EUROPEAN ASSESSMENT DOCUMENT

EAD 160129-00-0301

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COUPLERS FOR MECHANICAL SPLICES OF REINFORCING STEEL BARS

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

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD covers couplers for mechanical splices of reinforcing steel bars for concrete (in the following referred to as couplers) with sizes ranging from 8 to 50 mm with the following property:

$A_{s,nom,bar} \cdot R_{e,nom,bar} \leq A_{s,nom,coupler} \cdot R_{e,nom,coupler}$

The load bearing parts of the couplers are completely made of steel or cast steel.

Types of couplers are standard couplers or e.g. position couplers, bridging couplers or transition couplers.

Positional couplers are used to join two bars when neither bar can be rotated and/or connect bars whose ends are at a defined maximum distance from each other. For the situation when rebars cannot be rotated but can move axially and only the coupler can rotate, there should be left-hand thread on one bar and corresponding side of the coupler and right-hand thread on the opposite bar and corresponding side of coupler.

Transition couplers connect bars of different diameters.

Below is a selection of couplers as examples, different thread designs (e.g. tapered) and coupler designs are possible.

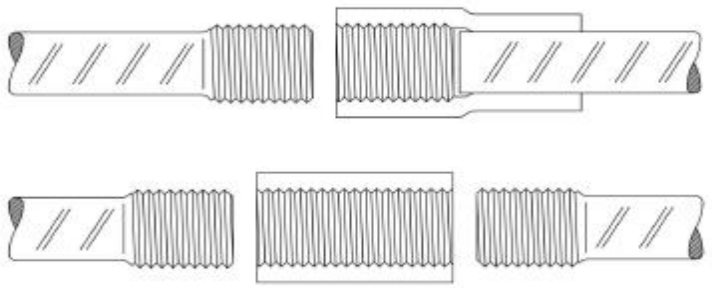


Figure 1.1: Standard coupler

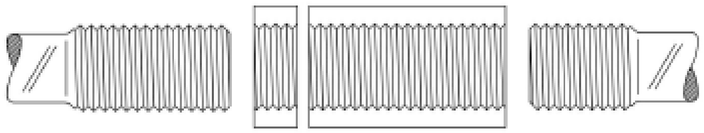


Figure 1.2: Positional coupler

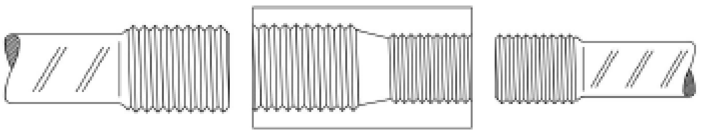


Figure 1.3: Transition coupler

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 all couplers will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

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

1.2 Information on the intended use of the construction product

1.2.1 Intended use

The couplers are intended to be used for mechanical splices of reinforcing steel bars for concrete structures designed according to EN 1992-1-1[1] and EN 1998-1 for:

- Transfer of axial tension and/or compression forces of the connected bars according to EN 1992-1-1, Clause 8.7 and 8.8(4)
- Limitation of slip according to EN 1992-1-1, Clause 7.3
- Resistance to high-cycle fatigue loading according to EN 1992-1-1, Clause 6.8.4
- Resistance to low-cycle seismic loading according to EN 1998-1, Clause 5.6.3(2)

This EAD covers the following specifications of the intended use:

- Connection between reinforcing bars avoiding lapped splicing
- Mechanical splices of reinforcing steel bars with a nominal yield strength of 400 MPa ≤ $R_{e,nom}$ ≤ 600 MPa and of ductility classes B or C according to EN 1992-1-1, Clause C.1
- Mechanical splices of reinforcing steel bars positioned such that the concrete cover complies with the provisions according to EN 1992-1-1, Clause 4.4.1

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the product for the intended use of 100 years when installed in the works (provided that the product is subject to appropriate installation (see 1.1)) These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

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

1.3 Specific terms used in this EAD (if necessary in addition to the definitions in CPR, Art 2)

1.3.1 Abbreviations

Symbol	Unit	Designation
$A_{gt,act}$	%	Actual total elongation at maximum tensile force in the spliced bars in case of failure inside the the length of the mechanical splice
$A_{gt,nom}$	%	Nominal total elongation at maximum tensile force of the reinforcing bar
$R_{e,nom,bar}$	MPa	Nominal yield strength of the reinforcing bar
$R_{e,nom,coupler}$	MPa	Nominal yield strength of the coupler

