splice with turnbuckle shall be tested according to Clause 2.2.1.1 in tensile test. Resistance to static load and measurement of displacement of the splice can be tested in one common test.

Slip of Option 1 and Option 2 according to ISO 15835-1, clause 5.4.1, and ISO 15835-2, clauses 5.4.4 and 5.4.5, shall be determined with the force-displacement-plots, see Clause 2.2.1.1, at $0.65 \cdot R_{e,nom}$ of the third load cycle and at $0.02 \cdot R_{e,nom}$ after the third load cycle, see Figure 2.2.2.2.2, see also Clause 2.2.2.1. Stresses shall be calculated with the nominal cross-sectional area of the thread bar, S_n.

With slip of Option 1, Option 2, and with s_1 according to Figure 1.1.1.3, ratios according to Equation 2.2.2.2.1 and Equation 2.2.2.2.2 shall be calculated. As length in Figure 1.1.1.3, the length of coupler or turnbuckle plus length of both nuts of the splice shall be taken.

$r_{O,1} = \frac{s_{O,1}}{s_1}$ Equation 2.2.2.2.1

$r_{O,2} = \frac{s_{O,2}}{s_1}$ Equation 2.2.2.2.2

Record measurements and observations in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

$R_{e, nom}$ .... MPa .... Nominal yield strength of thread bar

S_n .... mm^2 .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

$s_{O, 1}$ .... mm .... Slip of Option 1

$s_{O, 2}$ .... mm .... Slip of Option 2

s_1 .... mm .... Value according to Figure 1.1.1.3

$r_{O, 1}$, $r_{O, 2}$ .... — .... Ratios for Option 1 and Option 2

– Maximum value of ratio $r_{O, 1}$ and
– Maximum value of ratio $r_{O, 2}$

shall be given in the ETA.

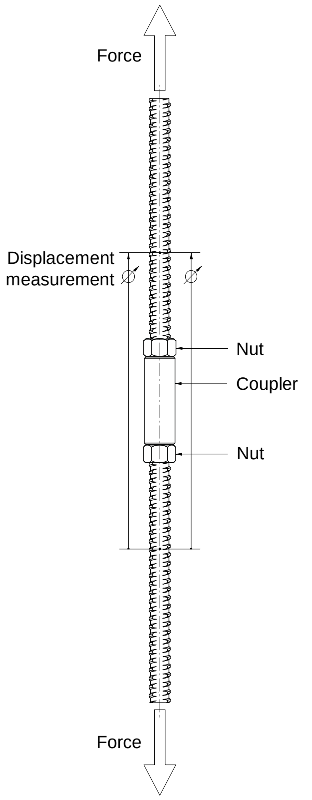

Figure 2.2.2.2.1 Torqued splice – Measurement of displacement – Schematic

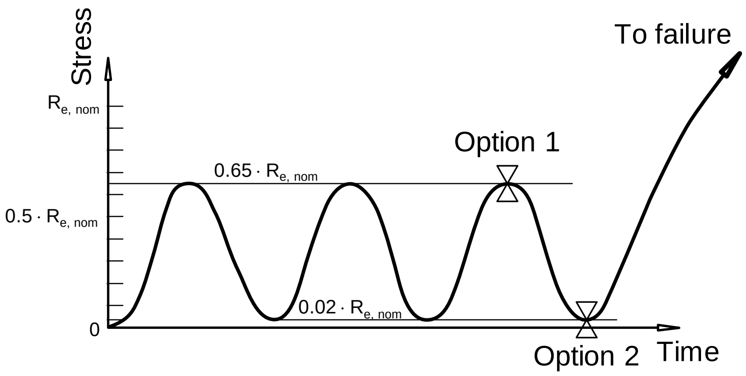

Figure 2.2.2.2.2 Slip measurement, 3 load cycles, Option 1, and Option 2

2.2.2.3 Torqued anchorage with torqued anchor piece

Measurement of displacement of the torqued anchor piece shall be tested according to Clause 2.2.1.2 in tensile test. Resistance to static load and measurement of displacement of torqued anchor piece can be tested in one common test.

Slip of Option 1 and Option 2 including calculation of ratios $r_{O, 1}$ and $r_{O, 2}$ shall be determined according to Clause 2.2.2.2. As length in Figure 1.1.1.3, the length of anchor piece plus length of nut shall be taken.

For torqued anchor piece, installed with an additional bonded length, the load of the thread bar reduces along the additional bonded length and the torqued anchor piece only transfers a remaining part of that load. To consider the effect of bond a mechanical model is employed. The mechanical model comprises a beam representing the thread bar, a beam representing the concrete with an additional bonded length as installed on site, springs representing bond in the additional bonded length and a spring representing the torqued anchor piece, see Figure 2.2.2.3.1. Slip is the displacement of the spring representing the torqued anchor piece.

The parameters of the mechanical model are obtained from:

– Clause 2.2.9.1 and Clause 2.2.11 with regard to thread bar
– Clause 2.2.5 and Clause C.1 with regard to concrete
– Results of pull-out tests, Clause 2.2.14.2, with regard to bond
– Static load tests according to Figure 2.2.1.2.2 with regard to torqued anchor piece
– Additional bonded length is taken from the MPII.

Load transfer test, see Figure 2.2.1.2.1 and Clause 2.2.5, shall be employed to calibrate the mechanical model. Calibration is performed by comparison of displacement measured in load transfer test and displacement calculated with the mechanical model.

The mechanical model shall be loaded to $0.65 \cdot R_{e,\,nom}$ and force in spring and displacement of spring representing the torqued anchor piece shall be calculated using a simple finite element program that can be select from all available calculation programs capable of modelling bars and springs. Stresses shall be calculated with the nominal cross-sectional area of the thread bar, S_n. The calculated displacement and force shall be used to determine slip of Option 1 and Option 2 and calculate ratios $r_{O,\,1}$ and $r_{O,\,2}$ with Equation 2.2.2.1.3 and Equation 2.2.2.1.4.

Record measurements and observations of testing, and description, parameters, and result of the mechanical model in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

$r_{O,\,1}$, $r_{O,\,2}$ ....—....................... Ratios for Option 1 and Option 2
$R_{e,\,nom}$ ....MPa..................... Nominal yield strength of thread bar
S_n ....mm^2..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

For anchorage with torqued anchor piece without bonded length:

– Maximum value of ratio $r_{O,\,1}$ from tensile test,
– Maximum value of ratio $r_{O,\,2}$ from tensile test,

shall be given in the ETA.

For anchorage with torqued anchor piece with additional bonded length:

– Maximum value of ratio $r_{O,\,1}$ from mechanical model,
– Maximum value of ratio $r_{O,\,2}$ from mechanical model,

shall be given in the ETA.

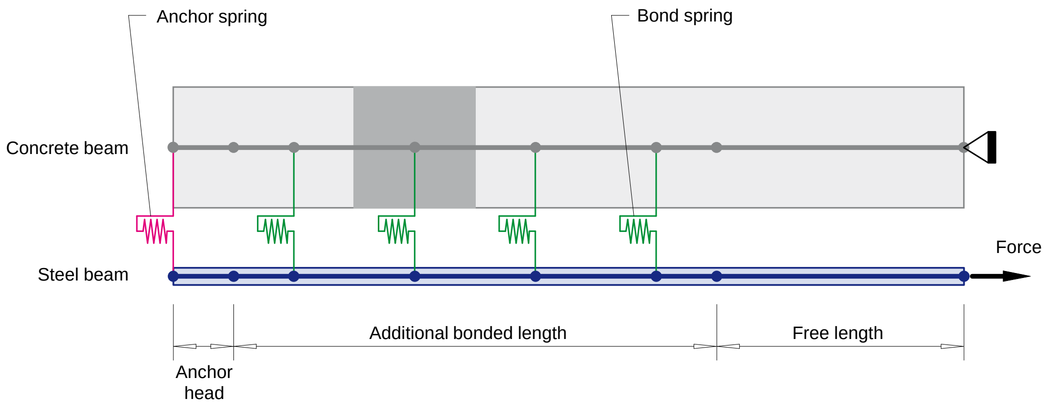

Figure 2.2.2.3.1 Torqued anchorage with torqued anchor piece – Model for slip calculation

2.2.3 Resistance to fatigue

The assessment of resistance to fatigue shall be carried out by means of assessment of resistance to fatigue of anchorage, splice, and thread bar that are representative of this essential characteristic for the Kit with high strength reinforcing steel.

2.2.3.1 Resistance to fatigue of anchorage and splice

Resistance to fatigue of anchorage and splice shall be tested in tension following ISO 15835-1, clause 4 and ISO 15835-2, clauses 5.2 and 5.5.1. Anchorage and splice shall be subjected to a fatigue test according to ISO 15835-2, clause 5.5.1. The following parameters apply in relation to ISO 15835-2, clause 5.5.1:

- Upper stress level $\sigma_{max} = 0.65 \cdot R_{e, nom}$
- Stress range $2 \cdot \sigma_a$
- Continue the fatigue test until failure of the specimen. The fatigue test shall be terminated once $2 \cdot 10^6$ load cycles have been attained.

