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Steel for the reinforcement and prestressing of concrete — Test methods —

Part 1: Reinforcing bars, rods and wire

Aciers pour l'armature et la précontrainte du béton — Méthodes d'essai —

Partie 1: Barres, fils machine et fils pour béton armé

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 17, *Steel*, Subcommittee SC 16, *Steels for the reinforcement and prestressing of concrete.*

This third edition cancels and replaces the second edition (ISO 15630-1:2010), which has been technically revised. Changes have been introduced in the Introduction, Clause 2, Clause 3, Clause 4, Clause 5 (only the title), 5.3, 6.3, 8.3, 8.4.5, 10.3.1.1, 10.3.1.2, 10.3.3 and 11.3.2 and Figure 6. A new Clause 13 has been added for "specialized" tests. The Bibliography has been updated and the dated references have been replaced by undated references.

A list of all parts in the ISO 15360 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The aim of ISO 15630 (all parts) is to provide all relevant test methods for reinforcing and prestressing steels in one standard series.

This document covers standard test methods (see Clauses 5 to 12), as well as specialized test methods (gathered in Clause 13) that are not commonly used in routine testing and that should only be considered where relevant (or specified) in the applicable product standard.

Reference is made to International Standards on the testing of metals, in general, as they are applicable. Complementary provisions have been given if needed.

Steel for the reinforcement and prestressing of concrete — Test methods —

Part 1:
Reinforcing bars, rods and wire

1 Scope

This document specifies chemical and mechanical test methods and measurement methods of geometrical characteristics applicable to reinforcing bars, rods and wire for concrete.

This document does not cover the sampling conditions that are dealt with in the product standards.

A list of options for agreement between the parties involved is provided in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 4965-1, *Metallic materials — Dynamic force calibration for uniaxial fatigue testing — Part 1: Testing systems*

ISO 4965-2, *Metallic materials — Dynamic force calibration for uniaxial fatigue testing — Part 2: Dynamic calibration device (DCD) instrumentation*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature*

ISO 6892-3, *Metallic materials — Tensile testing — Part 3: Method of test at low temperature*

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

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

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

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 16020 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

For the purposes of this document, the following symbols apply.

Symbol	Unit	Description	Reference
a'	mm	Height of longitudinal rib	10.3.2, 11.3
a_m	mm	Rib height at the mid-point or indentation depth in the centre	10.3.1.2, Figure 6, 11.3.2, 11.4.1, 11.4.2
a_{max}[a]	mm	Maximum height of transverse rib or maximum indentation depth	10.3.1.1
$a_{s,i}$	mm	Average height of a portion i of a rib subdivided into p parts of length Δl, or average depth of a portion i of an indentation subdivided into p parts of length Δx	Figure 6, 11.3.1, 11.4.1
$a_{1/4}$	mm	Rib height at the quarter-point or indentation depth at the quarter of their length	10.3.1.2, 11.3.2, 11.4.2
$a_{3/4}$	mm	Rib height at the three-quarters point or indentation depth at the three-quarters of their length	10.3.1.2, 11.3.2, 11.4.2
A	%	Percentage elongation after fracture	5.1, 5.3
A_g	%	Percentage plastic extension at maximum force (F_m)	5.3
A_{gt}	%	Percentage total extension at maximum force (F_m)	Clause 5
A_r	%	Percentage uniform elongation after fracture	5.3
b	mm	Width of transverse rib at the mid-point or width of indentation	10.3.8
c	mm	Transverse rib or indentation spacing	Figure 6, 10.3.3, 11.3
d	mm	Nominal diameter of the bar, rod or wire	5.3, Figure 3, 8.2, 8.4.7, 11.3, 11.4, Table 1, 13.3.4.8
D	mm	Diameter of the mandrel of the bending device in the bend or rebend test	Figure 2, 6.3, 7.3.2
e	mm	Average gap between two adjacent rib or indentation rows	10.3.5, Figure 6, 11.3.2, Figure 7
f	Hz	Frequency of force cycles in the axial force fatigue test	8.1, 8.4.3, Table 1
f_P	—	Relative indentation area	Clause 11
f_R	—	Relative rib area	Clause 11
F_m	N	Maximum force in the tensile test	5.3
F_P	mm^2	Area of the longitudinal section of one indentation	11.4.1
F_r	N	Force range in the axial force fatigue test	8.1, 8.3, 8.4.2, 8.4.3
F_R	mm^2	Area of the longitudinal section of one rib	Figure 6, 11.3.1
F_{up}	N	Upper force in the axial force fatigue test	8.1, 8.3, 8.4.2, 8.4.3
l	mm	Length of the transverse rib at the rib-core interface	Figure 6
n, m, q, p	—	Quantities used in formulae defining f_R, f_P, F_R and F_P	11.3, 11.4
P	mm	Pitch for cold-twisted bars	10.3.4, 11.3
r_1	mm	Distance between the grips and the gauge length for the manual measurement of A_{gt}	5.3
r_2	mm	Distance between the fracture and the gauge length for the manual measurement of A_{gt}	5.3
R_{eH}	MPa	Upper yield strength	5.3
R_m	MPa	Tensile strength	5.3
$R_{p0,2}$	MPa	0,2 % proof strength, plastic extension	5.2, 5.3
S_n	mm^2	Nominal cross-sectional area of the bar, rod or wire	8.4.2
x	mm	Length of an indentation	Figure 7

NOTE 1 MPa = 1 N/mm^2.

[a] In some product standards, the symbol h is also used for this parameter.

