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ISO
15835-2

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Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars —

Part 2:
Test methods

Aciers pour l'armature du béton — Coupleurs d'armature destinés aux raboutages mécaniques de barres —

Partie 2: Méthodes d'essai

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15835-2 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 16, *Steels for the reinforcement and prestressing of concrete*.

ISO 15835 consists of the following parts, under the general title *Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars*:

⎯ *Part 1: Requirements*

⎯ *Part 2: Test methods*

Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars —

Part 2:
Test methods

1 Scope

This part of ISO 15835 specifies test methods applicable to couplers for mechanical splices of steel reinforcing bars.

This part of ISO 15835 is intended to be applicable in relation to the various standards for steel reinforcing bars as well as in relation to the various reinforced concrete design standards.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines -- Verification and calibration of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing*

ISO 15630-1, *Steel for the reinforcement and prestressing of concrete — Test methods — Part 1: Reinforcing bars, wire rod and wire*

ISO 15835-1:2009, *Steels for the reinforcement of concrete — Reinforcement couplers for mechanical splices of bars — Part 1: Requirements*

ISO 16020, *Steel for the reinforcement and prestressing of concrete — Vocabulary*

3 Terms and definitions

For the purposes of this part of ISO 15835, the terms and definitions given in ISO 15835-1 and ISO 16020 apply.

4 Symbols

See Table 1.

Table 1 — Symbols

Symbol	Unit	Designation
A_{gt}	%	Percentage total elongation at maximum tensile force, F_{max}
d	mm	Nominal diameter of the reinforcing bar
E	MPa[a]	Nominal modulus of elasticity of the reinforcing bar
L	mm	Length of mechanical splice as defined in ISO 15835-1
L_1	mm	Coupler length
L_g	mm	Gauge length
N	—	Specified number of load cycles in axial load fatigue test
$R_{eH, spec}$	MPa	Specified characteristic (or nominal) yield strength value of the reinforcing bar
ΔL_e	mm	Calculated elastic elongation of an unspliced bar
ΔL_g	mm	Total elongation of the spliced bar measured as elongation of the gauge length
ΔL_s	mm	Slip of the mechanical splice
ε_y	%	Strain at nominal yield strength
$2\sigma_a$	MPa	Stress range for high cycle fatigue test
σ_{max}	MPa	Maximum stress in the axial load fatigue test
σ_{min}	MPa	Minimum stress in the axial load fatigue test
[a] 1 MPa $= 1$ N/mm^2.		

5 Testing of mechanical splices

5.1 General

All tests shall be carried out on mechanical splices assembled in the same manner as they are prepared for normal use, see 5.2.

The installation instruction documents for the coupler shall be made available to the testing laboratory.

A reference bar from the same heat shall be tested to determine its actual mechanical properties.

The test methods covered by this part of ISO 15835 are:

a)   tensile test;

b)   slip test;

c)   high cycle fatigue test;

d)   low cycle fatigue tests.

The performance of mechanical splices may be dependent on the rib geometry of the steel reinforcing bar. The specified rib geometry of the test bar shall be provided by the supplier and recorded with the test results.