Stresses shall be calculated with the nominal cross-sectional area of the thread bar, S_n. The stress range is taken from the MPII.

Record measurements and observations in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

σ_{max} ....MPa..................... Upper stress level in fatigue test

$R_{e, nom}$ ....MPa..................... Nominal yield strength of the thread bar

S_n ....mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

$2 \cdot \sigma_a$ ....MPa..................... Stress range in fatigue test, i.e., two times the stress amplitude.

- Stress range, $2 \cdot \sigma_a$ and
- Number of load cycles attained

shall be given in the ETA.

2.2.3.2 Resistance to fatigue of thread bar

Specimens of thread bar shall be tested according to EN 10080, clause 7.2.5. The thread bar shall be subjected to a fatigue test according to EN ISO 15630-1, clause 8. The following parameters apply in relation to EN ISO 15630-1, clause 8:

- Upper stress level $\sigma_{max} = 0.7 \cdot R_{e, nom}$
- Stress range $2 \cdot \sigma_a$
- The fatigue test shall be continued until failure of the thread bar. The fatigue test shall be terminated once $2 \cdot 10^6$ load cycles have been attained.

Stresses shall be calculated with the nominal cross-sectional area of the thread bar, S_n. The stress range is taken from the MPII.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

σ_{max} ....MPa..................... Upper stress level in fatigue test

$R_{e, nom}$ ....MPa..................... Nominal yield strength of the thread bar

$2 \cdot \sigma_a$ ....MPa..................... Stress range in fatigue test, i.e., two times the stress amplitude

S_n ....mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

- Stress range, $2 \cdot \sigma_a$, and

– Number of load cycles attained

shall be given in the ETA.

2.2.4 Low-cycle fatigue

Resistance to low-cycle fatigue of anchorage and splice shall be tested according to ISO 15835-1, clauses 4 and 5.6, and ISO 15835-2, clauses 5.2 and 5.6. Anchorage and splice shall be subjected to a low-cycle loading test according to ISO 15835-2, clause 5.6. The following parameters apply in relation to ISO 15835-2, clause 5.6.

- $R_{eH, spec} = R_{e, nom}$
- $A_s = S_n$

In testing, the following items according to ISO 15835-1, clause 5.6, are relevant:

- Average residual elongation after first 20 cycles u_{20} applies but not the limit.
- Failure of splice can occur in stage 2 and 3.
- Maximum force applies but not the limit.

In case of failure in stage 2 or 3 in low-cycle loading test according to ISO 15835-2, clause 5.6, location and mode of failure shall be determined.

With maximum force of the test, $F_{u, lcf}$, the ratio by Equation 2.2.4.1 shall be calculated.

$$r_{t, lcf} = \frac{F_{u, lcf}}{F_{m, nom}} \qquad \text{Equation 2.2.4.1}$$

Record measurements and observations in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

$R_{eH, spec}$ .... MPa .... Test parameter in ISO 15835-2

$R_{e, nom}$ .... MPa .... Nominal yield strength of thread bar

A_s .... mm² .... Test parameter in ISO 15835-2

S_n .... mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

u_{20} .... mm .... Residual elongation after first 20 cycles

$F_{u, lcf}$ .... N .... Maximum force in low-cycle loading test

$F_{m, nom}$ .... N .... Nominal maximum force of thread bar, $F_{m, nom} = S_n \cdot R_{m, nom}$

$R_{m, nom}$ .... MPa .... Nominal tensile strength of thread bar

- Maximum residual elongation after the first 20 cycles, u_{20},
- Description of location and mode of failure or the conclusion no failure in stage 2 and 3, and
- Minimum Ratio $r_{t, lcf}$

shall be given in the ETA.

2.2.5 Load transfer to the structure

The torqued anchor piece including bursting reinforcement and an additional bonded length shall be subjected to a load transfer test according to Annex C. Due to the additional bonded length the test shall be performed in tension. The additional bonded length is taken from the MPII.

The maximum force F_u[3] measured in the load transfer test on a specimen with bursting reinforcement shall be at least as by Equation 2.2.5.1.

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[3] The required performance originates from EAD 160004-00-0301.

$$F_u \geq 1.1 \cdot F_{m,\,nom} \cdot \frac{f_{cm,\,e}}{f_{cm,\,0}}$$ Equation 2.2.5.1

Concrete strength at end of load transfer test shall be $f_{cm,\,e} \leq 0.8 \cdot f_{cm,\,0} + 3$. In case a thread bar with a strength of at least $R_m \cdot S_n \geq 1.1 \cdot F_{m,\,nom}$ is available, the test can be performed with concrete strength of $f_{cm,\,e} \leq f_{cm,\,0} + 3$.

Slip between thread bar and concrete should be measured.

Record measurements and observations in accordance with Annex E.

Number of tests and test configurations shall be performed according to Annex D.

Where

F_u .... kN .... Maximum force in load transfer test

$F_{m,\,nom}$.......... kN .... Nominal maximum force of thread bar, $F_{m,\,nom} = R_{m,\,nom} \cdot S_n / 1\,000$

$f_{cm,\,e}$ ....MPa..................... Concrete compressive strength at time of end of load transfer test

$f_{cm,\,0}$ ....MPa..................... Nominal concrete compressive strength for load transfer test

$R_{m,\,nom}$ ....MPa ....Nominal tensile strength of thread bar

R_m...............MPa ....Actual tensile strength of thread bar

S_n ....mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

– Description of bursting reinforcement and
– Nominal maximum force of thread bar, $F_{m,\,nom}$,

shall be given in the ETA.

2.2.6 Reinforcement corrosion protection and detailing

2.2.6.1 General

Corrosion protection of the Kit with high strength reinforcing steel is provided by concrete cover. Concrete cover and detailing aspects of Kit with high strength reinforcing steel are related to the dimensions of Clause 2.2.6.2 and Clause 2.2.6.3 that are representative essential characteristic for the Kit with high strength reinforcing steel.

2.2.6.2 Thread bar

Dimensions relevant for concrete cover are:

– Nominal diameter of thread bar
– Core diameter of thread bar, i.e., diameter of thread bar between ribs
– Height of ribs

The core diameter shall be measured with an instrument of a resolution of at least 0.1 mm. The core diameter shall be measured between the ribs, approximately in rib middle.

For measurement of height of ribs see Clause 2.2.14.1. The relevant height shall be height in approximately rib middle.

Mean of core diameters and mean of height of ribs shall be calculated.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

– Nominal diameter in mm,
– Mean core diameter of thread bar in mm, and
– Mean height of ribs in mm

shall be given in the ETA.

2.2.6.3 Nuts and couplers

Shape and external dimensions of nuts and couplers are relevant for concrete cover.

Shape of nut and coupler shall be determined by visual inspection by reference to workshop drawings.

External dimensions of nut and coupler shall be measured with a calliper of a resolution of at least 0.1 mm. Relevant external dimensions shall be identified on workshop drawings and measured.

Mean of external dimensions shall be calculated.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

- Shape of nuts and couplers in representations like outline drawings and
- Main external dimensions of nuts and couplers in mm

shall be given in the ETA.

2.2.7 Mass per metre

Nominal mass shall be calculated by Equation 2.2.7.1.

$$m_n = \frac{S_n \cdot \rho}{10^6} \qquad \text{Equation 2.2.7.1}$$

Actual mass per metre of thread bar shall be determined according to EN ISO 15630-1, clause 12.

Deviation of nominal mass in % shall be determined by Equation 2.2.7.2.

$$\left(\frac{m}{m_n} - 1\right) \cdot 100 \qquad \text{Equation 2.2.7.2}$$

Number of tests shall be performed according to Annex D.

Where

S_n .... mm^2 .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

m_n .... kg/m..................... Nominal mass per metre of thread bar

m................ kg/m..................... Actual mass per metre of thread bar

ρ .... kg/m^3 .... Density, 7 850 kg/m^3, for hot rolled thread bar

- Nominal mass per metre, m_n, and
- Range of deviations of nominal mass in %

shall be given in the ETA.

2.2.8 Weldability

Tests shall be performed on set-through bar transverse end plate joints according to EN ISO 17660-1, clause 6.6.2.2, see Figure 2.2.8.1. The specimens with set-through bar transverse end plate joints shall be manufactured according to welding procedures specified by the manufacturer.

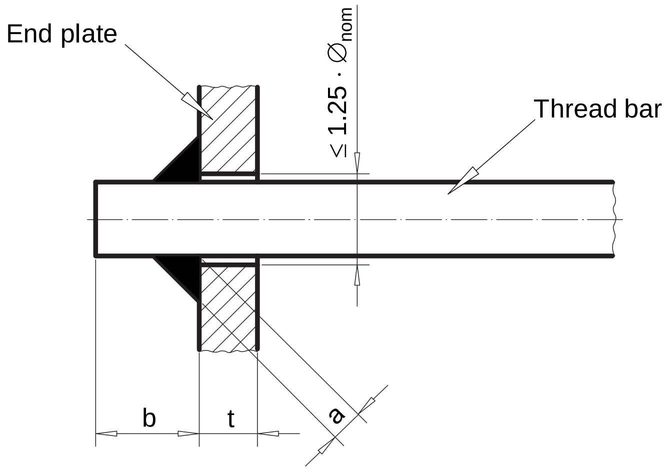


Figure 2.2.8.1 Set-through bar transverse end plate joint

$a = 0.4 \cdot \varnothing_{nom}$

$b \geq \varnothing_{nom}$

$t \geq 0.4 \cdot \varnothing_{nom}$

Tests on specimens with set-through bar transverse end plate joints shall be performed according to EN ISO 17660-1, clause 14.