Symbol	Unit	Description	Reference
α	°	Transverse rib flank inclination	10.3.7
β	°	Angle between the axis of a transverse rib or indentation and the bar, rod or wire axis	10.3.1, 10.3.6, Figure 6, 11.3, 11.4
γ	°	Angle of bend in the bend or rebend test	6.3, Figure 4, 7.3.2
Δl	mm	Incremental part of the length of the transverse rib at the rib-core interface	11.3.1, Figure 6
Δx	mm	Incremental part of the length of an indentation	11.4.1
δ	°	Angle of rebend in the rebend test	Figure 4, 7.3.4
λ	—	Empirical factor in empirical formulae of f_R and f_P	11.3.2, 11.4.2
φ	—	Empirical factor in formula of f_R for ribs of constant height	11.3.2
$2\sigma_a$	MPa	Stress range in the axial force fatigue test	8.4.2
σ_{max}	MPa	Maximum stress in the axial force fatigue test	8.4.2
$\sum e_i$	mm	Part of the circumference without indentation or rib	10.3.5, 11.3.2, 11.4.2

NOTE 1 MPa = 1 N/mm^2.

[a] In some product standards, the symbol *h* is also used for this parameter.

4 General provisions concerning test pieces

Unless otherwise agreed or specified in the product standard, the test piece shall be taken from the bar, rod or wire in the as-delivered condition.

In the case of a test piece taken from a coil (rod or wire), the test piece shall be straightened prior to any testing by a bend operation with a minimum amount of plastic deformation.

NOTE 1 The straightness of the test piece is critical for the tensile test at room temperature, the tensile test at low temperature, the axial force fatigue test and the cyclic inelastic load test.

The means of straightening the test piece (manual, machine) shall be indicated in the test report.

For routine tests conducted by the manufacturers of reinforcing steels, the test information, including the test piece condition and method of straightening, should be described within internal documentation.

For the determination of the mechanical properties in the tensile test at room temperature, the tensile test at low temperature, the axial force fatigue test and the cyclic inelastic load test, the test piece may be artificially aged (after straightening if applicable), depending on the requirements of the product standard.

If ageing is specified but the product standard does not specify the ageing treatment, the following conditions should be applied: heating the test piece to 100 °C, maintaining at this temperature ±10 °C for a period between 60 min and 75 min and then cooling in still air to ambient temperature.

NOTE 2 Depending on the conditions (number of test pieces, diameter of test pieces, type of heating device), different heating times can be required for the test piece to reach the temperature of 100 °C. Unless otherwise proven, a minimum heating time of 40 min can be assumed for the test pieces to reach the oven/bath operating temperature.

If an ageing treatment is applied to the test piece, the conditions of the ageing treatment shall be stated in the test report.

5 Tensile test at room temperature

5.1 Test piece

In addition to the general provisions given in Clause 4, the free length of the test piece shall be sufficient for the determination of the percentage elongation after fracture or the percentage total extension at maximum force in accordance with 5.3.

If the percentage elongation after fracture (A) is determined manually, the test piece shall be marked in accordance with ISO 6892-1.

If the percentage total extension at maximum force (A_{gt}) is determined by the manual method, equidistant marks shall be made on the free length of the test piece (see ISO 6892-1). The distance between the marks shall be 20 mm, 10 mm or 5 mm, depending on the test piece diameter.

5.2 Test equipment

The testing machine shall be verified and calibrated in accordance with ISO 7500-1 and shall be at least of class 1.

If an extensometer is used, it shall be of class 1 in accordance with ISO 9513 for the determination of $R_{p0,2}$; for the determination of A_{gt}, a class 2 extensometer (see ISO 9513) may be used.

Any extensometer used for the determination of the percentage total extension at maximum force (A_{gt}) shall have a gauge length of at least 100 mm. The gauge length shall be indicated in the test report.

5.3 Test procedure

The tensile test shall be performed in accordance with ISO 6892-1. For the determination of $R_{p0,2}$, if the straight portion of the force-extension diagram is limited or not clearly defined, one of the following methods shall be applied:

— the procedure recommended in ISO 6892-1;

— the straight portion of the force-extension diagram shall be considered as the line joining the points corresponding to $0,2F_m$ and $0,5F_m$.

F_m may be predefined as the force corresponding to the nominal tensile strength given in the applicable product standard.

For stainless steels, other values than the ones mentioned above, applicable to carbon steels, may be replaced by the appropriate values given in the product standard or agreed between the parties involved.

In case of dispute, the second procedure shall be applied.

The test may be considered invalid if the slope of this line differs by more than 10 % from the theoretical value of the modulus of elasticity.

For the calculation of tensile properties (R_{eH} or $R_{p0,2}$, R_m), the nominal cross-sectional area shall be used, unless otherwise specified in the relevant product standard.

Where fracture occurs in the grips or at a distance from the grips less than 20 mm or d (whichever is the greater), the test may be considered as invalid.

For the determination of percentage elongation after fracture (A), the original gauge length shall be five times the nominal diameter (d), unless otherwise specified in the relevant product standard. In case of dispute, A shall be determined manually.

The percentage total extension at maximum force (A_{gt}) shall be determined either by using an extensometer or by the manual method described in this document.

If A_{gt} is measured by using an extensometer, ISO 6892-1 shall be applied with the following modification. A_{gt} shall be recorded before the force has dropped more than 0,2 % from its maximum value.

NOTE This provision is aimed at avoiding different values with different methods (manual vs. extensometer). It is recognized that the use of extensometers tends to give on average a lower value of A_{gt} than the one measured manually.

If A_{gt} is determined by the manual method after fracture, A_{gt} shall be calculated from Formula (1):

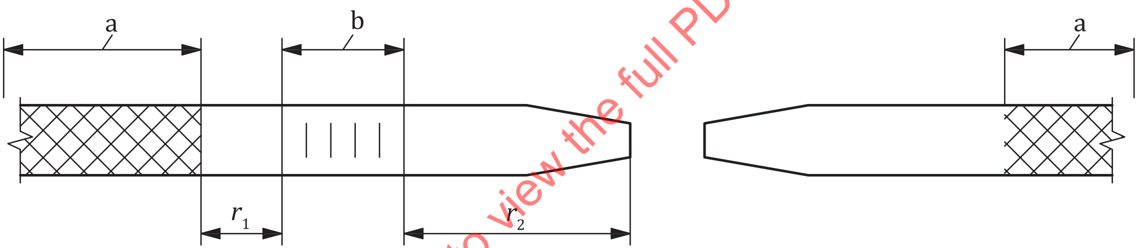
$$A_{gt} = A_r + R_m / 2\,000 \tag{1}$$

where A_r is the percentage uniform elongation after fracture.