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

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

$R_{e,act}$	MPa	Actual yield strength of the reinforcing bar
$R_{m,nom}$	MPa	Nominal tensile strength of the reinforcing bar
$R_{m,act}$	MPa	Actual tensile strength of the reinforcing bar
$A_{S,nom,bar}$	mm²	Nominal cross-sectional area of the reinforcing bar
$A_{S,nom,coupler}$	mm²	Nominal cross-sectional area of the coupler
$A_{S,act}$	mm²	Actual area of the reinforcing bar
F_{act}	kN	Actual maximum force in tensile test
$F_{e,nom}$	kN	Nominal force in low-cycle loading test $A_{S,nom,bar} * R_{e,nom,bar}$
F_u	kN	Ultimate tensile load after the low-cycle loading
$f_{u,min,bar,outside}$	MPa	Minimum strength at failure outside the splice length (failure of rebar)
$f_{u,min,bar,inside}$	MPa	Minimum strength at failure inside the splice length (shear of thread, failure of the rebar inside the coupler, bar pull-out out of the coupler)
$f_{u,min,coupler}$	MPa	Minimum strength at failure of the coupler
k_1, k_2	-	Stress exponent for S-N-curve
$\Delta\sigma_{Rsk}$	MPa	Characteristic fatigue strength for N* load cycles
$\Delta\sigma_{Rsk,n=2\cdot10^6}$	MPa	Characteristic fatigue strength for $2\cdot10^6$ load cycles
N	-	Specified number of load cycles in fatigue test
N*	-	Number of load cycles in fatigue test at the kink point of S-N-curve
$(R_m/R_e)_k$	-	Tensile/yield strength ratio
d	mm	Nominal diameter of the reinforcing bar
Δd	mm	Difference between maximum and minimum diameter of reinforcing bar range
L	mm	Length of the mechanical splice
L_1	mm	Coupler length
L_2	mm	$2\cdot d$
L_3	mm	Minimum free length for measurement of $A_{gt,act}$
L_g	mm	Gauge length for measurement of slip
L_0	mm	Gauge length in the low-cycle loading test
S	mm	Slip
s_1	mm	Slip under initial loading
s_2	mm	Slip after unloading
ε_y	%	Strain at nominal yield strength
ε_1	%	2 ε_y strain of the reinforcing bar, measured over L_0
ε_2	%	5 ε_y strain of the reinforcing bar, measured over L_0
σ_{max}	MPa	Upper stress level for the high-cycle fatigue test
$2\cdot\sigma_a$	MPa	Stress range for the high-cycle fatigue test
u_{20}	mm	Difference between the average of residual elongation after 20 cycles in low-cycle loading test and those of an unspliced reference length of the same bar, measured on the same gauge length

1.3.2 Definitions

coupler
coupling sleeve or threaded coupler for mechanical splicing of reinforcing bars for the purpose of providing transfer of axial tension and/or compression from one bar to the other

mechanical splice
complete assembly of a coupler, including other components providing a splice of two reinforcing bars

coupler length
actual length of the coupler including all load-transferring parts

length of mechanical splice
coupler length plus two times the nominal bar diameter at both ends of the coupler

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1 shows how the performance of the mechanical couplers is assessed in relation to the essential characteristics.

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

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Resistance to static or quasi-static loading	2.2.2	Level: $f_{u,min,bar,outside}$ [MPa] or $f_{u,min,bar,inside}$ [MPa]; $A_{gt,act}$ [%] or $f_{u,min,coupler}$ [MPa]; $A_{gt,act}$ [%]
2	Slip under static or quasi-static load	2.2.3	Level: s_1 [mm]
3	Slip after static or quasi-static loading	2.2.3	Level: s_2 [mm]
4	Fatigue strength for N = $2{\cdot}10^6$ load cycles	2.2.4	Level: $\Delta\sigma_{Rsk,n=2\cdot10^6}$ [MPa]
5	Fatigue strength for S-N curve with k_1 [-] and k_2 [-] according to EN 1992-1-1	2.2.4	Level: $\Delta\sigma_{Rsk}$ [MPa]; k_1 [-] and k_2 [-]
6	Fatigue strength for S-N curve with specific k_1 [-] and k_2 [-]	2.2.4	Level: $\Delta\sigma_{Rsk}$ [MPa]; k_1 [-] and k_2 [-]
7	Resistance to low cycle loading (seismic actions)	2.2.5	Level: u_{20} [mm] and F_u [kN]
Basic Works Requirement 2: Safety in case of fire			
8	Reaction to fire	2.2.6	Class

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

2.2.1 General

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.

For a same system, if various types of splices are very similar and use identical components, the Technical Assessment Body may decide not to test all of them. For example fatigue tests may be more critical for transition or positional couplers rather than for standard couplers.

2.2.2 Resistance to static or quasi-static loading

The resistance to static or quasi static loading according to Table 2.2 is determined by means of testing. The tests shall be performed and evaluated according to the method given in Table 2.2.

Table 2.2 Resistance to static and quasi-static loading

No	characteristic	number of samples per type of coupler	test method and evaluation	expression of performance
1	Minimum force at failure due to tension loading	≥ 3 for min d ≥ 3 for medium d (where Δd> 10 mm) ≥ 3 for max d	Annex A.3	$f_{u,min,bar,outside}$ [MPa] or $f_{u,min,bar,inside}$ [MPa]; $A_{gt,act}$ [%] or $f_{u,min,coupler}$ [MPa]]; $A_{gt,act}$ [%]

2.2.3 Slip under or after static or quasi-static loading

The slip according to Table 2.3 shall be determined by means of testing. The tests shall be performed according to the method given in Table 2.3.