Specimens of the thread bar shall be taken adjacent to the thread bar used for the set-through bar transverse end plate joints. Tensile tests on the specimens shall be performed according to EN ISO 15630-1, clause 5, see Clause 2.2.9.2. The mean value of the test results per nominal diameter yields the actual maximum force of the thread bar, $F_{m,\,act}$.

With maximum force of tensile tests on set-through bar transverse end plate joints, $F_{u,\,w}$, and on thread bars, ratios according to Equation 2.2.8.1 and Equation 2.2.8.2 shall be calculated.

$$r_1 = \frac{F_{u,\,w}}{F_{m,\,nom}} \qquad \text{Equation 2.2.8.1}$$

$$r_2 = \frac{F_{u,\,w}}{0.97 \cdot F_{m,\,act}} \qquad \text{Equation 2.2.8.2}$$

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

a	mm	Throat thickness
b	mm	Length of bar protrusion
t	mm	Steel plate thickness
$\varnothing_{nom}$	mm	Nominal diameter of thread bar
$F_{u,\,w}$	N	Maximum force in tensile test on set-through bar transverse end plate joint
$F_{m,\,act}$	N	Actual maximum force of thread bar
$F_{m,\,nom}$	N	Nominal maximum force of thread bar, $F_{m,\,nom} = S_n \cdot R_{m,\,nom}$
S_n	mm²	Nominal cross-sectional area of thread bar, Clause 2.2.9.1
$R_{m,\,nom}$	MPa	Nominal tensile strength of thread bar
r_1, r_2	—	Ratios

- Minimum value of ratio r_1 and
- Minimum value of ratio r_2

shall be given in the ETA.

2.2.9 Strength characteristics of thread bar

2.2.9.1 Cross-sectional area

Nominal cross-sectional area of thread bar shall be calculated with the nominal diameter by Equation 2.2.9.1.1.

$$S_n = \frac{\varnothing_{nom}^2 \cdot \pi}{4}$$ Equation 2.2.9.1.1

Where

S_n .... mm^2 .... Nominal cross-sectional area of thread bar

$\varnothing_{nom}$ .... mm...................... Nominal diameter

2.2.9.2 Strength characteristics

Strength characteristics shall be determined in tension. The stress values shall be calculated based on the nominal cross-sectional area, S_n. Relevant strength characteristics according to EN 10080, clause 7.2.3, are:

- Tensile strength, R_m
- Yield strength, R_e
- Ratio tensile strength to yield strength, R_m/R_e
- Elongation at maximum force, A_{gt}

Modulus of elasticity, E, shall be determined with the force-extension diagram of the tensile test.

The tensile test on specimen of thread bar shall be carried out in accordance with EN ISO 15630-1, clause 5. The following parameters and procedures apply in relation to EN ISO 15630-1:

- Specimen shall be according to EN ISO 15630-1, clause 4, without artificial ageing and according to EN ISO 15630-1, clause 5.1.
- Test equipment shall be according to EN ISO 15630-1, clause 5.2.
- Tensile test shall be performed at room temperature.
- EN ISO 6892-1, clauses 10.1 and 10.2 apply.
- Force-extension diagram shall be recorded.
- Testing rate shall be according to EN ISO 6892-1, clauses 10.3.3.1, 10.3.3.2.1, 10.3.3.2.4, 10.3.3.2.5, and 10.3.3.3, whereby the crosshead separation rate applies.
- Determination of R_e shall be according to EN ISO 6892-1, clauses 11 and 13, or EN ISO 15630-1, clause 5.3. These procedures are considered as equivalent. Reference procedure for proof strength is EN ISO 15630-1, clause 5.3, second method.
- Determination of R_m shall be with the maximum force in tensile test, considering EN ISO 15630-1, clause 5.3.
- Determination of A_{gt} shall be according to EN ISO 15630-1, clause 5.3, and EN ISO 6892-1, clause 3.4. Reference procedure is the manual method.
- From yield strength, R_e, and tensile strength, R_m, the ratio tensile strength to yield strength, R_m/R_e, shall be calculated according to Equation 2.2.9.2.1.

$$R_m/R_e = \frac{R_m}{R_e}$$ Equation 2.2.9.2.1

Characteristic values shall be calculated according to EN 10080, clause 8.5.2:

– Tensile strength with 5 % fractile as characteristic value, $R_{m,\,k}$.

– Yield strength with 5 % fractile as characteristic value, $R_{e,\,k}$.

– Ratio tensile strength to yield strength with 10 % fractile as characteristic value, $(R_m/R_e)_k$.

With characteristic values and nominal values of tensile strength and yield strength, ratios according to Equation 2.2.9.2.2 and Equation 2.2.9.2.3 shall be calculated.

$$r_{Rm} = \frac{R_{m,\,k}}{R_{m,\,nom}}$$ Equation 2.2.9.2.2

$$r_{Re} = \frac{R_{e,\,k}}{R_{e,\,nom}}$$ Equation 2.2.9.2.3

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

R_m/R_e .... — .... Ratio tensile strength to yield strength
A_{gt} .... % .... Elongation at maximum force in tensile test
E .... MPa .... Modulus of elasticity
$(R_m/R_e)_k$ .... — .... Characteristic value of the ratio tensile strength to yield strength
R_e .... MPa .... Yield strength in tensile test
$R_{e,\,k}$ .... MPa .... Characteristic value of yield strength
$R_{e,\,nom}$ .... MPa .... Nominal yield strength
R_m .... MPa .... Tensile strength in tensile test
$R_{m,\,k}$ .... MPa .... Characteristic value of tensile strength
$R_{m,\,nom}$ .... MPa .... Nominal tensile strength
r_{Rm}, r_{Re} .... — .... Ratios
S_n .... mm² .... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

– Nominal cross-sectional area, S_n

– Minimum ratio r_{Rm} and nominal tensile strength, $R_{m,\,nom}$,

– Minimum ratio r_{Re} and nominal yield strength, $R_{e,\,nom}$, and

– Characteristic ratio tensile strength to yield strength, $(R_m/R_e)_k$

shall be given in the ETA.

2.2.10 Compression

For compression test on thread bar, the specimen shall be according to EN ISO 15630-1, clause 4, without artificial ageing and with a length of five times the nominal diameter, $5 \cdot \varnothing_{nom}$. The end faces of the specimens shall be machined to flat and parallel load transfer planes, perpendicular to the thread bar axis.

Testing shall be performed with a compression testing machine according to EN 12390-4. Hardened load transfer steel platens shall be inserted between testing machine and specimen. Extensometers according to EN ISO 6892-1, clause 9, shall be placed on the specimen but gauge length shall be limited to ≤ 80 % of specimen length.

Compressive loading by the testing machine shall be performed following EN ISO 6892-1 up to ≥ 5 ‰ strain in compression. The following parameters and procedures apply in relation to EN ISO 6892-1:

– Compression test shall be performed at room temperature.

- Force-extension diagram shall be recorded.
- Testing rate shall be according to EN ISO 6892-1, clauses 10.3.3.1, 10.3.3.2.1, 10.3.3.2.4, and 10.3.3.2.5 whereby the crosshead separation rate apply.

To assess equivalence, stress-strain-plots in compression shall be compared with stress-strain-plots in tension. Criteria for assessment of equivalence are:

- Equivalent shape of stress-strain-plots in compression and tension
- Equivalent yield strength in compression and tension. Yield strength in compression shall be defined same as in tension according to EN 10080, clause 7.2.3, determined with the reference procedure according to EN ISO 15630-1, clause 5.3, second method.
- Equivalence shall be given once the difference is not more than 10 % of the respective feature.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

$\varnothing_{nom}$ .... mm...................... Nominal diameter

Description whether or not tension and compression are equivalent shall be given in the ETA.

2.2.11 Modulus of elasticity

Modulus of elasticity shall be determined with the force-extension diagram according to Clause 2.2.9. Modulus of elasticity and strength characteristics can be tested in one common test.

The modulus of elasticity shall be calculated as secant modulus in the force-extension diagram between $0.20 \cdot R_{m,\,nom} \cdot S_n$ and $0.50 \cdot R_{m,\,nom} \cdot S_n$ by Equation 2.2.11.1.

$$E = \frac{0.50 \cdot R_{m,\,nom} - 0.20 \cdot R_{m,\,nom}}{\varepsilon_{50} - \varepsilon_{20}} \cdot 100 \qquad \text{Equation 2.2.11.1}$$

The mean value shall be calculated for modulus of elasticity.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

E ....MPa..................... Modulus of elasticity

$R_{m,\,nom}$ ....MPa..................... Nominal tensile strength

ε_{50} ....%....................... Extension at $0.50 \cdot R_{m,\,nom}$ in force-extension diagram

ε_{20} ....%....................... Extension at $0.20 \cdot R_{m,\,nom}$ in force-extension diagram

S_n ....mm²..................... Nominal cross-sectional area of thread bar, see Clause 2.2.9.1

Arithmetic mean of modulus of elasticity, E, shall be given in the ETA.