For stainless steels, the value 2 000 in Formula (1) should be replaced by the appropriate value given in the product standard or agreed between the parties involved.

The measurement of A_r shall be made, as the measurement of A (see ISO 6892-1), on the longer of the two fractured parts of the test piece on a gauge length of 100 mm, as close as possible to the fracture but at a distance, r_2, of at least 50 mm or $2d$ (whichever is the greater) away from the fracture. This measurement may be considered as invalid if the distance, r_1, between the grips and the gauge length is less than 20 mm or d (whichever is the greater). See Figure 1.

In case of dispute, the manual method shall apply.



a Grip length.

b Gauge length 100 mm.

Figure 1 — Measurement of A_{gt} by the manual method

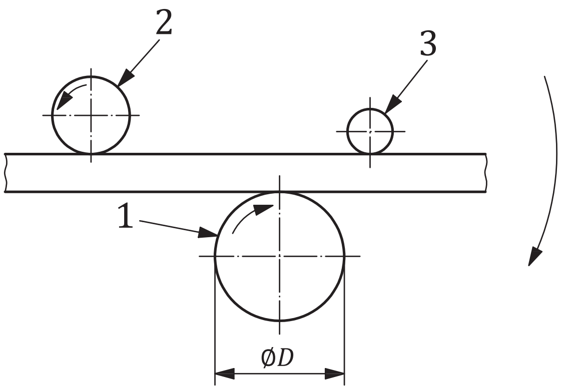
6 Bend test

6.1 Test piece

The general provisions given in Clause 4 apply.

6.2 Test equipment

6.2.1 A bending device, the principle of which is shown in Figure 2, shall be used.



Key

1 mandrel

2 support

3 carrier

Figure 2 — Principle of a bending device

NOTE Figure 2 shows a configuration where the mandrel and support rotate and the carrier is locked. It is also possible that the carrier rotates and the support or mandrel is locked.

6.2.2 The bend test may also be performed by using a device with supports and a mandrel (e.g. see ISO 7438).

6.3 Test procedure

The bend test shall be performed at a temperature between 10 °C and 35 °C, unless otherwise agreed by the parties involved.

For testing at a low temperature, if the agreement between the parties involved does not specify all the testing conditions, a deviation of ±2 °C on the agreed temperature should be applied. The test piece should be immersed in the cooling medium for a sufficient time to ensure that the required temperature is reached throughout the test piece (for example, at least 10 min in a liquid medium or at least 30 min in a gaseous medium). The bend test should start within 5 s from removal from the medium. The transfer device should be designed and used in such a way that the temperature of the test piece is maintained within the temperature range.

The test piece shall be bent over a mandrel.

In the case of hot-rolled threaded bars, the mandrel shall be placed on the longitudinal flat part of the bar unless otherwise stated in the product standard or agreed between the parties involved.

The angle of bend (γ) and the diameter of the mandrel (D) shall be in accordance with the relevant product standard.

6.4 Interpretation of test results

The interpretation of the bend test shall be performed in accordance with the requirements of the relevant product standard.

If requirements are not specified in the relevant product standard, the absence of cracks visible to a person with normal or corrected vision shall be considered as evidence that the test piece withstood the bend test.

A superficial ductile tear may occur at the base of the ribs or indentations and is not considered to be a failure. The tear may be considered superficial when the depth of the tear is not greater than the width of the tear.

7 Rebend test

7.1 Test piece

The general provisions given in Clause 4 apply.

7.2 Test equipment

7.2.1 Bending device

A bending device as specified in 6.2 shall be used.

7.2.2 Rebending device

Rebending can be performed on a bending device as shown in Figure 2. An example of an alternative rebending device is shown in Figure 3.

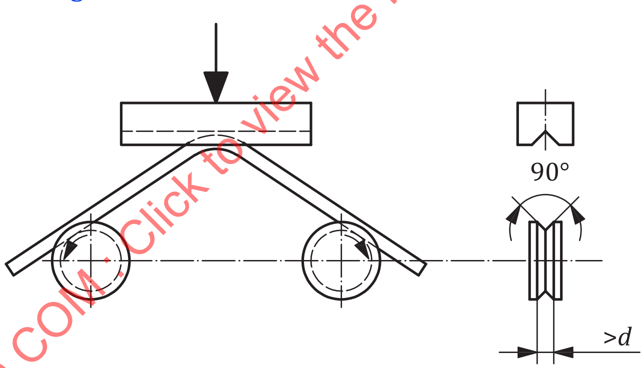


Figure 3 — Example of a rebending device

7.3 Test procedure

7.3.1 General

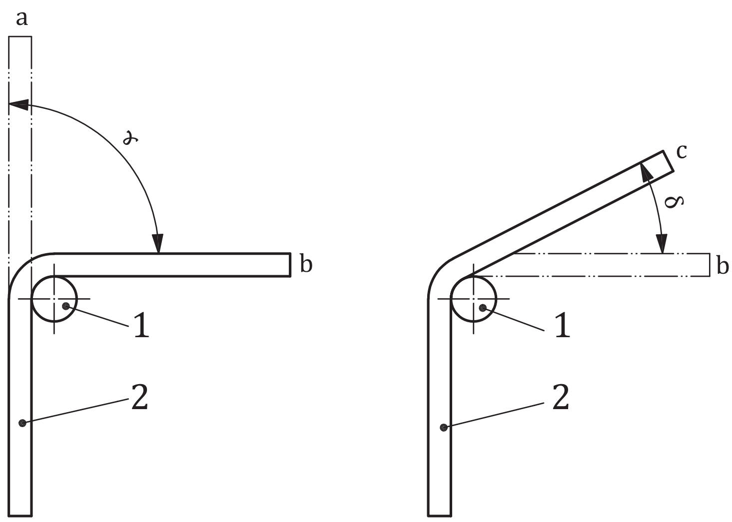
The test procedure consists of three steps:

a) bending;

b) artificial ageing;

c) rebending.