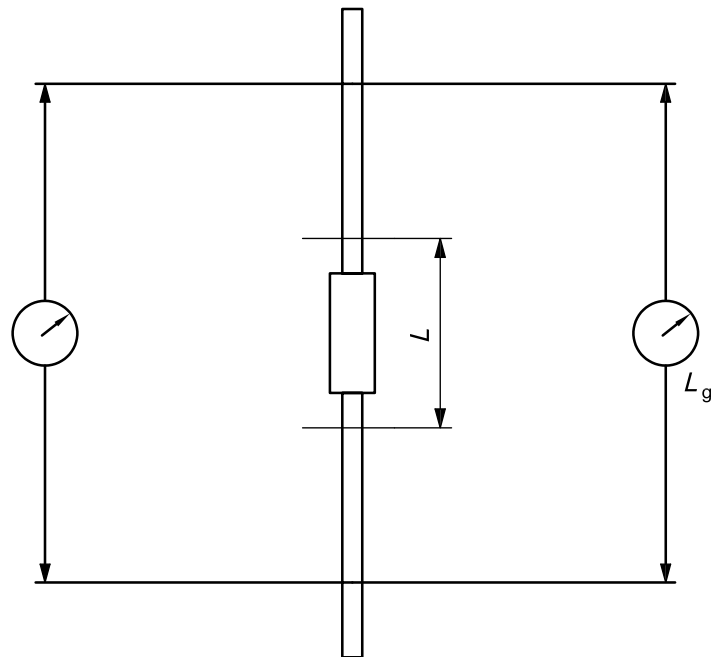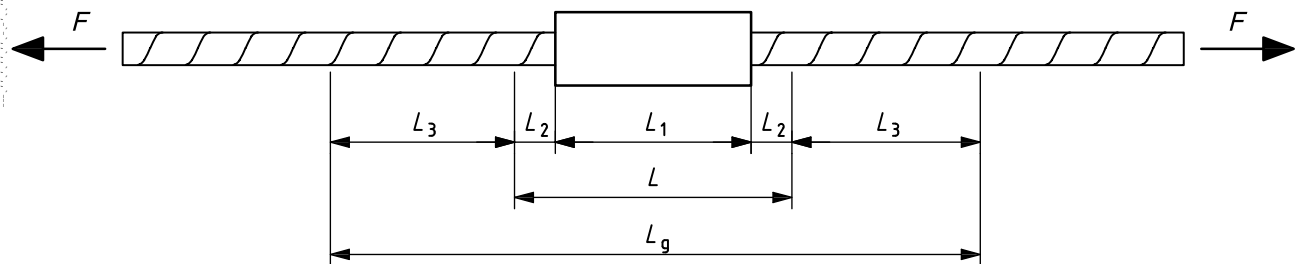The principle of measurement and the geometry for the measuring of elongations is shown in Figures 1 and 2.

Figure 1 — Principle of measurement

Key

F applied force

L length of the mechanical splice (as defined in ISO 15835-1)

L_1 coupler length

L_2 $2d$ where d is the nominal diameter of the reinforcing bar

L_3 in the range, $2d$ to $3d$

L_g overall gauge length, in the range from $L_1 + 8d$ to $L_1 + 10d$

Figure 2 — Definition of lengths for measuring elongations of the mechanical splice

5.2   Preparation of test pieces

The test pieces shall be assembled and prepared according to written installation instructions from the supplier of the coupler.

The coupler shall be positioned in the middle of the test piece.

The test piece for the tensile test shall be sufficiently long to ensure a free length between the grips of the testing machine to allow determination of A_{gt}. The minimum sufficient free length, in millimetres, of the test piece for the tensile test is $400 + L$, where L is the length of mechanical splice (as defined in ISO 15835-1).

The test piece for the slip test may have a shorter free length than the test piece for the tensile test. However, the free length, in millimetres, should not be less than $250 + L$.

The gauge length for determining A_{gt} shall, for both bars, be located outside the length of the mechanical splice (as defined in ISO 15835-1).

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

5.3 Tensile test

5.3.1 General

The strength and ductility are determined by means of a tensile test. The test pieces from the slip test may be used for this test.

5.3.2 Testing equipment

The testing equipment shall conform to ISO 15630-1.

5.3.3 Test procedure

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

The A_{gt} in the spliced bar shall be tested and measured according to ISO 15630-1 outside the length of the mechanical splice (as defined in ISO 15835-1) on both sides of the connection. Both values shall be recorded and the largest shall be used to assess conformity.

For the calculation of stresses, the nominal cross-sectional area of the reinforcing bar shall be used.

5.3.4 Failure mode and location

The location of the failure shall be reported as one of the following two locations:

a) within the mechanical splice length as this is defined in ISO 15835-1;

b) outside the mechanical splice length as this is defined in ISO 15835-1.

The failure mode shall be reported, if requested.

5.4 Slip test

5.4.1 General

The slip shall be measured overall according to Figure 1. If the coupler consists of more than one load-transferring part, an additional slip measurement between each load-carrying part should also be taken. The slip measurement shall be taken as the largest of the overall measurement and the sum of measurements for each part.

Determine the slip measurement, ΔL_s, according to Option 1 of 5.3.1 (in ISO 15835-1:2009), for each position, by Equation (1):

$$\Delta L_s = \Delta L_t - \Delta L_e \tag{1}$$

The elastic elongation of the unspliced bar, ΔL_e, is given by Equation (2)

$$\Delta L_e = \frac{\sigma}{E} \times L_g \tag{2}$$

where

$$\sigma = \frac{4F}{\pi d^2}$$

in which F is the applied force.

For carbon steel and low-alloy steel reinforcing bars, the value for E shall be taken as $2,0 \times 10^5$ MPa.

NOTE   By this option a reduced stiffness of the splice is compensated by a stiff coupling. The test result can, in special cases, be registered as a negative slip.