Table 2.3 Slip

No	characteristic	number of samples per type of coupler	test method and evaluation	expression of performance
1	Slip at specific load level	≥ 3 for min d ≥ 3 for medium d (where Δd> 10 mm) ≥ 3 for max d	Annex A.4	Average of all s_1, s_2 values per type for each tested size [mm]

2.2.4 Resistance to high cycle fatigue loading

The fatigue strength according to Table 2.4 shall be determined by means of testing. The tests shall be performed according to the method given in Table 2.4.

Table 2.4 Resistance to high cycle fatigue loading

No	characteristic	number of samples per type of coupler	test method and evaluation	expression of performance
1	Fatigue strength for $N = 2 \cdot 10^6$ load cycles	≥ 3 for min d ≥ 3 for medium d (where Δd> 10 mm) ≥ 3 for max d	Annex A.5	$\Delta\sigma_{Rsk,n=2\cdot10^6}$ [MPa]
2	Fatigue strength for S-N curve with k_1 [-] and k_2 [-] according to EN 1992-1-1	≥ 3 for min d ≥ 3 for medium d (where Δd> 10 mm) ≥ 3 for max d	Annex A.5	$\Delta\sigma_{Rsk}$ [MPa]; k_1 [-] and k_2 [-]
3	Fatigue strength for S-N curve with specific k_1 [-] and k_2 [-]	≥ 24 with most unfavourable d	Annex A.5	$\Delta\sigma_{Rsk}$ [MPa]; k_1 [-] and k_2 [-]

2.2.5 Resistance to low cycle loading (seismic actions)

The resistance according to Table 2.5 shall be determined by means of testing. The tests shall be performed according to the method given in Table 2.5.

Table 2.5 Characteristic resistance to low cycle loading (seismic actions)

No	characteristic	number of samples per type of coupler	test method and evaluation	expression of performance
1	Strain value and ultimate strength – Alternating tension and compression test	≥ 3 for min d ≥ 3 for medium d (where Δd> 10 mm) ≥ 3 for max d	Annex A.6	u_{20} [mm]; F_u [kN]

2.2.6 Reaction to fire

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

Therefore, the performance of the product is class A1.

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 products covered by this EAD the applicable European legal act is Commission Decision 2000/606/EC.

The system is **1+**.

3.2 Tasks of the manufacturer

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

Table 3.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC)					
1	Raw material – mechanical characteristics (inspection certificate)	Clause 3.4	1)		every heat of material
2	Coupler - tensile strength	Clause 3.4	1)	1 per size	every 2500[2)] pieces of each batch or per each batch[3)]
3	Coupler - dimension and tolerances (diameter, length of the sleeve; diameter, length and pitch for thread of sleeve and of rebar)	Clause 3.4	1)	1 per size	every 500 pieces of each batch or per each batch[3)]

1) according to the control plan

2) After successful results of continuous testing during the first year of production, the test frequency may be reduced to one every 5000.

3) whichever criterion is the more rigorous

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 the mechanical couplers are laid down in Table 3.2.

Table 3.2 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	The notified body shall ascertain that, in accordance with the control plan, the manufacturing plant of the product manufacturer, in particular personnel and equipment and the factory production control are suitable to ensure a continuous and orderly manufacturing of the mechanical coupler. In particular it shall be checked if all tasks given in Table 3.1 were performed.[3)]	-	[1)]	-	When starting the production or a new production line
Continuous surveillance, assessment and evaluation of factory production control					
2	It shall be verified that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan. In particular it shall be checked if all tasks given in Table 3.1 were performed.[3)]	-	[1)]	-	1 per year for each factory
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
3	Tensile strength	Clause 3.4	[1)]	3 for one size per type[2)]	1 per year
4	High-cycle fatigue	Clause 3.4	[1)]	3 for one size per type[2)]	1 per year
5	Low-cycle loading	Clause 3.4	[1)]	1 for one size per type[2)]	1 per year
6	Slip	Clause 3.4	[1)]	1 for one size per type[2)]	1 per year
7	Dimension and tolerances	Clause 3.4	[1)]	3 for one size per type[2)]	1 per year

1) as defined in the control plan

2) all sizes shall be tested within a period of 5 years

3) If the product criteria in Table3.1 are observed, it is not necessary to monitor specific stages of production.

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

The methods of control and testing are given in Annex B.