The test procedure is illustrated in Figure 4.



Key

1 mandrel

2 test piece

a Initial position

b Position after operation described in 7.3.2

c Position after operation described in 7.3.4

Figure 4 — Illustration of the test procedure for rebend tests

7.3.2 Bending

Bending shall be performed at a temperature between 10 °C and 35 °C. The test piece shall be bent over a mandrel. In the case of hot-rolled threaded bars, the mandrel shall be placed on the longitudinal flat part of the bar unless otherwise stated in the product standard or agreed between the parties involved.

The angle of bend (γ) and diameter of mandrel (D) shall be in accordance with the relevant product standard.

The test piece shall be carefully inspected for cracks and fissures visible to a person with normal or corrected vision.

7.3.3 Artificial ageing

The temperature and time of artificial ageing shall be in accordance with the relevant product standard.

If the product standard does not specify any ageing treatment, the conditions specified in Clause 4 should be applied.

7.3.4 Rebending

After free cooling in still air to a temperature between 10 °C and 35 °C, the test piece shall be bent back by a specified angle (δ) in accordance with the relevant product standard.

7.4 Interpretation of test results

The interpretation of the rebend test results shall be performed in accordance with the requirements of the relevant product standard.

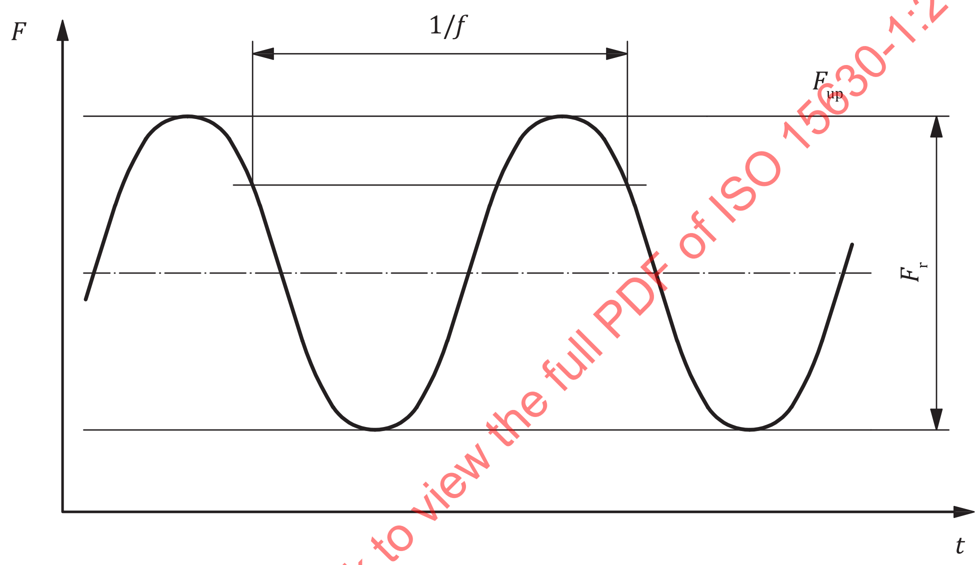
If these requirements are not specified, the absence of cracks visible to a person with a normal or corrected vision shall be considered as evidence that the test piece has withstood the rebend test.

A superficial ductile tear may occur at the base of the ribs or indentations and shall not be considered to be a failure. The tear may be considered superficial when the depth of the tear is not greater than the width of the tear.

8 Axial force fatigue test

8.1 Principle of test

The axial force fatigue test consists of submitting the test piece to an axial tensile force, which varies cyclically according to a sinusoidal wave-form of constant frequency (f) in the elastic range (see Figure 5). The test is performed until failure of the test piece or until reaching, without failure, the number of force cycles specified in the relevant product standard.



Key

F_{up} upper value of F

F_r range of F per cycle

$1/f$ one cycle

F force

t time

Figure 5 — Force cycle diagram

8.2 Test piece

The general provisions given in Clause 4 apply. For the straightening of the test piece, a machine used for the fabrication of reinforcing steels may be used.

The surface of the free length between the grips shall not be subjected to any surface treatment of any kind. The free length shall be at least 140 mm or 14d (whichever is the greater).

8.3 Test equipment

The fatigue-testing machine shall be calibrated in accordance with either ISO 4965-1 and ISO 4965-2, or ISO 7500-1. The relative error of accuracy shall be less than or equal to ±1 %. The fatigue-testing machine shall be capable of maintaining the upper force (F_{up}) within ±2 % of the specified value, and the force range (F_r) within ±4 % of the specified value.

8.4 Test procedure

8.4.1 Provisions concerning the test piece

The test piece shall be gripped in the fatigue-testing machine in such a way that force is transmitted axially and free of any bending moment along the test piece.

8.4.2 Upper force (F_{up}) and force range (F_r)

The upper force (F_{up}) and the force range (F_r) shall be as given in the relevant product standard.

NOTE F_{up} and F_r can be determined from the maximum stress (σ_{max}) and the stress range ($2\sigma_a$) given in the relevant product standard as shown by Formulae (2) and (3):

$$F_{up} = \sigma_{max} \cdot S_n \quad (2)$$

$$F_r = 2\sigma_a \cdot S_n \quad (3)$$

where S_n is the nominal cross-sectional area of the bar, rod or wire.