2.2.12 Elongation at maximum force

Elongation at maximum force shall be determined according to Clause 2.2.9. Elongation at maximum force and strength characteristics can be tested in one common test.

Characteristic values of elongation at maximum force shall be calculated according to EN 10080, clause 8.5.2:

- Elongation at maximum force with 10 % fractile as characteristic value, $A_{gt,\,k}$.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

$A_{gt,\,k}$ .... % .... Characteristic value of elongation at maximum force

Characteristic elongation at maximum force, $A_{gt,\,k}$, shall be given in the ETA.

2.2.13 Bendability

Specimens of thread bar shall be tested according to EN 10080:

- For nominal diameter $Ø_{nom} < 22$ mm bend test according to EN 10080, clause 7.2.6.2 and re-bend test according to EN 10080, clause 7.2.6.3 shall be performed
- For nominal diameter 22 mm $\leq Ø_{nom} \leq$ 57.5 mm bend test according to EN 10080, clause 7.2.6.2 shall be performed.
- After bending in bend test and
- After bending to and fro in re-bend test,

  inspect the specimen visually for fracture and cracks and record the findings.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Description of fracture or signs of cracks, or the conclusion no fracture and no cracks are present shall be given in the ETA.

2.2.14 Bond characteristics

2.2.14.1 Surface geometry

Properties subject to testing shall be taken from EN 10080, clause 7.4.2. Measurement of surface geometry dimensions as well as determination of relative rib area shall be carried out in accordance with EN ISO 15630-1, clauses 10 and 11.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

- Description of surface geometry in representations like outline drawings,
- Dimensions of surface geometry in mm, and
- Relative rib area

shall be given in the ETA.

2.2.14.2 Bond strength

Specimens with thread bar shall be subjected to pull-out test following EN 10080, Annex D, to determine the bond behaviour. Testing shall be carried out using three concrete grades, C25/30, C60/75, and C80/95. External dimensions of the concrete part of the specimen may be larger than $10 \cdot \varnothing_{nom}$.

The characteristics as defined in EN 10080, Annex D, shall be determined.

The bond strength shall be evaluated from the results of the pull-out tests by Equation 2.2.14.2.1 and Equation 2.2.14.2.2.

$$F_{mean} = \frac{F_{0.01} + F_{0.1} + F_1}{3} \qquad \text{Equation 2.2.14.2.1}$$

$$\tau_{dk} = \frac{F_{mean,\,d}}{d \cdot \pi \cdot l} \cdot \frac{\sqrt[3]{f^2_{cm,\,0}}}{\sqrt[3]{f^2_{cm,\,e}}} \cdot 0.7 \qquad \text{Equation 2.2.14.2.2}$$

NOTE The coefficient 0.7 is applied in the absence of a more in-depth statistical evaluation.

Characteristic bond strength for nominal diameters not tested may be interpolated.

Record measurements and observations in accordance with Annex E.

Number of tests shall be performed according to Annex D.

Where

- $F_{mean, d}$ .... N .... Mean value of all F_{mean} of a nominal diameter, $\varnothing_{nom}$ = d
- $F_{0.01}$ .... N .... Force in pull-out test at a slip of 0.01 mm
- $F_{0.1}$ .... N .... Force in pull-out test at a slip of 0.1 mm
- F_1 .... N .... Force in pull-out test at a slip of 1 mm
- τ_{dk} ....MPa..................... Characteristic bond strength for diameter, $\varnothing_{nom}$ = d
- $\varnothing_{nom}$ .... mm...................... Nominal diameter of thread bar
- l.................. mm...................... Length of bonded section in pull-out test
- $f_{cm, 0}$ ....MPa..................... Nominal compressive strength of concrete
- $f_{cm, e}$ ....MPa..................... Actual mean compressive strength of concrete at end of test

Characteristic bond strength, τ_{dk}, shall be given in the ETA.

2.2.15 Reaction to fire

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

Therefore, the performance of the product is class A1.

Reaction to fire class shall be given in the ETA.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the product covered by this EAD the applicable European legal act is Commission Decision 97/597/EC.

The system is 1+.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

The manufacturer (regarding the components he buys from the market with DoP) shall take into account the Declaration of Performance issued by the manufacturer of that component. No retesting is necessary.

Table 3.2.1 Control plan for the manufacturer – Cornerstones

№	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples [1)]	Minimum frequency of control
Factory production control (FPC), including testing of samples taken at the factory in accordance with a prescribed test plan					
1	Static load test of torqued anchorage, slip [2)]	2.2.1, 2.2.2	[3)]	0.2 % [4), 5)] ≥ 2 [5)]	per year
2	Static load test of torqued splice, slip [2)]	2.2.1, 2.2.2	[3)]	0.2 % [4), 5)] ≥ 2 [5)]	per year
3	Resistance to fatigue of torqued anchorage [2)]	2.2.3.1	[3)]	1 [5)]	per year
4	Resistance to fatigue of torqued splice [2)]	2.2.3.1	[3)]	1 [5)]	per year
5	Low cycle fatigue of torqued anchorage and torqued splice [2)]	2.2.4	[3)]	1 [6)]	per year
6	Mass per metre, cross-sectional area, surface geometry of thread bar [7)]	2.2.7, 2.2.9.1, 2.2.14.1	[3)]	≥ 3 [8)]	per year
7	Weldability of thread bar	CEV [9)] 3.4.1	[9)]	100 %	per year
8	Strength characteristics of thread bar [7)] $\varnothing_{nom} < 57.5$ mm $\varnothing_{nom} \geq 57.5$ mm	2.2.9	[3)]	≥ 3 [8)] ≥ 1 [10)]	per year
9	Elongation at maximum force of thread bar [7)] $\varnothing_{nom} < 57.5$ mm $\varnothing_{nom} \geq 57.5$ mm	2.2.12	[3)]	≥ 3 [8)] ≥ 1 [10)]	per year
10	Resistance to fatigue of thread bar	2.2.3.2	[3)]	≥ 5 [11)]	per year

№	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples [1]	Minimum frequency of control
11	Bendability of thread bar $\varnothing_{nom}$ < 22 mm re-bend test $\varnothing_{nom}$ < 22 mm bend test $\varnothing_{nom} \geq$ 22 mm, $\varnothing_{nom} \leq$ 57.5 mm bend test	2.2.13	[3]	≥ 1 [12] ≥ 1 [12] ≥ 1 [12]	per year
12	Visual inspection of thread bar [13]	[14]	[14]	100 %	per year
13	Dimensions of anchorage and splice components	[3]	[3]	0.4 % [15], [5] ≥ 2 [5]	per year
14	Hardness of anchorage and splice components	[3]	[3]	0.1 % [15], [5] ≥ 2 [5]	per year
15	Material of anchorage and splice components	3.1 [16]	[17]	100 %	per year
16	Visual inspection of anchorage and splice components [13]	[18]	[18]	100 %	per year

1) For two specified numbers of samples, the higher number applies.
2) Not for end bearing splice with contact coupler and not for end bearing anchorage.
3) According to the control plan.
4) Percentage of produced anchorages or splices per nominal diameter. After 5 years of successful manufacturing the frequency may be reduced to 0.1 %.
5) For at least 1 nominal diameter. In case of a production of less than 20 anchorages or couplers of 1 nominal diameter per year, testing is not required. However, all nominal diameters shall be tested within 5 years.
6) For at least 1 nominal diameter. In case of a production of less than 20 anchorages or couplers of 1 nominal diameter per year, testing is not required. However, all nominal diameters shall be tested within 5 years. For kits with verified low-cycle fatigue performance only.
7) Assessment of long-term quality level according to EN 10080, clause 8.5.
8) Per nominal diameter and rolling batch, at least however, as specified in EN 10080, clause 8.1.
9) Carbon equivalent, CEV, not greater than specification of thread bar.
10) Per nominal diameter and rolling batch, at least however, as specified in EN 10080, clause 8.1, with 1 specimen instead of 3 specimens.
11) Of one nominal diameter. Nominal diameters < 57.5 mm are all tested within 5 years. Nominal diameters ≥ 57.5 mm are represented by one of these nominal diameters, rotating for every 5 years. However, in case of failure, all of these nominal diameters are tested.
12) Bend test and re-bend test per nominal diameter and rolling batch, at least however, as specified in EN 10080, clause 8.1.
13) Successful visual inspection does not need to be documented.
14) Visual inspections mean e.g., main dimensions, gauge testing, correct marking or labelling, appropriate performance, surface, corrosion, according to the component's specification.
15) Percentage of produced component per nominal diameter and batch
16) Inspection certificate type "3.1" according to EN 10204.
17) As defined by reference standard of the component's material.
18) Visual inspections mean e.g., main dimensions, gauge testing, correct marking or labelling, appropriate performance, surface, fins, kinks, smoothness, corrosion, according to the component's specification.