4 REFERENCE DOCUMENTS

EN 1990:2005	Eurocode - Basis of structural design
EN 1992-1-1:2004	Design of concrete structures – Part 1-1: General rules and rules for buildings
EN 1998-1:2004	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings
EN ISO 9513:2012	Metallic materials – Calibration of extensometers used in uniaxial testing
EN 10204:2014	Metallic products - Types of inspection documents
EN ISO 15630-1:2019	Steel for the reinforcement and prestressing of concrete – Test methods – Part 1: Reinforcing bars, wire rod and wire

ANNEX A DETAILS OF TESTS AND EVALUATION OF THE TEST RESULTS

A.1 General

All the dimensions with tolerances and material properties of load bearing parts of the coupler have to be determined before testing according to table 2.2 to 2.5.

In the tests, the yield strength and the ductility of the coupler parts raw material have to be reported. If the raw material properties of the coupler parts are modified (e.g. forming), then additional relevant testing on those parts (e.g. hardness, tensile strength) shall be performed and reported.

If the diameters given in table 2.2.to 2.5 do not cover those cases where material or geometrical properties are most unfavourable in terms of strength, ductility, slip and fatigue strength, then these sizes shall be considered in the tests accordingly. The diameters which are not tested should be verified by affinity.

The procedure of testing the manufacturing and the installation safety of a mechanical coupler type shall take into account any variations which may occur at the place of production and on site. The parameters to be investigated are defined on the basis of the tolerances specified by the manufacturer in each individual case referring to the manufacturer's instruction respectively for the rebar preparation and for the splice assembly or installation.

Before carrying out the tests, it is necessary to verify that the tested sizes are unfavourable in terms of strength, ductility, slip and fatigue strength. In most of the cases the largest diameter is unfavourable in terms of slip and fatigue strength. Examples are:

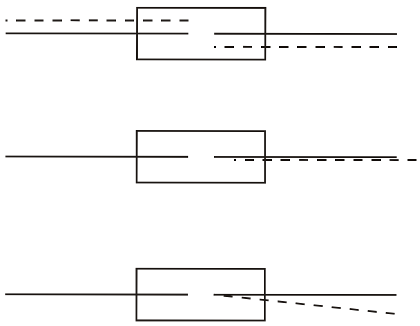
(1) Unfavourable geometrical and material tolerances of the mechanical couplers and the reinforcing bars

(2) Lateral offset of the reinforcing bars referring to the coupler longitudinal axis

(3) Longitudinal outwards offset of the reinforcing bars referring to the coupler longitudinal axis

(4) Angular misalignment of the reinforcing bars longitudinal axis referring to the coupler longitudinal axis

(5) Inaccurate processing (e.g. low turning moment, imperfect pressing)



Example to clause 2

Example to clause3

Example to clause 4

Figure A.1 Examples of deviations

A.2 Test specimens

The specimens shall be prepared according to the installation instructions from the supplier of the mechanical coupler and according to the relevant parameters see clause A.1.

The specimens for the tensile tests shall be sufficiently long to ensure a free length between the grips of the testing machine to allow the determination of A_{gt}. The following free lengths are the minimum required lengths:

i. For d < 25 mm: free length = 400 mm + length of mechanical splice

ii. For d ≥ 25 mm: free length = 350 mm + 2 x d + length of mechanical splice

The specimens for the fatigue tests shall be sufficiently long to ensure a free length between the grips of testing machine, which is larger than the length of the mechanical splice.

The coupler or coupling sleeve should be positioned in the middle of the test piece.

The reinforcing bars shall be portion of the same bar, or at least from the same casting.

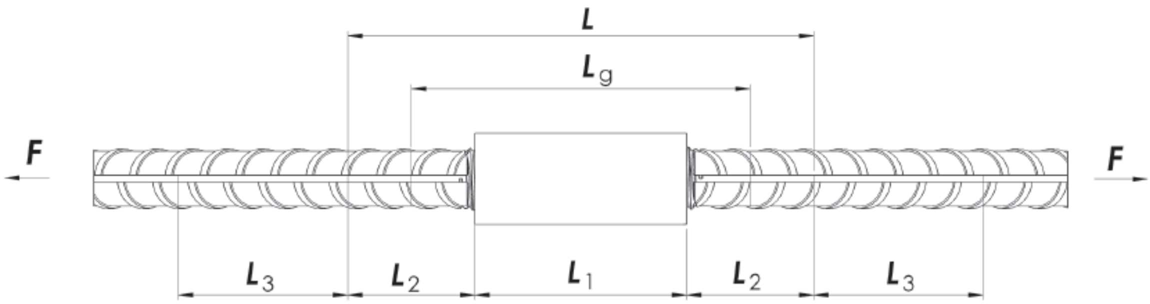


Figure A.2 Definition of lengths for measurement of elongations of the mechanical splice

A.3 Resistance to static or quasi-static loading

For the diameters according to Table 2.2 at least 3 tests until failure shall be performed.

The test specimens for the slip test may also be used for this test.

The tests shall be carried out according to EN ISO 15630-1.

