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ISO 10544

Second edition
2024-01

Cold-reduced steel wire for the reinforcement of concrete and the manufacture of welded fabric

Fils en acier à béton transformés à froid pour armatures passives et la fabrication des treillis soudés

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Foreword

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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 document 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).

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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 Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 16, *Steels for the reinforcement and prestressing of concrete*.

This second edition cancels and replaces the first edition (ISO 10544:1992), which has been technically revised.

The main changes are as follows:

— normative references have been revised;

— terms and definitions have been revised;

— diameters have been extended to 18 mm;

— geometry of ribbed and indented wires have been revised;

— steel grade and chemical composition have been revised;

— example of identification of manufacturer on ribbed wire and indented wire have been added.

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.

Cold-reduced steel wire for the reinforcement of concrete and the manufacture of welded fabric

1 Scope

This document specifies technical requirements for cold-reduced steel wire designed for the reinforcement of concrete or for use in welded fabric.

Two steel grades, CRB500 and CRB540H are defined as examples. Other grades can be used.

This document is applicable to wire made from rod by working through dies or rollers. The production process is at the discretion of the manufacturer.

For wire supplied in coil form, this document is applicable to the straightened product.

Wires produced from finished products, such as plates and railway rails, are outside the scope of this document.

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 404, *Steel and steel products — General technical delivery requirements*

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

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
cast analysis
chemical analysis of a sample of the molten steel during casting

3.2
characteristic value
value having a prescribed probability of not being attained in a hypothetical unlimited test series

Note 1 to entry: Equivalent to fractile, which is defined in ISO 3534-1:2006.

[SOURCE: ISO 16020:2005, 2.4.10]

3.3
core
part of cross-section of the wire that contains neither ribs nor indentations

3.4
indentation inclination
β_{ind}
angle between the indentation and the longitudinal axis of the wire

Note 1 to entry: See Figure 3 and Figure 4.

3.5
indentation spacing
c_{ind}
distance between the centres of two consecutive indentations measured parallel to the axis of the wire

Note 1 to entry: See Figures 3 and 4.

3.6
indented wire
wire whose surface has indentations at regular intervals along the length

3.7
inspection
activities such as measuring, examining, testing, gauging one or more characteristics of a product or service and comparing these with specified requirements to determine conformity

3.8
nominal cross-sectional area
cross-sectional area equivalent to the area of a circular plain wire of the nominal diameter

3.9
plain wire
smooth surfaced wire without bond enhancing properties

3.10
product analysis
chemical analysis of a sample from a wire

3.11
rib height
a
distance from the highest point of the rib to the surface of the core, measured normal to the axis of the wire

Note 1 to entry: See Figures 1 and 2.

3.12
rib inclination
β_{rib}
angle between the rib and the longitudinal axis of the wire

Note 1 to entry: See Figures 1 and 2.

3.13
rib spacing
c_{rib}
distance between the centres of two consecutive transverse ribs measured parallel to the axis of the wire

Note 1 to entry: See Figures 1 and 2.

3.14
ribbed wire
wire whose surface has ribs at regular intervals along the length

3.15
test unit
number of pieces or the tonnage of products to be accepted or rejected together, on the basis of the tests carried out on sample products in accordance with the requirements of the product standard or order

3.16
specific projected indentation area
f_p
area of the projections of all indentations on a plane perpendicular to the longitudinal axis of the wire, divided by the wire length and the nominal circumference

Note 1 to entry: See 5.2.

3.17
specific projected rib area
f_r
area of the projections of all ribs on a plane perpendicular to the longitudinal axis of the wire, divided by the wire length and the nominal circumference

Note 1 to entry: See 5.1.

3.18
transversal indentationless perimeter
$\sum e_i$
sum of the distances along the surface of the core between the transverse indentations of adjacent rows measured as the projection on a plan perpendicular to the wire axis

Note 1 to entry: See Figures 3 and 4.