8.4.3 Stability of force and frequency

The test shall be performed under conditions of stable upper force (F_{up}), force range (F_r) and frequency (f). There shall be no planned interruptions in the cyclic loading throughout the test. However, it shall be permissible to continue a test which is accidentally interrupted. Any interruption shall be reported; an interrupted test may be considered as invalid.

8.4.4 Counting of force cycles

The number of force cycles shall be counted inclusively from the first full force-range cycle.

8.4.5 Frequency

The frequency of force cycles shall be stable during the test and also during a series of tests with identical testing conditions. The frequency shall be between 1 Hz and 200 Hz.

8.4.6 Temperature

The temperature of the test piece shall not exceed 40 °C throughout the test. The temperature of the testing laboratory shall be between 10 °C and 35 °C, unless otherwise specified.

8.4.7 Validity of the test

If failure occurs in the grips or within a distance of $2d$ of the grips, or initiates at an exceptional feature of the test piece, the test may be considered as invalid.

9 Chemical analysis

In general, the chemical composition is determined by spectrometric methods.

In case of dispute about analytical methods, the chemical composition shall be determined by an appropriate reference method specified in one of the relevant International Standards.

NOTE A list of the relevant International Standards for the determination of the chemical composition is given in the Bibliography.

10 Measurement of the geometrical characteristics

10.1 Test piece

The general provisions given in Clause 4 apply.

The length of the test piece shall be sufficient to allow the measurements in accordance with 10.3.

10.2 Test equipment

The geometrical characteristics shall be measured with an instrument of an accuracy of at least the following:

— 0,01 mm for the height of transverse or longitudinal ribs and depth of indentations for the measurements less than or equal to 1 mm;

— 0,02 mm for the height of transverse or longitudinal ribs and depth of indentations for the measurements greater than 1 mm;

— 0,05 mm for the gap between the transverse ribs or indentations of two adjacent transverse rib or indentation rows;

— 0,05 mm for the width of the transverse ribs or indentations;

— 0,5 mm for the distance between transverse ribs or indentations when determining the transverse rib or indentation spacing (see 10.3.3) or for the distance between two corresponding points of a longitudinal rib of cold-twisted bars when determining the pitch (see 10.3.4);

— one degree for the inclination between the transverse rib or indentation and the longitudinal axis of the bar, rod or wire or the rib flank inclination.

In cases of dispute, conventional direct-reading instruments, e.g. callipers, depth gauges, shall be used.

10.3 Test procedure

10.3.1 Heights of transverse ribs or depths of indentations

10.3.1.1 Maximum value (a_{max})

The maximum height of transverse ribs or depth of indentations (a_{max}) shall be determined as the mean value of the average maximum heights of transverse ribs or average maximum depths of indentations for the different rows. This average maximum height or average maximum depth per row shall be determined from at least three measurements on individual transverse ribs or individual indentations not used for the identification of the bar, rod or wire.

If, in a row, there are different transverse rib or indentation angles (β) to the longitudinal bar, rod or wire axis, at least three measurements on individual transverse ribs or individual indentations shall be made per transverse rib or indentation angle.

10.3.1.2 Value at a given position

The height of transverse ribs or depth of indentations at a given position, e.g. at the quarter-point or at the mid-point or at the three-quarters point, respectively designated $a_{1/4}$, a_m and $a_{3/4}$, shall be determined as the mean value of the average heights of transverse ribs or average depths of indentations at this given position for the different rows. This average height or average depth at this given position per row shall be determined from at least three measurements on individual transverse ribs or individual indentations not used for the identification of the bar, rod or wire.

If, in a row, there are different transverse rib or indentation angles (β) to the longitudinal bar, rod or wire axis, at least three measurements on individual transverse ribs or individual indentations shall be made per transverse rib or indentation angle.

10.3.2 Height of longitudinal ribs (a')

The height of longitudinal ribs (a') shall be determined as the mean value of the average heights of all longitudinal ribs. The average height of each longitudinal rib shall be determined from at least three measurements of the height at three different positions.

10.3.3 Transverse rib or indentation spacing (c)

The spacing of the transverse ribs or indentations (c) shall be determined as the mean value of the average spacing of transverse ribs or indentations for the different rows.

For each row, the spacing of the transverse ribs or indentations (c) shall be determined from a measured length divided by the number of the rib gaps or protrusions between indentations included in the measured length.

The measured length is deemed to be the interval between the centre of a rib or indentation and the centre of another rib or indentation of the same transverse rib or indentation angle on the same row of the test piece determined in a straight line and parallel to the longitudinal axis of the test piece. The measured length shall

— include at least 10 rib gaps or protrusions between indentations, or

— be one pitch length for cold-twisted bars.

10.3.4 Pitch (P)

The pitch (P) for cold-twisted bars shall be determined as the mean of the distances between two consecutive corresponding points of a longitudinal rib on the same longitudinal line, for each longitudinal rib.

10.3.5 Part of the circumference without ribs or indentations (Σe_i)

The part of the circumference without ribs or indentations (Σe_i) shall be determined as the sum of the average gap (e) between each pair of two adjacent ribs or indentation rows. The average gap (e) shall be determined from at least three measurements.