3 modes of failure, or a combination thereof, are possible:

a) Failure of the reinforcing steel bar outside the length of the mechanical splice
b) Failure of the reinforcing steel bar inside the length of the mechanical splice
c) Failure of the coupler

The resistance is the minimum failure load of all tests.

For failure mode a) the resistance is $f_{u,min,bar,outside}$ [MPa].

For failure mode b) the resistance is $f_{u,min,bar,inside}$ [MPa]

For failure mode c) the resistance is $f_{u,min,coupler}$ [MPa]

In addition, for failure modes b) and c) the rupture elongation $A_{gt,act}$ shall be measured according to EN ISO 15630-1 at the part of the reinforcing steel bar which is ruptured outside the splice. If this is not possible, $A_{gt,act}$ may be measured on a separate bar of the same heat at the same load level as the spliced bar and from the same length which was used in the coupled assembly.

A.4 Slip under or after static or quasi-static loading

A.4.1 General

Slip is the relative displacement of the reinforcing bar to the end of the mechanical coupler and / or of two different components of the coupler itself under defined load (see A.4.3).

The slip shall be measured at both ends of the coupler or coupling sleeve. If both ends of the coupler or coupling sleeve are identical, a slip measurement at one side is sufficient. If the coupler or coupling sleeve consists of more than one load transferring part, either an additional slip measurement between each load carrying part shall be performed or the slip shall be measured across the whole splice.

The slip is the overall slip of the mechanical splice, i.e. to the sum of all relative displacements.

Slip measurement and determination shall be performed according to A.4.1.1 or A.4.1.2.

A.4.1.1. Slip under load s_1

The slip s_1 across the mechanical splice shall be measured and determined under initial loading of $0{,}6 \cdot R_{e,nom} \cdot A_{s,nom}$ according to one of the described procedures A.4.4 to A.4.6 (equivalent test procedures). In case of dispute, procedure 2 according to Clause A.4.5 shall be used as reference procedure.

A.4.1.2. Slip after unloading s_2

The slip s_2 across the mechanical splice shall be measured after unloading from a load level of $0{,}6 \cdot R_{e,nom} \cdot A_{s,nom}$ until a load level of $0{,}02 \cdot R_{e,nom} \cdot A_{s,nom}$. The slip s_2 shall be determined as the measured length of the mechanical splice after unloading minus the length measured prior to loading minus the elastic elongation of the unspliced bar under the stress at load release.

A.4.2 Test equipment

The tensile testing machine to be used shall comply with clause 5.2 of EN ISO 15630-1.

The slip shall be measured with an accuracy of at least 0.01 mm. The extensometers shall be of class 1 or better according to EN ISO 9513, Table 2.

3 extensometers shall be used, arranged in the same plane at 120° from each other, as close to the axis of the specimen as possible. The slip value shall be reported as the average of the 3 measurements.

A.4.3 Test procedure

The slip measurement should be carried out without any pre-loading, as the latter would distort the slip measurement. In any case, any pre-loading stress, which could not be avoided when clamping the sample to the testing apparatus, should be less than $0{,}02 \cdot R_{e,nom} \cdot A_{s,nom}$.

The specimen is gripped in such a way that the load is transmitted axially and as much as possible free of bending moment on the whole length of the specimen.

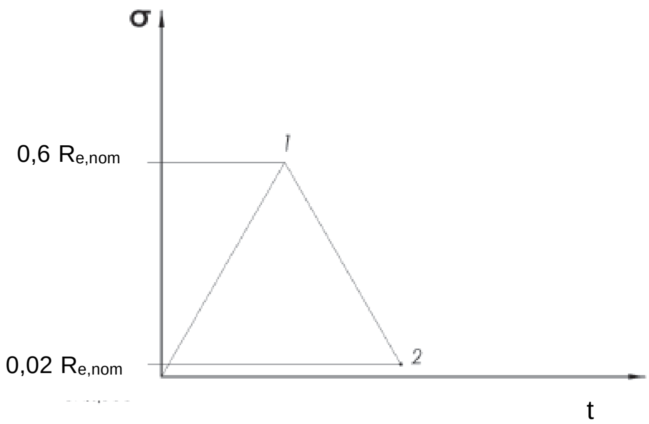


Figure A.3 Slip test procedure for s_1 and s_2

The slip and the stress shall be measured continuously. The force to be applied shall be determined using the nominal cross-sectional area of the reinforcing bar and shall not be differ more than ± 3% of $0{,}6 \cdot R_{e,nom} \cdot A_{s,nom}$.

The recommended maximum speed of loading is 500 MPa/min.