3.19
transversal ribless perimeter
$\sum f_i$
sum of the distances along the surface of the core between the transverse ribs of adjacent rows measured as the projection on a plane perpendicular to the wire axis

Note 1 to entry: See Figures 1 and 2.

3.20
passive reinforcement
reinforcement that does not apply a compressive stress to the concrete

4 Dimensions, masses and tolerances

The nominal diameter of the wire shall be in the range from 4 mm to 18 mm. Recommended nominal diameters, *d*, are given in Table 1.

For nominal diameters not listed in Table 1, the mass divided by length shall be 7 850 kg/m^3 x nominal cross-sectional area.

Table 1 — Recommended diameters and required masses

Nominal wire diameter d mm	Nominal cross-sectional area mm^2	Mass divided by length	
		Requirement kg/m	Permissible deviation [a] %
4	12,6	0,099	±4
5	19,6	0,154	
6	28,3	0,222	
7	38,5	0,302	
8	50,3	0,395	
9	63,6	0,499	
10	78,5	0,617	
12	113,1	0,888	
14	153,9	1,208	
16	201,1	1,578	
18	254,5	1,998	

[a] Refers to a single wire.

5 Geometry of ribbed and indented wires

5.1 Ribbed wire

Ribbed wire shall have two or more rows of transverse ribs equally distributed around the perimeter with a substantially uniform spacing between 0,6d to 1,0d, where d is the nominal diameter. Figure 1 shows an example with two rows, Figure 2 shows an example with three rows.

The minimum value for the specific projected rib area, f_r, shall be

0,036 for 4 mm ≤ d < 5 mm;

0,039 for 5 mm ≤ d ≤ 6 mm;

0,045 for 6 mm < d ≤ 8 mm;

0,052 for 8 mm < d ≤ 10 mm;

0,056 for 10 mm < d ≤ 18 mm.

f_r is calculated using Formula (1):

$$f_r = \frac{k \times F_R \times \sin\beta_{rib}}{\pi \times d \times c_{rib}} \quad (1)$$

where

k is the number of rib rows;

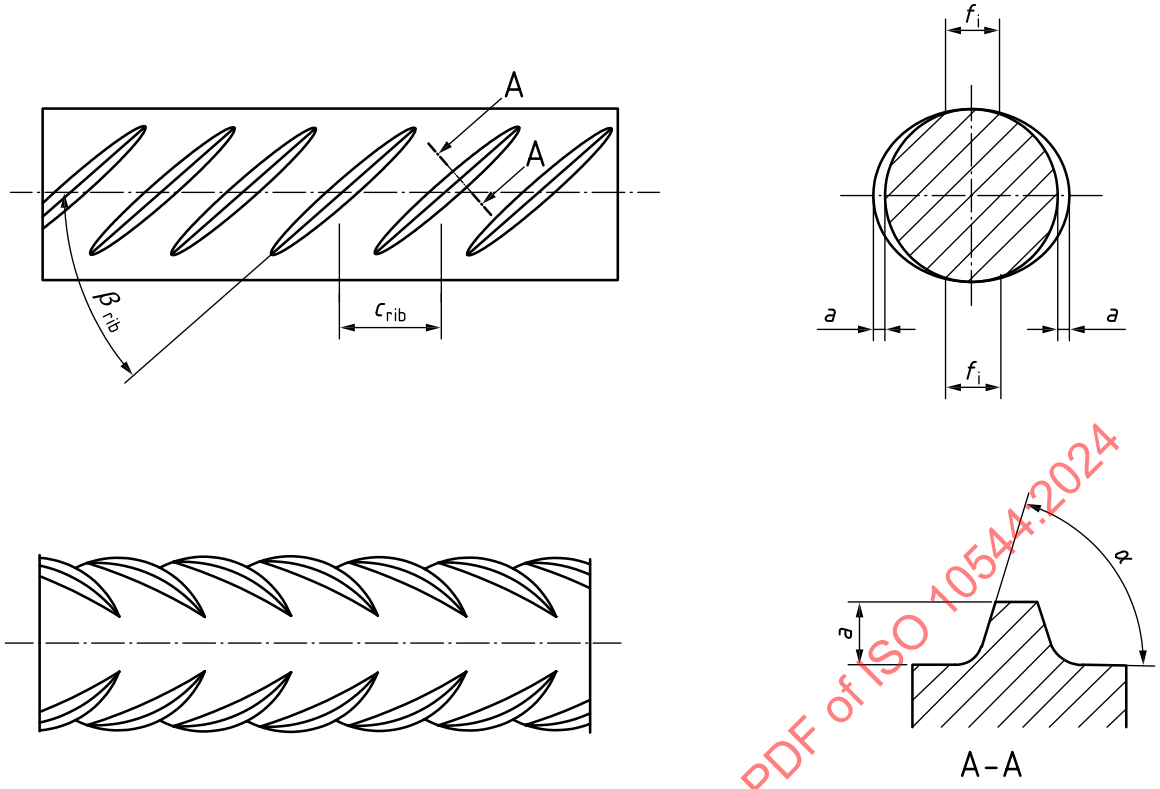
F_R is the area of the projection of one rib on a plane parallel to that rib;