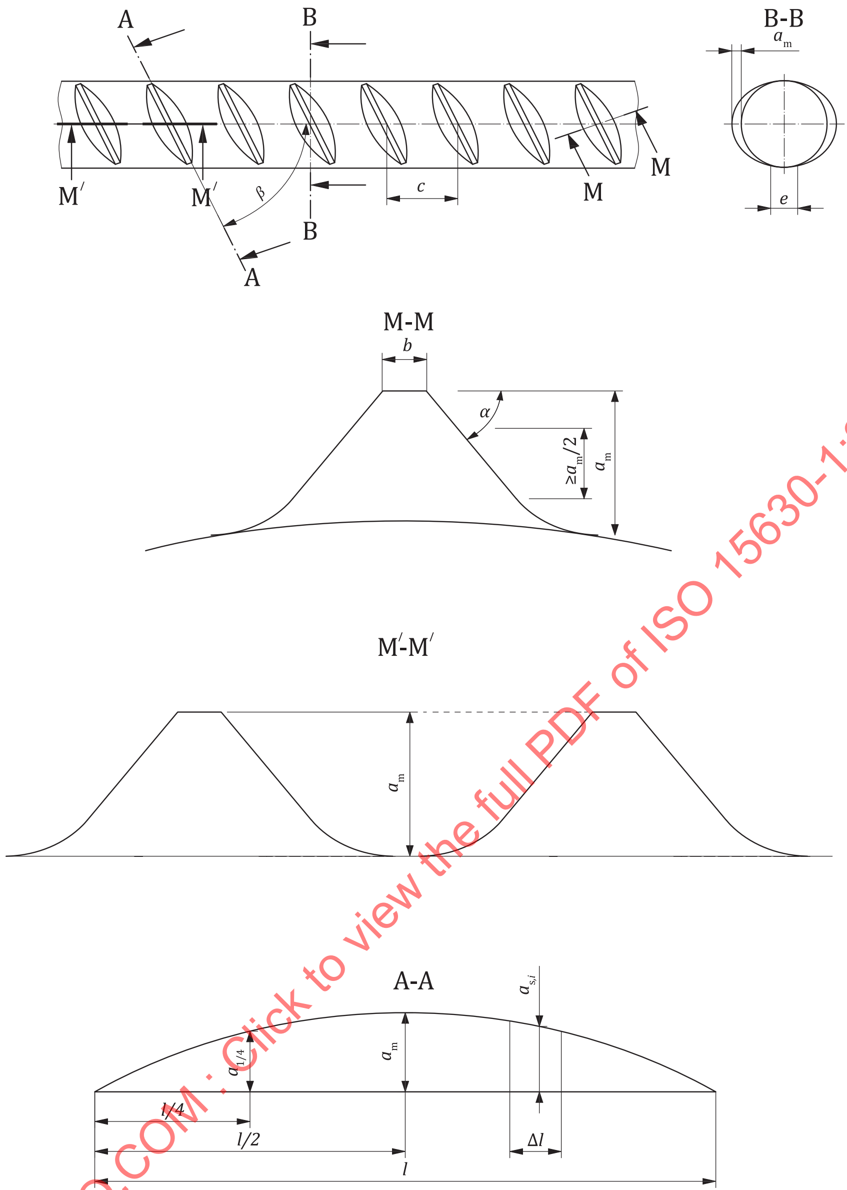
10.3.6 Transverse rib or indentation angle (β)

The transverse rib or indentation angle (β) to the longitudinal bar, rod or wire axis shall be determined as the mean of the individual angles measured for each row of ribs or indentations with the same nominal angle.

10.3.7 Transverse rib flank inclination (α)

Each transverse rib flank inclination (α) shall be determined as the mean of the individual inclinations on the same side of the ribs, measured as indicated in Figure 6 on at least two different transverse ribs per row not used for the identification of the bar, rod or wire.

The transverse rib flank inclination (α) shall be measured by determining the line of best fit between two points on the slope, far enough apart to give a representation of the inclined angle, but avoiding the slope at the extreme ends of the base and peak of the ribs, e.g. as shown in Figure 6.



NOTE Section A-A is a flattened representation of a transverse rib.

Figure 6 — Determination of the rib flank inclination (α) and determination of the area of the longitudinal section of one rib (F_R)

10.3.8 Width of transverse rib or width of indentation (b)

Unless otherwise specified in the product standard, the width of transverse rib (b) shall be determined as the mean of three measurements on each row, at the mid-point of the rib, made normal to the axis of the rib. Only ribs which are not used for identification shall be considered.

The width of indentation (b) shall be determined as the mean of three measurements on each row made parallel to the longitudinal axis of the bar, rod or wire along a line crossing the indentation at the surface level of the bar, rod or wire.

11 Determination of the relative rib or indentation area (f_R or f_P)

11.1 General

The interaction between steel and concrete permits mutual force transfer.

The main effect on bond is given by the shear bond caused by ribs or indentations on the surface of the reinforcing steel.

In the case of ribbed or indented reinforcing steel, the bond behaviour can be determined by different methods:

— measurement of the geometric characteristics of the ribs or indentations;

— measurement of the interaction between the concrete and reinforcing steel in a pull-out test or beam test.

On the basis of the geometric data, a bond factor, called relative rib area (f_R) or relative indentation area (f_P) is calculated.

11.2 Measurements

The determination of the relative rib or indentation area (f_R or f_P) shall be based on the results of measurements of the geometrical characteristics made in accordance with Clause 10.

11.3 Calculation of f_R

11.3.1 Relative rib area

The relative rib area is defined by Formula (4):

$$f_R = \frac{1}{\pi d} \sum_{i=1}^{n} \frac{\frac{1}{m} \sum_{j=1}^{m} F_{R,i,j} \sin\beta_{i,j}}{c_i} + \frac{1}{P} \sum_{k=1}^{q} a'_k \quad (4)$$

where

n is the number of rows of transverse ribs on the circumference;

m is the number of different transverse rib inclinations per row;

q is the number of longitudinal ribs for cold-twisted bars.

$F_R = \sum_{i=1}^{p} (a_{s,i} \Delta l)$ is the area of the longitudinal section of one rib (see Figure 6), where $a_{s,i}$ is the average height of a portion i of a rib subdivided into p parts of length Δl.

The second summand applies only for cold-twisted bars and shall only be taken into account up to a value of 30 % of the total value of f_R.