A.4.4 Procedure 1

The measurement between the end of the coupler or coupling sleeve and the reinforcing bar shall be performed. The slip is the difference between the measured elongation s_G and either the theoretical elastic elongation s_{th} of the unspliced bar over the gauge length or the actual elongation of the unspliced bar measured on a reference bar. The slip shall be measured at both ends of the coupler or coupling sleeve. If both ends of the coupler or coupling sleeve are identical, a slip measurement at one side is sufficient.

$$s = s_G - s_{th}$$

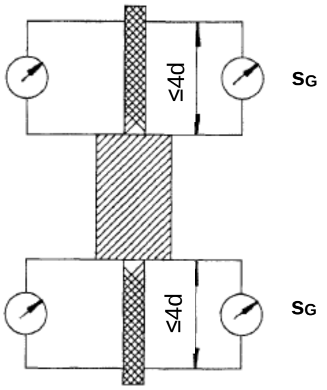


Figure A.4 Slip measurement – Procedure 1

A.4.5 Procedure 2

The slip s_G shall be measured overall and from one end of the coupler or coupling sleeve to the other. The slip s is the difference between the measured elongation s_G, the measured elongation s_c of the coupler or coupling sleeve and either the theoretical elastic elongation s_{th} of the unspliced bar over the actual length of rebar included in the gauge length or the actual elongation of the actual length of rebar included in the gauge length, measured on a reference bar. $s = s_G – s_C - s_{th}$

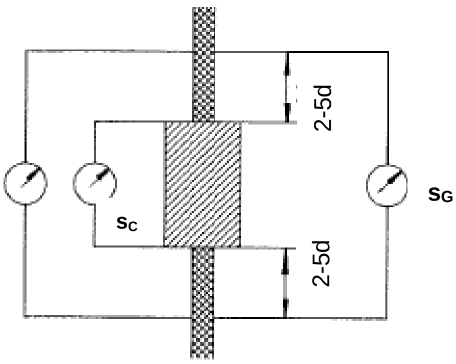


Figure A.5 Slip measurement – Procedure 2

A.4.6 Procedure 3:

The slip shall be measured from the end of the coupler or coupling sleeve to the opposite reinforcing bar and from one end of the coupler or coupling sleeve to the other. The slip is the difference between the measured elongation s_G, the measured elongation of the coupler or coupling sleeve s_C and either the theoretical elastic elongation s_{th} of the unspliced bar over the actual length of rebar included in the gauge length or the actual elongation of the actual length of rebar included in the gauge length, measured on a reference bar. $s = s_G – s_C - s_{th}$

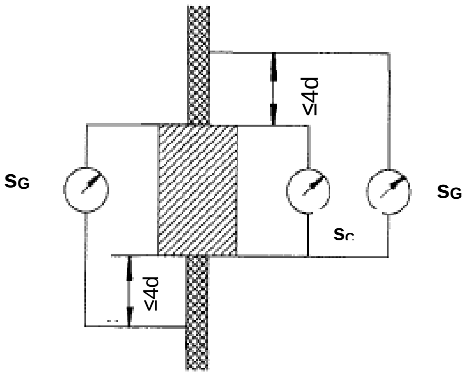


Figure A.6 Slip measurement – Procedure 3

A.5 Resistance to high-cycle fatigue loading

A.5.1 General

The tests shall be carried out according to EN ISO 15630-1, clause 8, with the following modifications:

- The free length of the specimen shall be chosen as described in clause A.2
- If the specimen fails in the grips of the testing machine or within a distance of 2·d of the grips and the mechanical coupler is still intact, the test may be continued after re-gripping the specimen with the same stress range, if the minimum free length is still available.
- The tests shall be performed with an upper stress level (σ_{max}) of 0,6·$R_{e,nom}$.
- The maximum frequency shall be 200 Hz. For frequencies higher than 60 Hz, it shall be checked that the surface temperature of the sample does not exceed 40°C during the test.

A.5.2 Fatigue strength for N = 2·10⁶ load cycles

For the diameters according to Table 2.4 at least 3 load-cycle tests according to A.5.1 with a certain stress range of $\Delta\sigma_s = 2\cdot\sigma_a$ [MPa] and at least N = 2·10^6 load cycles shall be performed.

All steel grades of coupler and rebar material specified by the manufacturer shall be tested. Steels of the same grade but different ductility class do not need to be both tested.

The value $2\cdot\sigma_a$ may be specified by the manufacturer. The minimum stress range in the tests should be $\Delta\sigma_s = 2\cdot\sigma_a$ = 60 MPa based on the nominal cross section of the bar.

If in all 9 tests no fracture occurs up to N = 2·10^6 load cycles the characteristic stress range $\Delta\sigma_{Rs,k}$ shall be determined as follows:

$\Delta\sigma_{Rsk,n=2\cdot10^6} = 0.78\cdot(2\cdot\sigma_a)$ [MPa]

If a fracture occurs before reaching N = 2·10^6 load cycles the test series shall be repeated with a smaller value $2\cdot\sigma_a$ [MPa].

If no fracture occurs in 3 further tests on a reduced stress level, the stress range $\Delta\sigma_{Rsk,n=2\cdot10^6}$ shall be determined as shown before.