Determine slip measurement, ΔL_s, according to Option 2 of 5.3.1 (in ISO 15835-1:2009), for each position, by Equation (3):

$$\Delta L_s = L_{g2} - L_{g1} \tag{3}$$

where

L_{g2} is the measured length, L_g, after loading;

L_{g1} is the measured length, L_g, before loading.

5.4.2 Testing equipment

The tensile testing machine to be used shall conform to ISO 15630-1.

The extensometer used shall be in accordance with ISO 9513, class 2 or better. The extensometer used to determine the slip shall be at least a two-point (averaging) type, but preferably a three-point (averaging) type.

The slip measurement device shall be rigid enough, and fixed securely, so that the slip can be measured with an accuracy of not less than 0,01 mm.

This accuracy should be checked periodically (e.g. annually and always if there is a change in the testing conditions) by performing the test on a control bar with the same gauge length. The measurement accuracy is computed as the sum of the accuracy of the extensometer (as stated by its manufacturer) plus the error that could be generated by the fixing devices. If the slip measurement is done under load, the measurement accuracy is the difference between the measured and the calculated elastic elongation. If the measurement is done after load release, the measurement accuracy is the reading after the load is returned to zero.

5.4.3 Test procedure

The test piece shall be gripped in the testing equipment in such a way that the load is transmitted axially and as much as possible free of any bending moment on the whole length of the test piece.

The slip measurement should be carried out without any preloading of the test piece. If a small preloading is unavoidable to clamp the bar, the preloading stress in the bar shall be less than 4 MPa and the corresponding slip measurement, if any, shall be noted and included in the test report.

NOTE 1   Preloading of the test piece will normally take most of the slip out. A preloading does not normally occur for spliced bars in a structure.

The gauges shall be set to zero after closure of the jaws of the tensile testing machine.

The load cycling for qualification testing shall be carried out in accordance with the principle shown in Figure 3.

NOTE 2   Qualification testing consists of tests carried out to provide the characteristics of the mechanical splice.

Key
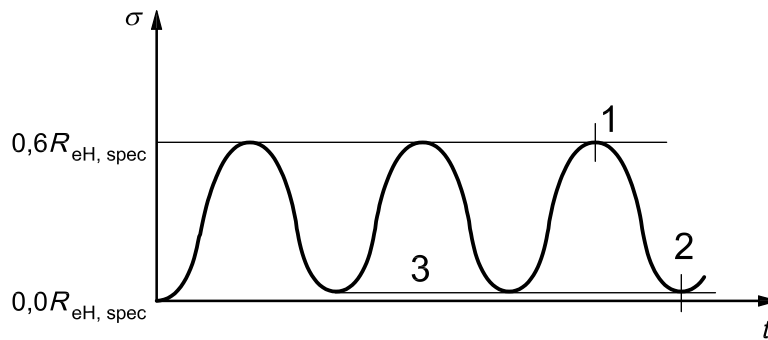
σ stress

t time

1   stresses for option 1 measurement

2   stresses for option 2 measurement

3   target value $0{,}02R_{eH, spec}$

Figure 3 — Slip test load cycling

If option 1 for testing of 5.3.1 (in ISO 15835-1:2009) is used, the slip shall be measured at a stress equivalent to minimum $0{,}6R_{eH, spec}$, where $R_{eH, spec}$ is the specified minimum yield strength of the bar after three load cycles. The force to be applied shall be determined using the nominal cross-sectional area of the reinforcing bar.

The stresses effectively applied to achieve $0{,}6R_{eH, spec}$ shall not deviate by more than $\pm$ 3 % from this value.

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

If Option 1 (see ISO 15835-1) for testing is used, the elongation of the spliced bar shall be recorded when the specified stress is reached at the third load cycle. The slip shall be calculated using Equation (1).

If Option 2 (see ISO 15835-1) for testing is used, the slip can be taken as the length measured after unloading minus the length measured prior to loading using Equation (3).

The options shall not be interchanged.