11.3.2 Simplified formulae

11.3.2.1 Where Formula (4) is not strictly applied by using special devices designed to account for this formula, a simplified formula may be used.

11.3.2.2 Examples of simplified formulae for transverse ribs of crescent shape are given in Formulae (5) to (8).

a) Trapezium formula:

$$f_R = (a_{1/4} + a_m + a_{3/4})(\pi d - \sum e_i)\frac{1}{4\pi dc} + \frac{1}{P} qa' \quad (5)$$

b) Simpson's rule formula:

$$f_R = (2a_{1/4} + a_m + 2a_{3/4})(\pi d - \sum e_i)\frac{1}{6\pi dc} + \frac{1}{P} qa' \quad (6)$$

c) Parabola formula:

$$f_R = \frac{2a_m}{3\pi dc}(\pi d - \sum e_i) + \frac{1}{P} qa' \quad (7)$$

d) Empirical formula:

$$f_R = \lambda \frac{a_m}{c} \quad (8)$$

where λ is an empirical factor, which may be shown to relate f_R to a_m/c for a particular bar, rod or wire profile.

11.3.2.3 An example of simplified formula for transverse ribs of constant height is shown by Formula (9):

$$f_R = \left(a_{1/4} + a_m + a_{3/4}\right)/3\pi dc \cdot \left(\pi d - \varphi \sum e_i\right) \quad (9)$$

where φ is an empirical factor to be determined for a particular bar, rod or wire profile.

11.3.2.4 The values $a_{1/4}$, a_m and $a_{3/4}$ shall be determined in accordance with 10.3.1.2.

$\sum e_i$ shall be determined in accordance with 10.3.5.

11.3.3 Formula used for the calculation of f_R

The formula used for the calculation of f_R shall be in accordance with the product standard and be stated in the test report.

11.4 Calculation of f_P

11.4.1 Relative indentation area

The relative indentation area is defined by Formula (10):

$$f_P = \frac{1}{\pi d} \sum_{i=1}^{n} \frac{F_{P,i} \sin\beta_i}{c_i} \quad (10)$$

where n is the number of indentation rows.

$F_P = \sum_{i=1}^{p} (a_{s,i} \Delta x)$ is the area of the longitudinal section of one indentation (see Figure 7), where $a_{s,i}$ is the average depth of a portion i of an indentation subdivided into p parts of length Δx.

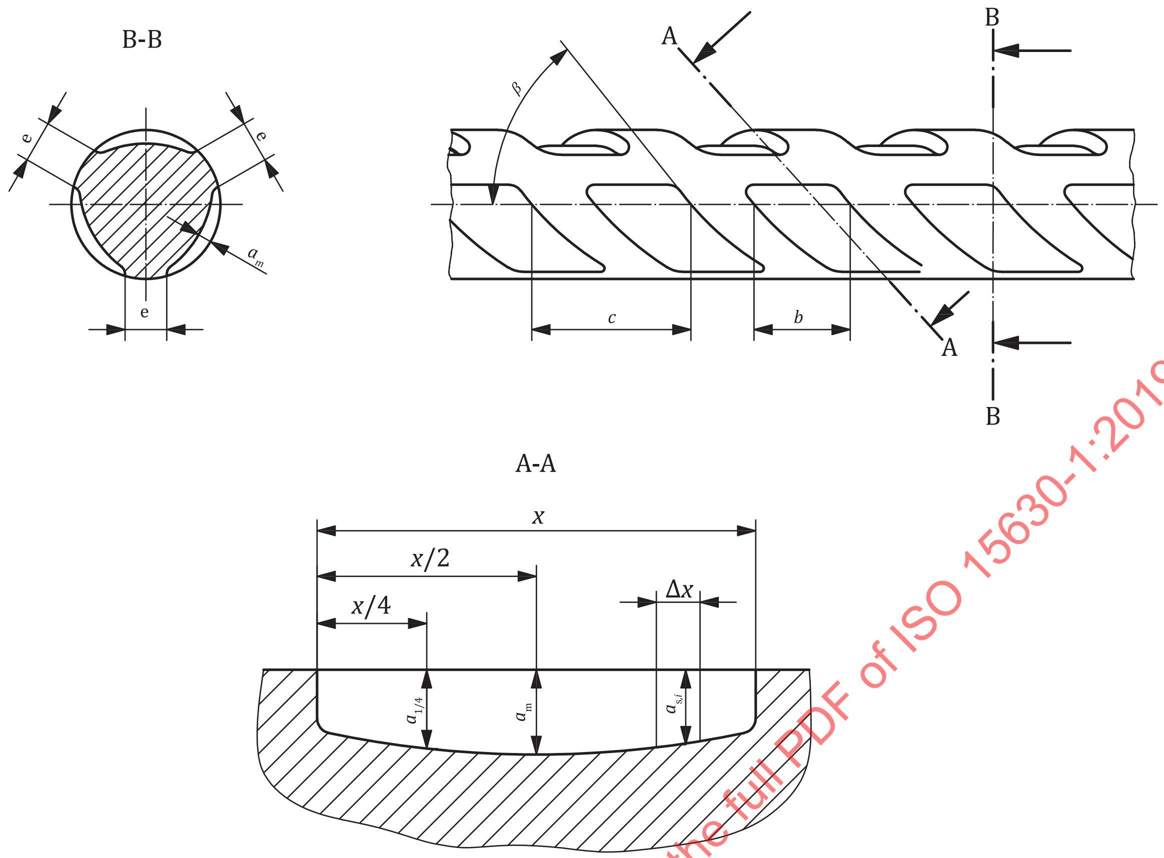


Figure 7 — Determination of the area of the longitudinal section of one indentation F_P

11.4.2 Simplified formulae

Where the general formula given in 11.4.1 is not strictly applied by using special devices designed to account for this formula, a simplified formula may be used.