A.5.3 Fatigue strength for S-N curve with k_1 [-] and k_2 [-] according to EN 1992-1-1

For each diameter according to Table 2.4 at least 3 load-cycle tests according to A.5.1 shall be performed, one test each with stress range 95 MPa, 75 MPa and 50 MPa.

If the splices sustain without fracture 0.5 million cycles at a stress range of 95 MPa, 1 million cycles at a stress range of 75 MPa and 3.5 million cycles at 50 MPa, the S-N curve according to EN 1992-1-1, Table 6.3N applies also for the couplers.

The values k_1 and k_2 according to EN 1992-1-1, Table 6.3N shall be stated in the ETA.

A.5.4 Fatigue strength for S-N curve with specific k_1 [-] and k_2 [-]

For the most unfavourable diameter at least 24 tests according to A.5.1 shall be performed in order to determine a complete S-N curve.

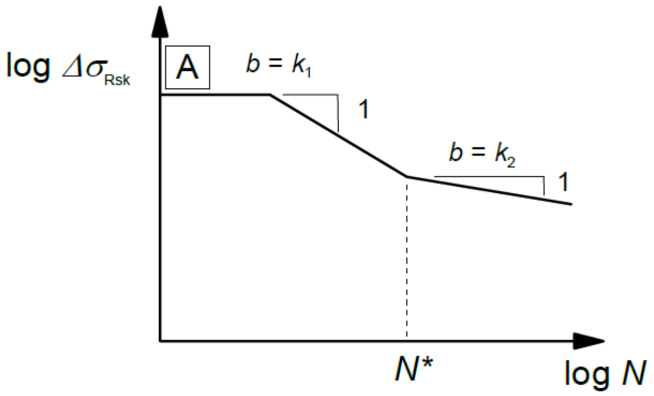


Figure A.7 S-N curve

All tests shall be carried out until the fracture of the specimen or until 10 million load cycles are reached.

The S-N curve shall be determined with respect to the following restrictions:

i. The 5-% and the 95-% quantile of the declining part of the S-N-curve (finite fatigue life range) have to be evaluated at a confidence level of 75 %, according to EN 1990.
ii. The stress ranges have to be distributed evenly in the finite fatigue life range.
ii. In the infinite fatigue life range the stress exponent k_2 according to EN 1992-1-1 has to be applied to consider long term effects.
iv. Another possibility is to test only the finite fatigue life range as given in i. - up to two million load cycles and to estimate the following stress exponents to get a complete S-N curve.

a) If the determined stress exponent k_1 is less than the exponent according to EN 1992-1-1, then the stress exponent k_1 determined in the tests shall be applied in the range from 2 million to 10 million load cycles, followed by the stress exponent $k_2 = 2k_1 - 1$.

b) If the determined stress exponent k_1 is greater than the exponent according to EN 1992-1-1, then the stress exponent k_1 according to EN 1992-1-1 shall be applied in the range from 2 million to 10 million load cycles, followed by the stress exponent k_2 according to EN 1992-1-1.

The 5 % quantile of the S-N curve ($\Delta\sigma_{Rsk}$ at N*; k_1, k_2) shall be given at a confidence level of 75 %.

A.6 Resistance to low-cycle loading (seismic actions)

A.6.1 General

Two extensometers are required to perform this test.

- First gauge to measure the bar strain ε, shall be placed on the L_3 portion of the reinforcing bar (see Figure A.2) with a gauge length L_0.
- Second gauge used to measure the residual elongation u_{20} (measured after step 1 according to Clause A.6.2 and Figure A.8), shall be placed across the mechanical splice with the gauge length L_g.

For the bars made of steels without a clear yield strain, ε_y may be taken as a strain equal the 0.2 % limit.

When deciding on the length of the specimen bars, the effective length of the reinforcing bars should be taken into account.

For the diameters according to Table 2.5 at least 3 tests in accordance with the loading program (A.6.2) shall be performed.

The resistance F_u is the minimum failure load of all tests.

A.6.2 Alternating tension and compression test

Loading program:

- Step 1: From zero stress to + 0.9·$F_{e,nom}$ down to - 0.5·$F_{e,nom}$, alternating 20 times,
- Step 2: Up to twice the calculated strain at nominal yield load in tension (ε_1), followed by downloading to a strain corresponding to the stress - 0.5·$F_{e,nom}$, alternating 4 times,
- Step 3: Thereafter up to five times the calculated strain at nominal yield load in tension (ε_2), followed by downloading to a strain corresponding to the stress - 0.5·$F_{e,nom}$, alternating 4 times,
- Step 4: Tensioning the specimen to failure.

Both residual deformation u_{20} and ultimate strength F_u shall be recorded.