Regarding traceability of components, full traceability of each anchorage component, splice component, and thread bar to its raw material applies.

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 Kit with high strength reinforcing steel are laid down in Table 3.3.1.

Table 3.3.1 Control plan for the notified body – Cornerstones

№	Subject of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the Kit with high strength reinforcing steel.	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer.	According to Control plan	According to Control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control					
1	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	1/year 2/year for thread bar
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
1	Static load test of torqued anchorage, slip	2.2.1, 2.2.2	1)	3 2)	Each inspection
2	Static load test of torqued splice, slip	2.2.1, 2.2.2	1)	3 2)	Each inspection
3	Mass per metre Cross-sectional area Surface geometry of thread bar	2.2.7 2.2.9.1 2.2.14.1	1)	3)	Each inspection
4	Weldability of thread bar	CEV 3.4.1	1)	3)	Each inspection
5	Strength properties Elongation at maximum force	2.2.9, 2.2.12	1)	3)	Each inspection

№	Subject of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
6	Thread bar $\varnothing_{nom}$ < 22 mm re-bend test $\varnothing_{nom}$ < 22 mm bend test $\varnothing_{nom} \geq$ 22 mm, $\varnothing_{nom} \leq$ 57.5 mm bend test	2.2.13	1)	3)	Each inspection
7	Visual inspection of thread bar	4)	1)	3)	Each inspection
8	Components of splice and anchorage Dimensions Material Visual inspection	 1) 3.1 [6)] 4)	 1) 1) 1)	 3 [5)] 3 [5)] 3 [7)]	Each inspection

1) According to the control plan.

2) 1 nominal diameter, all nominal diameters shall be tested within 5 years.

3) According to EN 10080, clause 8.3.1.

4) Visual inspections mean e.g., main dimensions, gauge testing, correct marking or labelling, appropriate performance, surface, corrosion according to the component's specification.

5) Per component. One nominal diameter shall be sampled. All nominal diameters shall be sampled within 5 years.

6) Inspection certificate type "3.1" according to EN 10204

7) Each kind of component for all nominal diameters.

3.4 Special methods of control and testing used for the verification of constancy of performance

3.4.1 Carbon equivalent

The carbon equivalent, CEV, shall be determined by Equation 3.4.1.

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$ Equation 3.4.1

Where

C .... Content of carbon
Mn .... Content of manganese
Mo .... Content of molybdenum
V .... Content of vanadium
Ni .... Content of nickel
Cu .... Content of copper

4 REFERENCE DOCUMENTS

EAD 160004-00-0301:2016	Post-tensioning kits for prestressing of structures
EN 1992-1-1:2004 EN 1992-1-1:2004/AC:2010 EN 1992-1-1:2004/A1:2014	Eurocode 2 – Design of concrete structures
EN 10080:2005	Steel for the reinforcement of concrete – Weldable reinforcing steel – General
EN 10204:2004	Metallic products – Types of inspection documents
EN 12390-4:2019	Testing hardened concrete – Part 4: Compressive strength – Specification for testing machines
EN ISO 6892-1:2019	Metallic materials – Tensile testing – Part 1: Method of test at room temperature
EN ISO 15630-1:2019	Steel for the reinforcement and prestressing of concrete – Test methods – Part 1: Reinforcing bars, rods and wire
EN ISO/IEC 17025:2017	General requirements for the competence of testing and calibration laboratories
EN ISO 17660-1:2006	Welding – Welding of reinforcing steel – Part 1: Loadbearing welded joints
ISO 15835-1:2018	Steels for the reinforcement of concrete – Reinforcement couplers for mechanical splices of bars – Part 1: Requirements
ISO 15835-2:2018	Steels for the reinforcement of concrete – Reinforcement couplers for mechanical splices of bars – Part 2: Test methods

ANNEX A DETERMINATION OF NOMINAL VALUES

A.1 General

Nominal values are determined only if the respective information in missing in the MPII.

A.2 Nominal diameter

Actual mass per metre of the specimen shall be determined according to EN ISO 15630-1, clause 12. The actual mass per metre, m_{act}, shall be calculated as the quotient of the specimen mass in kg, divided by the specimen length in m. From actual mass per metre, the actual diameter shall be calculated with Equation A.2.1.

$$d_{act} = 2\,000 \cdot \sqrt{\frac{m_{act}}{\pi \cdot \rho}} \qquad \text{Equation A.2.1}$$

The actual diameters of all specimens shall be divided into groups of diameters. Grouping is according to the criteria below:

- The arithmetic mean of actual diameters of all specimens of the group shall be calculated.
- The arithmetic mean is rounded according to Equation A.2.2.

$$\begin{aligned} &\leq 30.0 \text{ mm, rounded to the nearest } 0.1 \text{ mm} \\ &\left.\begin{matrix} > 30.0 \text{ mm} \\ \text{to} \\ 70.0 \text{ mm} \end{matrix}\right\}, \text{ rounded to the nearest } 0.2 \text{ mm} \\ &> 70.0 \text{ mm, rounded to the nearest } 0.5 \text{ mm} \end{aligned} \qquad \text{Equation A.2.2}$$

- The actual diameters of all specimens of the group do not deviate by more than ± 2.5 % of the rounded arithmetic mean.
- The rounded arithmetic mean of the group is the nominal diameter, $\varnothing_{nom}$, of that group.
- The nominal diameters of all groups establish a series of nominal diameters.

Nominal cross-sectional area of the group, S_n, shall be calculated with the nominal diameter, $\varnothing_{nom}$, by Equation 2.2.9.1.1

Where

d_{act}.............. mm...................... Actual diameter of specimen

m_{act}.............kg/m..................... Actual mass per metre of specimen

ρ................kg/m^3.................... Density, 7 850 kg/m^3, for hot rolled thread bar

$\varnothing_{nom}$ .... mm...................... Nominal diameter of the group

S_n...............mm^2..................... Nominal cross-sectional area of the group

A.3 Nominal yield strength and nominal tensile strength

Yield strength and tensile strength shall be determined in tension, see also EN 10080, clause 7.2.3. Stress values shall be calculated based on the nominal cross-sectional area, S_n according to Clause A.2. Tensile test on the specimen shall be carried out in accordance with EN ISO 15630-1, clause 5. The following parameters and procedures apply in relation to EN ISO 15630-1:

- Specimen shall be according to EN ISO 15630-1, clause 4, without artificial ageing and according to EN ISO 15630-1, clause 5.1.
- Test equipment shall be according to EN ISO 15630-1, clause 5.2.
- Tensile test shall be performed at room temperature.
- EN ISO 6892-1, clauses 10.1 and 10.2 apply.

- Force-extension diagram shall be recorded.
- Testing rate shall be according to EN ISO 6892-1, clauses 10.3.3.1, 10.3.3.2.1, 10.3.3.2.4, 10.3.3.2.5, and 10.3.3.3, whereby the crosshead separation rate applies.
- Determination of $R_{e, act}$ shall be according to EN ISO 6892-1, clauses 11 and 13, or EN ISO 15630-1, clause 5.3. These procedures are considered as equivalent. Reference procedure for proof strength is EN ISO 15630-1, clause 5.3, second method.
- Determination of $R_{m, act}$ shall be with the maximum force in tensile test, considering EN ISO 15630-1, clause 5.3.

The actual yield strengths, $R_{e, act}$, of the specimens shall be divided into groups of yield strength. Grouping is according to the criteria below:

- The arithmetic mean, $R_{e, mean}$, of actual yield strengths of all specimens of the group shall be calculated.
- The actual yield strengths of all specimens of the group do not deviate by more than $\pm$ 50 MPa of the arithmetic mean.

The nominal yield strength of the group shall be calculated with Equation A.3.1.

$R_{e, nom} = 0.85 \cdot R_{e, mean}$, rounded to the nearest 10 MPa Equation A.3.1

The arithmetic mean, $R_{m, mean}$, of actual tensile strengths of all specimens of the group shall be calculate and the nominal tensile strength shall be calculated with Equation A.3.2.