β_{rib} is the rib inclination relative to the axis of the wire;

d is the nominal diameter of the wire;

c_{rib} is the rib spacing.

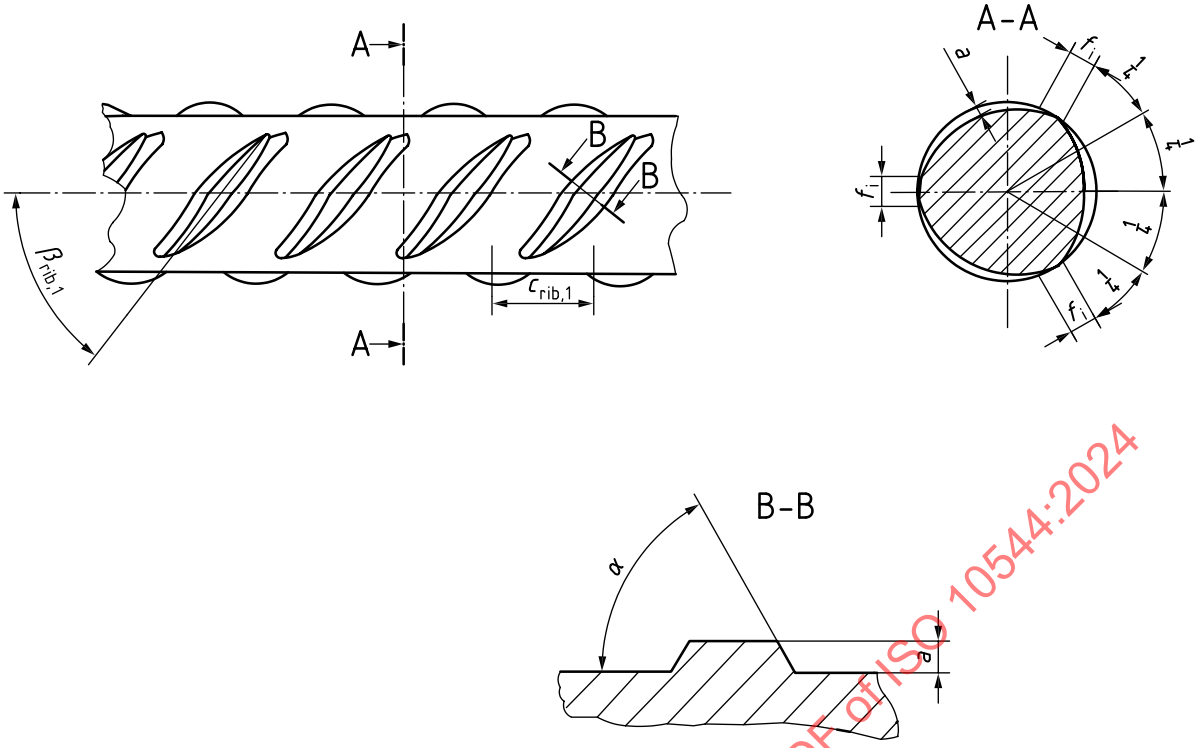
In the area of marking, deviations from the requirements of this subclause may occur (see 10.1).