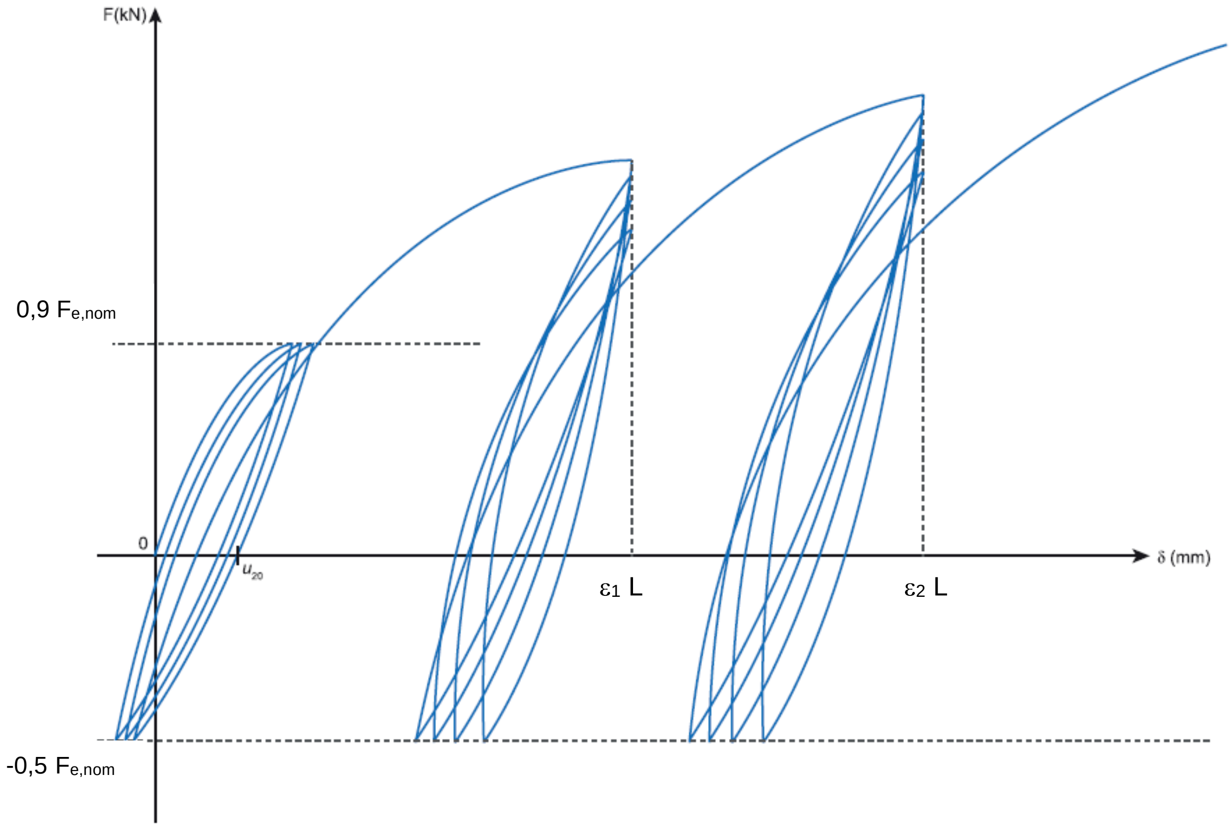


Figure A.8 Load cycle diagram for the load-cycle loading test

ANNEX B ASSESSMENT OF THE VERIFICATION OF CONSTANCY OF PERFORMANCE – DETAILS FOR AVCP

B.1 General

The different types of the mechanical coupler shall be considered. If various types of mechanical couplers are composed of identical coupling components, the notified body may decide that it is not necessary to test all of them in the course of FPC.

B.2 Raw material

The raw materials shall be subject to control and tests by the manufacturer before acceptance. Check of raw materials shall include control of the inspection documents presented by the supplies of the initial materials (comparison with nominal values).

The raw materials shall be supplied with the following documents:

Couplers:	Material and material properties to be proven by an inspection certificate 3.1 according to EN 10204 or equivalent
Reinforcement:	Material and material properties to be proven by an inspection certificate 3.1 according to EN 10204 or equivalent

B.3 Fatigue strength

B.3.1 High-cycle fatigue

Criteria for $\Delta\sigma_{Rsk,n=2\cdot10^6}$:

Load-cycle tests with a upper level of $\sigma_{up} = 0.6\ R_{e,nom}$, a stress level of $\Delta\sigma_{Rsk,n=2\cdot10^6}/0.78$ and at least $N = 2\cdot10^6$ load cycles shall be performed. The test setup shall correspond to A.5.1.

Criteria for S-N curve:

The following conditions shall be observed additional to section A.5.4 for the testing of the fatigue strength:

The specimens have to be tested with two different stress ranges in the finite fatigue life range.

The diameters have to be tested are to be varied annually in order to check the complete range of the diameters within a period of 5 years.

The location and the kind of the rupture shall be recorded.

Ruptures have to occur above the 5-% quantile of the S-N-curve determined according to A.5.3 or A.5.4. Otherwise an additional test has to be carried out directly.

B.3.2 Low-cycle loading

The test setup shall correspond to A.6.1 and tests shall be performed according to A.6.2.