$R_{m, nom} = 0.85 \cdot R_{m, mean}$, rounded to the nearest 10 MPa Equation A.3.2

Where

$R_{e, act}$ .... MPa .... Actual yield strength of specimen

$R_{e, mean}$ .... MPa .... Arithmetic mean of actual yield strengths of all specimens of the group

$R_{e, nom}$ .... MPa .... Nominal yield strength of the group

$R_{m, act}$ .... MPa .... Actual tensile strength of specimen

$R_{m, mean}$ .... MPa .... Arithmetic mean of actual tensile strengths of all specimens of the group

$R_{m, nom}$ .... MPa .... Nominal tensile strength of the group

S_n .... mm^2 .... Nominal cross-sectional area of specimen, see Clause A.2

ANNEX B ESSENTIAL CHARACTERISTICS FOR THE INTENDED USES

The essential characteristics relevant for the categories of intended use are listed in Table B.1. Categories of intended use are according to Table 1.2.1.1:

Column (1) in Table B.1, category of intended use Table 1.2.1.1, line 1

Column (2) in Table B.1, category of intended use Table 1.2.1.1, line 2

Table B.1 Essential characteristics for the categories of intended use

№ [1]	Essential characteristic	Category of intended use	
		1	2
Kit with high strength reinforcing steel			
Basic requirement for construction works 1: Mechanical resistance and stability			
1	Resistance to static load	+	+
2	Slip	+	+
3	Resistance to fatigue	+	+
4	Low-cycle fatigue	—	+
5	Load transfer to the structure	+	+
6	Reinforcement corrosion protection and detailing	+	+
7	Mass per metre	+	+
8	Weldability	+	+
9	Strength characteristics of thread bar	+	+
10	Compression	+	+
11	Modulus of elasticity	+	+
12	Elongation at maximum force	+	+
13	Bendability	+	+
14	Bond characteristics	+	+
Basic requirement for construction works 2: Safety in case of fire			
15	Reaction to fire	+	+

ANNEX C LOAD TRANSFER TO THE STRUCTURE TEST

C.1 Specimen

The specimen is schematically shown in Figure C.4.1 and Figure 2.2.1.2.1. The specimen shall contain those anchorage components and bursting reinforcement that will be embedded in the structural concrete, and their arrangement conforms to the intended application and with the specification as per MPII.

The test specimen shall be a concrete prism. Its concrete cross section $A_c = a \cdot b$ shall correspond to the minimum cross section and concrete strength as given in the MPII.

From these reference dimensions a and b, minimum anchorage centre spacing in the structure in x- and y-directions, x and y, and minimum edge distances shall be derived according to the MPII. Without specific testing, Equation C.1.1 may be applied.

$$A_c = x \cdot y \geq a \cdot b \qquad \text{Equation C.1.1}$$

The actual spacing / centre distance and edge distance in the structure shall conform to Equation C.1.2 and Equation C.1.3.

$$x \geq 0.85 \cdot a \qquad \text{Equation C.1.2}$$

$$y \geq 0.85 \cdot b \qquad \text{Equation C.1.3}$$

Edge distances in the structure shall be calculated with centre spacing in x- and y-direction by Equation C.1.4 and Equation C.1.5.

$$e_x = \frac{x}{2} - 10 \text{ mm} + c \qquad \text{Equation C.1.4}$$

$$e_y = \frac{y}{2} - 10 \text{ mm} + c \qquad \text{Equation C.1.5}$$

The height h of specimen shall be at least twice the longer of the two side lengths a or b, see Figure C.4.1. The height of the lower part of the specimen, i.e., with auxiliary reinforcement reinforced shall be at least $0.5 \cdot h$.

Reinforcement shall be placed as bursting reinforcement and auxiliary reinforcement:

- Bursting reinforcement is provided with amount and configuration as specified in the MPII. The part of the specimen with the anchorage components shall contain the bursting reinforcement.
- Auxiliary reinforcement comprises longitudinal reinforcement and transverse stirrups reinforcement:
  - Longitudinal reinforcement are bars with a total cross-sectional area of $\leq 0.003 \cdot A_c$
  - Transverse reinforcement are stirrups, uniformly distributed along the height of specimen, with $\leq$ 50 kg steel/(m^3 concrete).

    The 50 kg/m^3 stirrups, uniformly distributed along the height of specimen, can be placed over the entire height of the specimen.
  - Auxiliary reinforcement can also be combined with the bursting reinforcement. For combined reinforcement, only the reinforcement beyond the 50 kg/m^3 is considered as bursting reinforcement.
  - With specimen without bursting reinforcement, only the auxiliary reinforcement is placed.

The concrete cover to the reinforcement shall be 10 mm, see Figure C.4.1.

The concrete of the test specimen shall correspond to normal concrete used for concrete structures with respect to materials, composition, compaction and its compressive strength. The composition of the concrete used for the load transfer test specimen shall be given in the test records. The test specimen should be concreted normally in a horizontal position. After casting the specimen shall be de-moulded after one day and then moist-cured until testing. The test cylinders or cubes cast for determination of compressive strength of concrete shall be cured the same way.

Where

a, b	mm	Side lengths of test specimen
x, y	mm	Minimum specified centre spacing in x- and y-direction
A_c	mm^2	Gross cross-sectional concrete area of specimen
e_x, e_y	mm	Edge distance in x- and y-direction respectively
c	mm	Concrete cover of reinforcement
h	mm	Height of specimen

C.2 Test procedure

The specimen shall be mounted in a calibrated test rig or testing machine. The load shall be applied to the specimen on an area that simulates the loading condition in a complete anchorage.

The force shall be increased in steps, see Figure C.2.1, $0.12 \cdot F_{m, nom}$, $0.2 \cdot F_{m, nom}$, $0.4 \cdot F_{m, nom}$, $0.6 \cdot F_{m, nom}$, and $0.8 \cdot F_{m, nom}$. After attaining the $0.8 \cdot F_{m, nom}$ at least ten, i.e., $m \geq 10$, slow cycles shall be performed, with a force range of $0.8 \cdot F_{m, nom}$ and $0.12 \cdot F_{m, nom}$ being the upper and the lower force respectively. The necessary number of loading cycles depends upon stabilisation of strain readings and crack widths. Following cyclic loading, the specimen shall be loaded continuously to failure. The test may be terminated without concrete failure at a force exceeding Equation C.2.1.

$$F_u \geq 1.1 \cdot F_{m, nom} \cdot \frac{f_{cm, e}}{f_{cm, 0}} \qquad \text{Equation C.2.1}$$

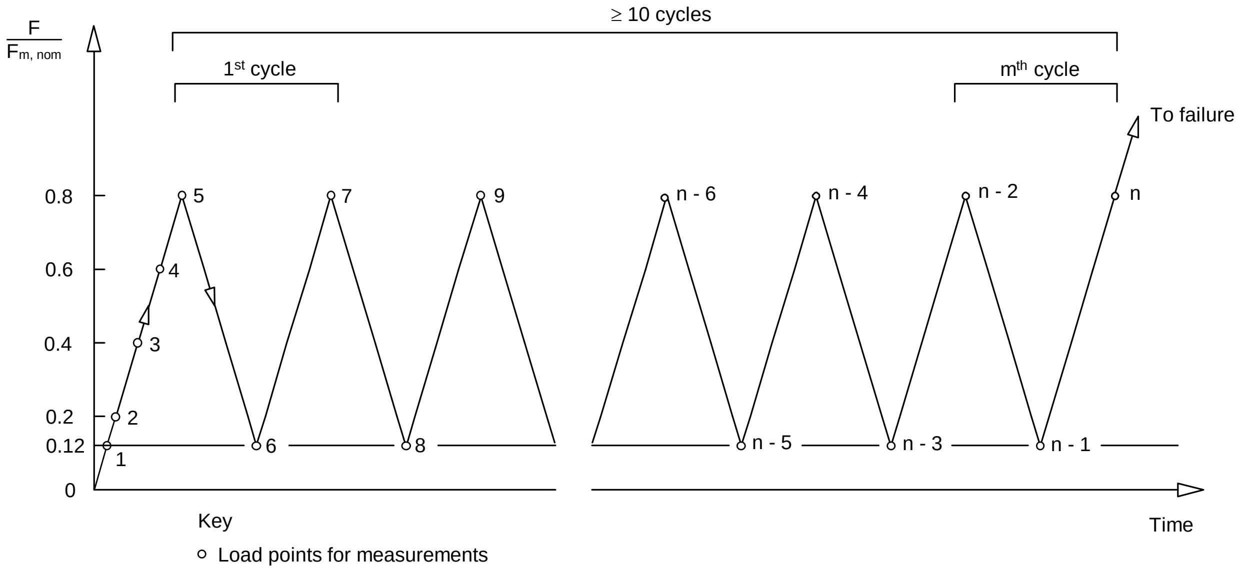


Figure C.2.1 Loading sequence in load transfer test

During cyclic loading measurement shall be taken at the points numbered in Figure C.2.1, i.e., 1, 2, … to n. At the upper and the lower loads of several cycles, the measurements shall permit to decide whether stabilisation of strains and crack widths is being attained, see Clause C.3.

The points for measurements at the beginning of the test, points 1 to 3 in Figure C.2.1, can be shifted to different forces. Measurement should be performed at least at 3 points.