Examples of simplified formulae are given in Formulae (11) to (14).

a) Trapezium formula:

$$f_P = (a_{1/4} + a_m + a_{3/4})(\pi d - \sum e_i)\frac{1}{4\pi dc} \tag{11}$$

b) Rectangular formula:

$$f_P = (a_{1/4} + a_m + a_{3/4})(\pi d - \sum e_i)\frac{1}{3\pi dc} \tag{12}$$

c) Parabola formula:

$$f_P = \frac{2a_m}{3\pi dc}(\pi d - \sum e_i) \tag{13}$$

d) Empirical formula:

$$f_P = \lambda \frac{a_m}{c} \tag{14}$$

where λ is an empirical factor, which may be shown to relate f_P to a_m/c for a particular bar, rod or wire profile.

The values $a_{1/4}$, a_m and $a_{3/4}$ shall be determined in accordance with 10.3.1.2.

$\sum e_i$ shall be determined in accordance with 10.3.5.

11.4.3 Formula used for the calculation of f_P

The formula used for the calculation of f_P shall be in accordance with the product standard and be stated in the test report.

12 Determination of deviation from nominal mass per metre

12.1 Test piece

The determination of the deviation from nominal mass per metre shall be performed on a test piece which shall have square-cut ends.

Variations in the rib/indentation profile related to the marking of the reinforcing bar, rod or wire may be taken into account to establish the length of the test piece.

12.2 Accuracy of measurement

The length and the mass of the test piece shall be measured with an accuracy of at least ±0,5 %.

12.3 Test procedure

The percentage deviation from nominal mass per metre shall be determined from the difference between the actual mass per metre of the test piece determined from its mass and length and the nominal mass per metre as specified by the relevant product standard.

13 Specialized tests

13.1 Tensile test at elevated temperature

13.1.1 General

The test is performed at a temperature higher than 35 °C, which means at temperatures higher than room temperature as specified in ISO 6892-1.

13.1.2 Test piece

See 5.1.

13.1.3 Test equipment

See 5.2.

13.1.4 Test procedure

The tensile test shall be performed in accordance with ISO 6892-2. For the determination of the properties, see 5.3.

13.2 Tensile test at low temperature

13.2.1 General

The tensile test at low temperature covers the range between +10 °C and –196 °C.

13.2.2 Test piece

See 5.1.

13.2.3 Test equipment

See 5.2.

13.2.4 Test procedure

The tensile test shall be performed in accordance with ISO 6892-3. For the determination of the properties, see 5.3.

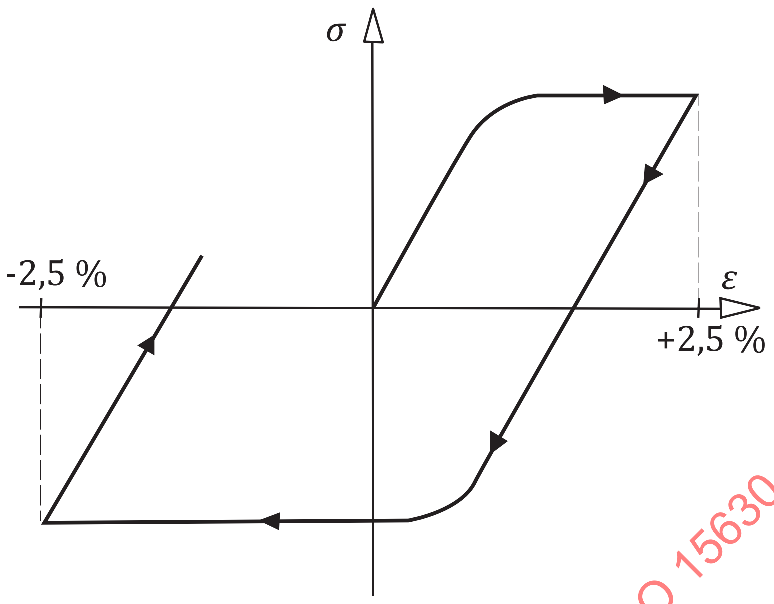
13.3 Cyclic inelastic load test

13.3.1 Principle of the test

The cyclic inelastic load test consists of subjecting the test piece to five complete symmetrical cycles of hysteresis under the conditions given in Table 1 and Figure 8. The test shall be terminated upon failure of the test piece before reaching the specified number of cycles, or on completion of the specified number of cycles without failure.

Table 1 — Testing conditions for cyclic inelastic load testing and specification of load cycles

Nominal diameter d mm	Free length between the grips	Tension strain %	Compression strain %	Number of complete hysteresis symmetrical cycles (cyclic load strength)	Frequency f Hz
All	10 d ± 5 %	2,5 ± 0,1	−2,5 ± 0,1	5	< 3



Key

σ stress

ε strain

Figure 8 — Cycle of hysteresis

13.3.2 Test piece

In addition to the general provisions given in Clause 4, the free length of the test piece shall conform to the requirement in Table 1.

The test piece shall be representative, not damaged and of the adequate length for the test equipment used to comply with the length between the grips given in Table 1. The surface of the free length between grips shall not be subjected to any surface treatment of any kind.

13.3.3 Test equipment

The testing machine shall be verified and calibrated in accordance with ISO 7500-1 and shall be at least of class 1.

For each cyclic inelastic load testing machine, the test conditions for each nominal diameter of bar, rod or wire (preliminary force, gripping pressure, test control by free length between grips) and the necessary test piece lengths shall be documented.

NOTE For provisions concerning the preliminary force and the control of the crosshead separation rate, see ISO 6892-1.

13.3.4 Test procedure

13.3.4.1 Provisions concerning the test piece

The test piece shall be gripped in the test equipment so that force is transmitted axially.

The grips used shall ensure that the test piece does not buckle during the test. The gripping pressure perpendicular to the test axis shall be the minimum to ensure that the displacement of the test piece does not occur.