If the qualification testing demonstrates that the difference between one and three cycles is less than 10 %, then only one cycle can be used for acceptance testing.
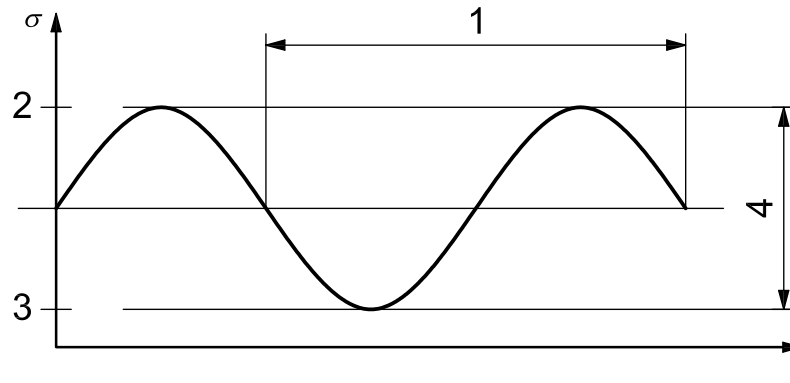
5.5   High cycle fatigue test

5.5.1   Principle of the test

The fatigue performance of a mechanically spliced bar will normally be lower than that of the unspliced bar. The purpose of fatigue testing of mechanical splices for steel reinforcing bars is to determine the fatigue strength of the mechanical splice.

In the axial load fatigue test, the test piece is subject to an axial tensile force which varies cyclically according to a sinusoidal wave-form of constant frequency in the elastic range (see Figure 4).

As an alternative to testing in air, the high cycle fatigue test may be performed with the mechanical splice concreted into a purpose-made beam. Conditions, including test procedure, are subject to national provisions.

Key

t time

σ stress

1   load cycle
2   upper stress level
3   lower stress level
4   stress range ($2\sigma_a$)

Figure 4 — Load cycle diagram for the high cycle fatigue test

5.5.2 Testing equipment

The fatigue test shall be carried out under force control.

The fatigue testing machine shall be calibrated according to ISO 7500-1, the accuracy shall be ± 1 % or better, and the machine shall be capable of maintaining the upper stress level, σ_{max}, within ± 2 % of the specified value and the lower stress level, σ_{min}, within ± 2 % of the specified value.

5.5.3 Test procedure

5.5.3.1 Gripping of test piece in the testing equipment

The test piece shall be gripped in the testing equipment in such a way that the force is transmitted axially and as much as possible free of any bending moment on the whole test piece.

5.5.3.2 Frequency and temperature

The frequency of load cycles shall be constant during the test and also during the test series. The frequency shall be between 1 Hz and 200 Hz.

NOTE   A frequency of less than 60 Hz normally gives an acceptable temperature of the samples throughout the test.

The temperature of the test piece shall not exceed 40 °C throughout the test. The temperature in the testing laboratory should be between 18 °C and 30 °C.

5.5.3.3 Termination of the test

The test is terminated upon fracture of the test piece or upon reaching a specified number of cycles without fracture.

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If the test piece fails outside the length of the mechanical splice (as defined in ISO 15835-1), the mechanical splice is still intact and there is enough bar length left for gripping, the test may be continued after re-gripping the test piece.
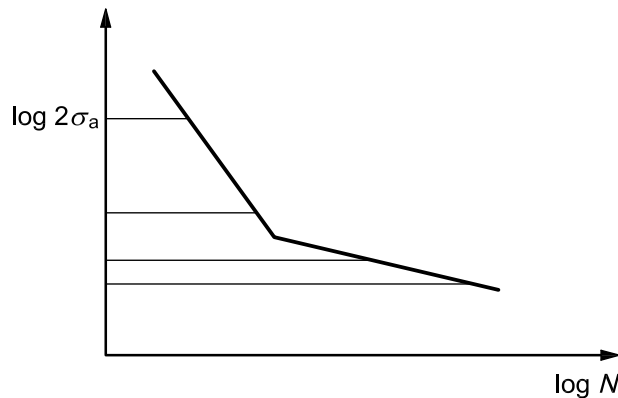
5.5.4 *S-N* diagram

The *S-N* diagram of a mechanical splice shall be determined by performing a minimum of 12 fatigue tests.

If a range of the same type of mechanical splice is to be tested, the smallest size, the largest size and an intermediate size shall be tested.

The tests shall be performed at four stress ranges with an upper stress level, σ_{max}, of $0{,}6R_{\mathrm{eH,\ spec}}$. A minimum of three test pieces at each stress range shall be tested.

The stress ranges selected shall be such that the slope of the two lines forming the *S-N* diagram can be generated (see Figure 5).

The values in the *S-N* diagram shall be determined by a regression analysis based on the lower limits of the 10 % quartile.