At the final test to failure, the mean compressive strength of concrete[4] of specimen shall be as by Equation C.2.2.

$$f_{cm,e} \leq f_{cm,0} + 3\ \text{MPa} \qquad \text{Equation C.2.2}$$

Where

F .... N .... Force in load transfer test

F_u .... N .... Maximum force in load transfer test

$F_{m,nom}$........... N .... Nominal maximum force of thread bar, $F_{m,nom} = R_{m,nom} \cdot S_n$

$R_{m,nom}$ ....MPa..................... Nominal tensile strength of thread bar

S_n ....mm^2..................... Nominal cross-sectional area of thread bar, Clause 2.2.9.1

$f_{cm,e}$ ....MPa..................... Concrete compressive strength at time of end of load transfer test

$f_{cm,0}$ ....MPa..................... Nominal concrete compressive strength for load transfer test

m.................—....................... Number of load cycles

n..................—....................... Number of load points for measurements

C.3 Stabilisation criteria

Crack widths[5] w shall be:

- Upon first attainment of upper load, $w_{max} \leq 0.15$ mm
- upon last attainment of lower load, $w_{max} \leq 0.15$ mm
- upon last attainment of upper load, $w_{max} \leq 0.25$ mm

Crack widths shall be considered to have stabilised, either if their width under upper load conforms to Equation C.3.1 or crack width does not exceed 0.10 mm throughout the test.

$$w_n - w_{n-8} \leq \frac{1}{3} \cdot (w_{n-8} - w_5),\ m \geq 10 \qquad \text{Equation C.3.1}$$

Longitudinal and transverse strains shall be considered to have stabilised if the increase of strain under the upper load conforms to Equation C.3.2.

$$\varepsilon_n - \varepsilon_{n-8} \leq \frac{1}{3} \cdot (\varepsilon_{n-8} - \varepsilon_5),\ m \geq 10 \qquad \text{Equation C.3.2}$$

See Figure C.4.3 and Figure C.4.4 for details on how to assess stabilisation criteria.

Where

w .... mm...................... Crack width

w_{max}........... mm...................... Maximum crack width

w_5, w_{n-8}, w_n .... mm...................... Crack width, measured at specific load cycles.

ε_5, ε_{n-8}, ε_n .... mm/m.................... Strain, measured at specific load cycles.

m.................—....................... Number of load cycles

n..................—....................... Number of load points for measurements

[4] The criterion regarding compressive strength of concrete originates from EAD 160004-00-0301.
[5] The criteria regarding crack width and stabilisation of crack width and strain originate from EAD 160004-00-0301.

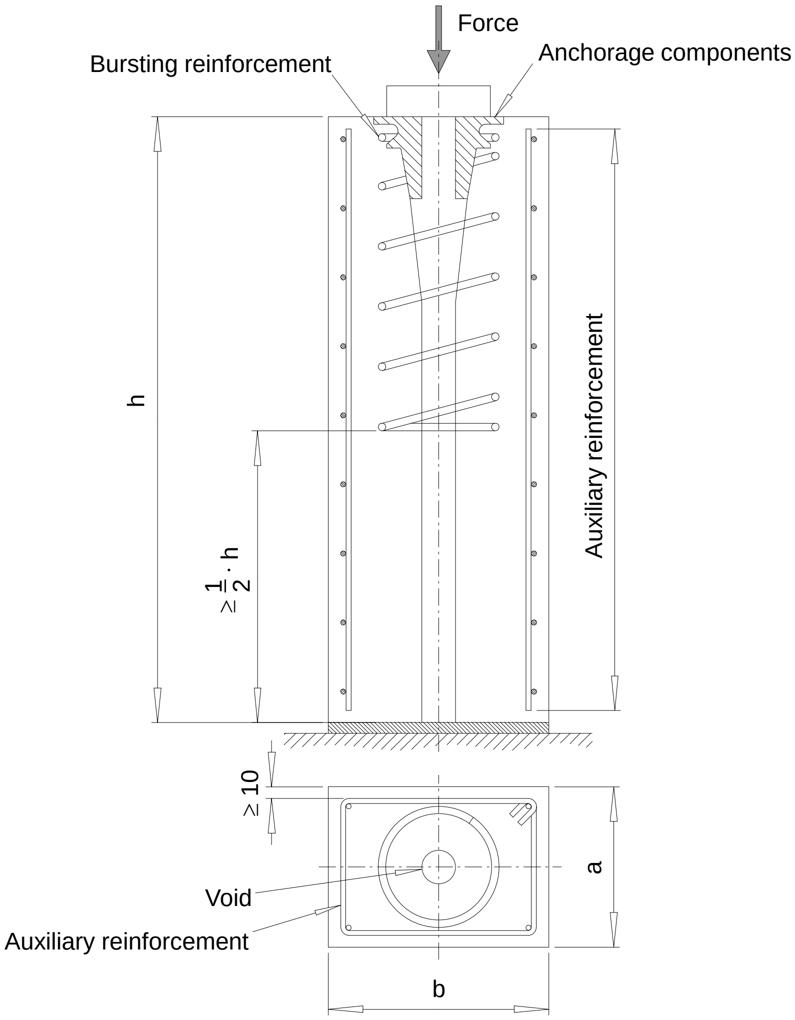
C.4 Measurements and observations

The following measurements and observations shall be made and recorded:

- Determination of actual material characteristics of tested components.
- Checking of the components for materials, machining, geometry, hardness, et cetera.
- Longitudinal and transverse concrete strains on at least two side faces of the specimen in the region of maximum bursting effect under the upper and lower load, dependent on number of load cycles. Longitudinal and transverse concrete strains and crack width and propagation shall also be recorded at measuring points 1, 2, and 3 indicated in Figure C.2.1.
- Formation, width and propagation of cracks on the side faces of the specimen, as mentioned above.
- Visual inspection and/or measurement of deformation of anchorage components in contact with concrete. Any unusual or excessive deformation, such as large permanent deformations, shall be documented in the test records, and such actual deformation may be measured.
- Location and mode of failure.
- Measured maximum force F_u.
- Examination of components and specimen after testing, photographic documentation, comments.

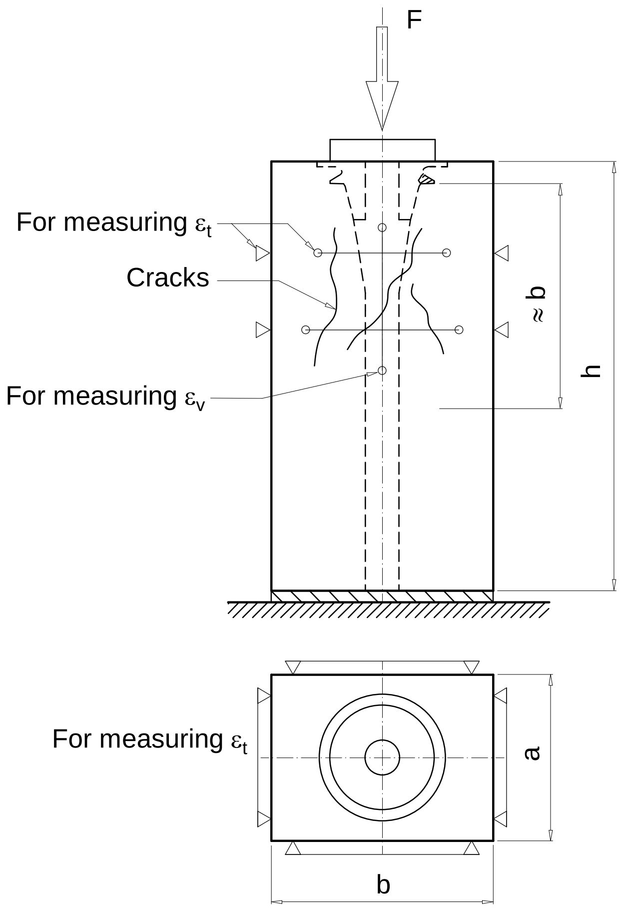
Where

F_u .... N .... Maximum force in load transfer test



Dimensions in mm

Figure C.4.1 Specimen for load transfer test – Schematic example



For b ≥ a

Gauge length for strain measurement ≈ 0.6 up to 0.8 · b

Figure C.4.2 Load transfer test – Measurements on at least 2 side faces – Schematic example

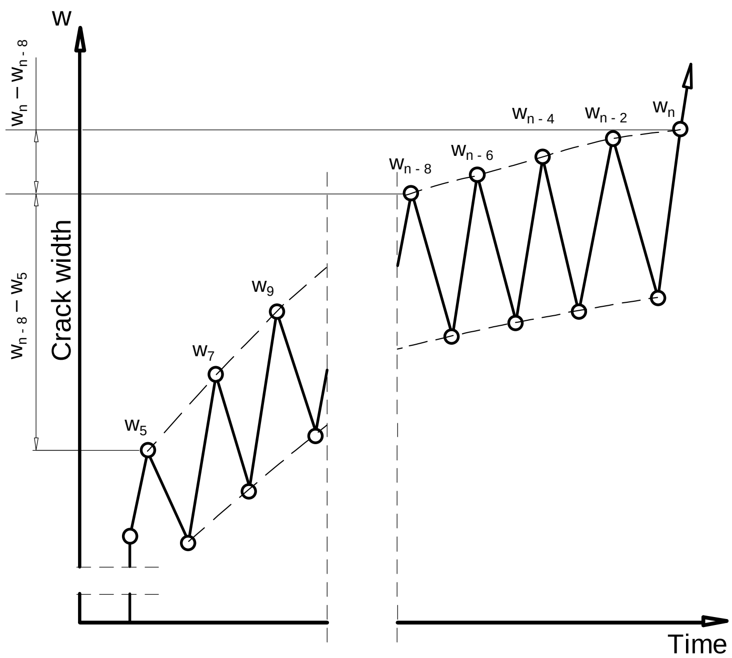


Figure C.4.3 Assessment of crack width stabilisation

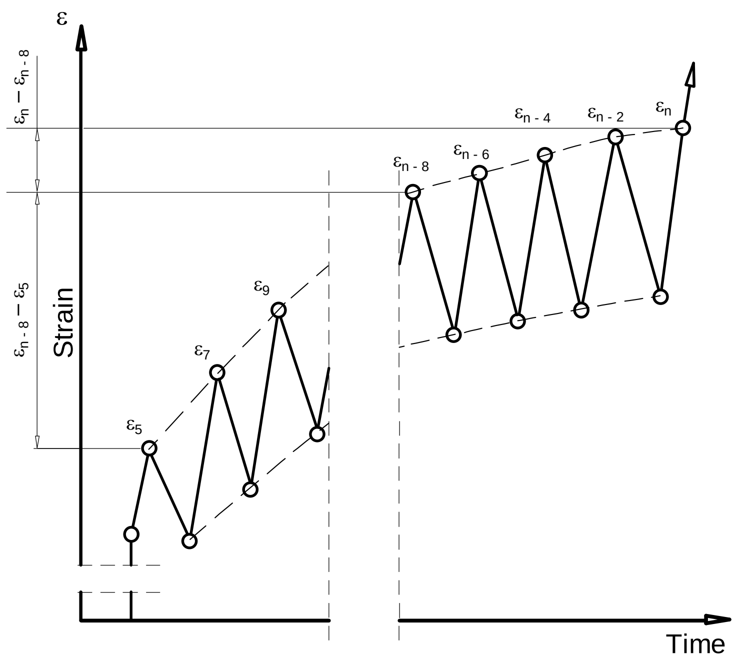


Figure C.4.4 Assessment of strain stabilisation

Where

ε_5, ε_7, ε_9, ε_{n-8}, ε_{n-6}, ε_{n-4}, ε_{n-2}, ε_n .... mm/m.................... Strain, measured at specific load points.

w_5, w_7, w_9, w_{n-8}, w_{n-6}, w_{n-4}, w_{n-2}, w_n .... mm...................... Crack width, measured at specific load points.

a, b .... mm...................... Side lengths of test specimen

ε .... mm/m.................... Strain

ε_t .... mm/m.................... Strain, measured perpendicular to loading direction – transversal strain

ε_v .... mm/m.................... Strain, measured parallel to loading direction – longitudinal strain

c .... mm...................... Concrete cover of reinforcement in the structure as required at the place of use

F .... N .... Applied force

$f_{cm,\,0}$ ....MPa..................... Nominal concrete compressive strength for load transfer test

$f_{cm,\,e}$ ....MPa..................... Concrete compressive strength at time of end of load transfer test

$F_{m,\,nom}$ .... N .... Nominal maximum force of thread bar

h................. mm...................... Height of specimen

m..................—....................... Number of load cycles

n...................—....................... Number of load points for measurement

w .... mm...................... Crack width

ANNEX D NUMBER OF TESTS

D.1 General

Table D.2.1 to Table D.2.2 rely on the concept of series. This concept presumes a series of sizes of thread bars and other components, where within each series there are similarities among others in terms of:

- Material
- Grade of material, strength of concrete
- Geometry
- The same method of anchoring the thread bars

Untested sizes shall be assessed based on affinity of the components. Criteria among others for affinity are:

- Dimensions follow sizes in a steady progression.
- Properties of lager sizes are also applicable to smaller sizes.
- Properties are interpolated between sizes.

Table D.1.1 Relevant tests on splices and anchorages

Component	Test or measurement				
	Static	Slip	Fatigue	Low cycle fatigue	Load transfer
Splice					
End bearing splice	— 1)	yes, in compression	—	—	— 2)
End bearing splice with reducing coupler	— 3)	— 3)	—	—	— 2)
Torqued splice	in tension	yes	yes	yes	— 2)
Torqued splice with reducing coupler	in tension	yes	— 4)	yes	— 2)
Torqued splice with turnbuckle	in tension	yes	— 4)	yes	— 2)

Anchorage					
End bearing anchorage with steel plate	— [5]	— [5]	—	—	—
Torqued anchorage with additional bonded length	in tension	yes	yes	yes	yes

Key

—...... Not relevant

[1] No specific testing is required as for end bearing splice the test results of strength characteristics under compression of thread bar are applicable.

[2] Load transfer not relevant for splices

[3] No specific testing is required as for reducing coupler the test results of the end bearing splice are applicable.

[4] No specific testing is required as the test results of the torqued splice are applicable.

[5] No specific testing is required as for end bearing anchorage with steel plate the test results of the end bearing splice are applicable.

D.2 Number of tests

Table D.2.1 Number of tests for anchorages and splices

Test method	Number of tests				
	Nominal diameter in mm				
	18	35	43	63.5	75
Resistance to static load [1], Clause 2.2.1					
end bearing splice [2]	—	—	—	—	—
torqued splice	3	3	3	3	3
torqued splice with reducing coupler	3	3	3	3	3
torqued splice with turnbuckle	3	3	3	3	3
torqued anchor piece	3	3	3	3	3
Slip measurement [1]					
end bearing splice, Clause 2.2.2	3	3	3	3	3
torqued splice	3	3	3	3	3
torqued splice with reducing coupler	3	3	3	3	3
torqued splice with turnbuckle	3	3	3	3	3
torqued anchor piece	3	3	3	3	3
Resistance to fatigue, Clause 2.2.3.1					
torqued splice	6 [3]				
torqued anchor piece	6 [3]				
Low cycle fatigue, Clause 2.2.4	—				
torqued splice		3	3	3	3
torqued splice with reducing coupler		3	3	3	3
torqued splice with turnbuckle		3	3	3	3
torqued anchor piece		3	3	3	3
Load transfer to the structure, torqued anchorage with an additional bonded length for 3 concrete grades, Clause 2.2.5	—				
C25/30		1	1	1	2
C60/75		1	1	1	2
C80/95		1	1	1	2
Dimensions of nuts and couplers, Clause 2.2.6	3	3	3	3	3

[1] Resistance to static load and slip can be tested in one common test.
[2] No specific testing is required, as compression test results of thread bar, Clause 2.2.10, are applicable.
[3] Number of tests for most critical nominal diameter, which is in general the largest nominal diameter.

Table D.2.2 Number of tests for the thread bar

Test method	Number of tests					
	Nominal diameter in mm					
	18	35	43	57.5	63.5	75
Mass per meter, cross-sectional area, surface geometry, core diameter, Clause 2.2.6, Clause 2.2.9.1, Clause 2.2.7, and Clause 2.2.14.1 3 heats per diameter, 3 tests each	9	9	9	—	9	9
Weldability, Clause 2.2.8 Per welding process Tensile test on thread bar	3 ≥ 2	— —	3 ≥ 2	— —	— —	3 ≥ 2
Strength characteristics, Clause 2.2.9 under tension [1), 2)] 3 heats per diameter, 10 tests each under compression, Clause 2.2.10 3 heats per diameter, 1 test each	30 3	30 3	30 3	—	30 3	30 3
Elongation at maximum force, Clause 2.2.12 under tension [1)] 3 heats per diameter, 10 tests each	30	30	30	—	30	30
Modulus of elasticity [2)], Clause 2.2.11	3	3	3	—	3	3
Bendability, Clause 2.2.13 3 heats per diameter, 3 tests each in bend test 3 heats per diameter, 3 tests each in re-bend test	9 9	9 —	9 —	9 —	— —	— —
Resistance to fatigue, Clause 2.2.3.2	5	5	5	—	5	5
Bond characteristics (pull-out test, transfer length), 3 concrete grades, Clause 2.2.14, C25/30 C60/75 C80/95	5 5 5	5 5 5	5 5 5	—	5 5 5	5 5 5

1) Strength characteristics in tension and elongation at maximum force can be tested in one common test.

2) Strength characteristics in tension and modulus of elasticity can be tested in one common test.

ANNEX E CONTENTS OF TEST RECORDS

Testing of the Kit with high strength reinforcing steel shall be documented with test records that should be prepared in accordance with the general principles of EN ISO/IEC 17025 and include at least the following specific information:

- Name and address of the test laboratory
- Document number or unique document identifier
- Name and address of the client who has contracted the laboratory
- Detailed description of all components of the Kit with high strength reinforcing steel
- Certificates of all relevant materials to confirm conformity with specifications. Actual characteristics of components (mechanical, chemical, metallurgical, geometrical, etc. as relevant) at time of testing and source of manufacture. These include in particular thread bar and anchorage and coupler components and ancillary components used in testing
- Certificates of equipment and test machine calibration
- Description and drawing of test specimen with actual dimensions
- Description and drawing of test set-up and measuring equipment including calibration certificate
- Reference to relevant clause of the EAD
- Actual ambient temperature, where relevant
- Record of all measurements and observations
- Photographs of test specimen prior, during, and after testing
- Any other information specified in the test procedures
- Statement of any unexpected or unusual behaviour / observation of components during testing
- Date and place of testing
- Name and signature of person responsible for testing.