Key

$2\sigma_{\mathrm{a}}$ stress range for high cycle fatigue test

N specified number of load cycles in axial load fatigue test

Figure 5 — Typical form of an *S-N* diagram

NOTE   The determination of an *S-N* diagram is optional and is not required in ISO 15835-1.

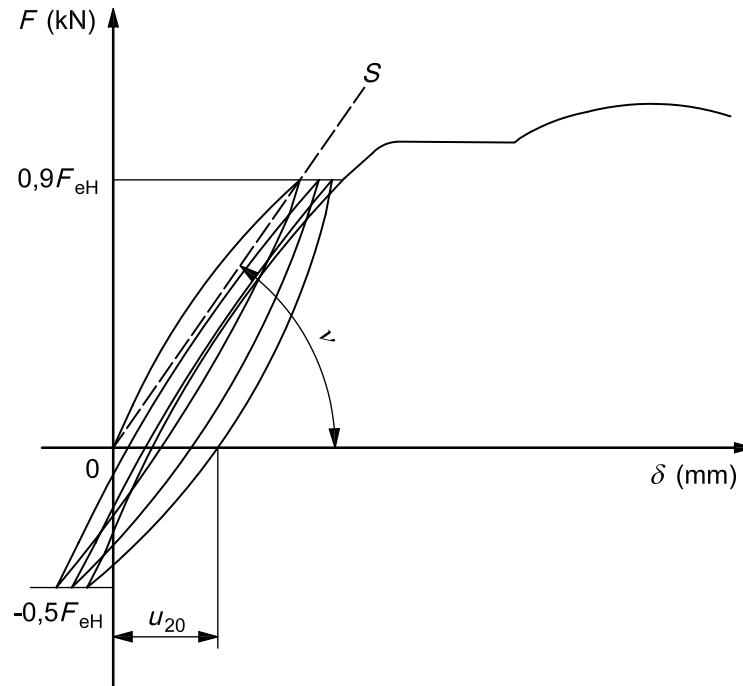## 5.6   Low cycle loading test

5.6.1   Alternating tension and compression test of high stresses in the mechanical splice

The intent of this test is to simulate elastic reverse loading of a reinforcing system during a moderate scale earthquake (category S1).

The test shall be performed as described hereafter.

The measuring gauge shall be mounted across the mechanical splice.

Loading programme: from zero stress to $0{,}9R_{\mathrm{eH,\ spec}}$ tension and down to $0{,}5R_{\mathrm{eH,\ spec}}$ in compression, alternating 20 times, followed by tensioning the test piece until failure. See Figure 6.

Key

F force

F_{eH} $A_s R_{eH,\,spec}$

S $E_s A_s / L_1$ where $E_s = 2 \times 10^5$ MPa

u_{20} residual elongation after 20 cycles

δ elongation value

ν arctan S

Figure 6 — Alternating tension and compression test for high stresses in the mechanical splice

### 5.6.2 Alternating tension and compression test of large strains in the mechanical splice

The intent of this test is to simulate large elastic-plastic reverse loading of the reinforcement system during a violent earthquake (category S2), see Figure 7.

The measuring gauge shall be mounted across the mechanical splice.

Testing of the performance requirements for mechanical splices shall have the following loading programme.

From zero strain up to twice the yield strain (strain at nominal yield strength) in tension followed by downloading to a strain corresponding to the stress $0,5 R_{eH,\,spec}$ in compression, alternating four times. Thereafter, from zero strain up to five times the yield strain in tension, followed by downloading to a strain corresponding to the stress $0,5 R_{eH,\,spec}$ in compression, alternating four times, followed by tensioning the test piece to failure, see Figure 7.

For reinforcing steels where the yield strain is not defined (i.e. where there is no clear point on the stress-strain curve to define start of yielding), ε_y may be taken as a strain equal to the 0,2 % limit.

Key
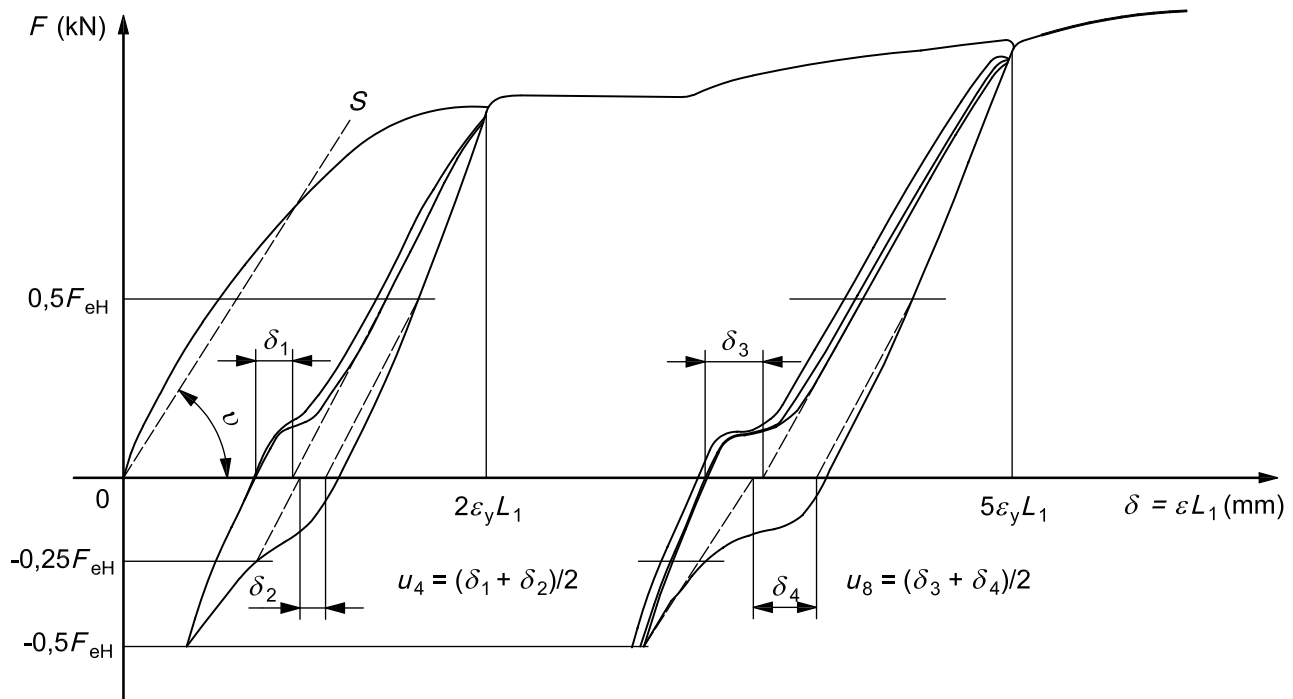
F	force
F_{eH}	$A_s R_{eH, spec}$
L_1	coupler length
S	$E_s A_s / L_1$ where $E_s = 2 \times 10^5$ MPa
u_4	residual elongation after four cycles
u_8	residual elongation after eight cycles
δ	elongation value
δ_1	elongation value represented by the distance between two crossing points on the horizontal axis, which are intersected with the parallel lines of S set from the level of loading of $0,5F_{eH}$ and from the level of reverse loading of $-0,25F_{eH}$, after alternative loading four times by $2\varepsilon_y$
δ_2	elongation value represented by the distance between two crossing points on the horizontal axis, which are intersected with the parallel lines of S set from the level of unloading stress $0,5F_{eH}$ and from the level of reverse unloading stress $-0,25F_{eH}$, after alternative loading four times by $2\varepsilon_y$
δ_3, δ_4	elongation values obtained by the same method as δ_1 and δ_2 after alternative loading four times by $5\varepsilon_y$
ε_y	strain at nominal yield strength
v	arctan S

Figure 7 — Alternating tension and compression test for large plastic strains in mechanical splice

5.7 Identification and marking

The identification and marking on the couplers shall be visually checked for their readability. The markings on the test pieces shall be stated in the test report.

6   Test report

The test report shall contain at least the following information:

a)   a reference to this part of ISO 15835;

b)   name of the laboratory;

c)   name of the organisation ordering the test (including the date);

d)   name of the individual who prepared the test piece;

e)   standard for, and grade of, reinforcement with which the test piece was prepared;

f)   nominal size of the bar;

g)   rib geometry of the bar;

h)   name of the supplier of the coupler and markings on the coupler (size, type and batch number, legibility of batch number);

i)   details of assembly of the test piece(s) (e.g. torque value used, temperature);

j)   diameter and length of the coupler;

k)   force used for slip testing;

l)   slip values obtained;

m)   tensile strength achieved;

n)   location of failure (i.e. in the bar, in the interface bar/coupler or in the coupler);

o)   the A_{gt} achieved including plots of load-elongation or stress-strain showing a continuous record of data from throughout the test;

p)   fatigue or low cycle test results where relevant;

q)   name of the laboratory operator;

r)   name and signature of the person responsible for preparation of the test report.

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