Key

β_{rib} rib inclination
c_{rib} rib spacing
f_i 1/2 of the transversal ribless perimeter
a rib height
α rib flank inclination

Figure 1 — Example of ribbed wire with two rows



Key

$\beta_{rib,1}$ rib inclination

$c_{rib,1}$ rib spacing

f_i 1/3 of the transversal ribless perimeter

a rib height

α rib flank inclination

Figure 2 — Example of ribbed wire with three rows

5.2 Indented wire

5.2.1 Indented wire shall have two or more rows of indentations. The indentations shall be distributed uniformly over the circumference and length of the wire.

5.2.2 The specific projected indentation area, f_p, shall be calculated in accordance with the full formula or one of the simplified formulas given in ISO 15630-1.

5.2.3 The f_p value shall be agreed upon at the time of ordering in accordance with of 5.2.3.1 or 5.2.3.2.

5.2.3.1 For prestressing of concrete indented steel wire, the indentation parameters in Table 2 and profiles are shown in Figure 3, the minimum value for the specific projected indentation area, f_p, shall be:

0,007 for 4 mm ≤ d < 5 mm;

0,008 for 5 mm ≤ d ≤ 6 mm;

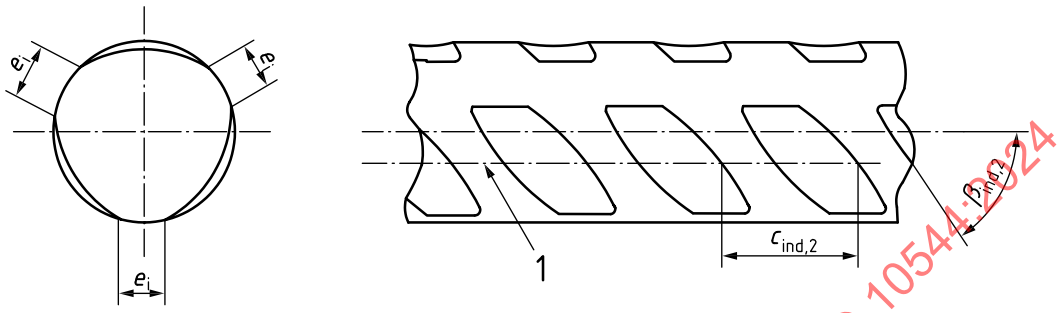
0,010 for 6 mm < d ≤ 8 mm;

0,013 for 8 mm < d ≤ 10 mm;

0,014 for 10 mm < d ≤ 18 mm.

Table 2 — Nominal indentation dimension for the steel wire

Nominal diameter	Nominal indentation dimension						
	Depth			Length	Spacing	Angle	Gape
d mm	$a_{1/4}$ mm	a_m mm	$a_{3/4}$ mm	b, min. mm	C_{ind}, min. mm	β_{ind} °	Σe mm
≤5,0	0,10 ± 0,05	0,12 ± 0,05	0,10 ± 0,05	3,5	5,5	≥40 ≤55	≤0,3πd
>5,0	0,12 ± 0,05	0,15 ± 0,05	0,12 ± 0,05	5,0	8,0		



Key

$c_{ind,2}$ indentation spacing

e_i 1/3 of the transversal indentationless perimeter

$\beta_{ind,2}$ indentation inclination

1 center-line of indentations

Figure 3 — Example of indented wire with three rows

5.2.3.2 For passive reinforcement of concrete indented steel wire, the indentation parameters in Table 3 and profiles are shown in Figure 4 the minimum value for the specific projected indentation are-a, f_p, shall be:

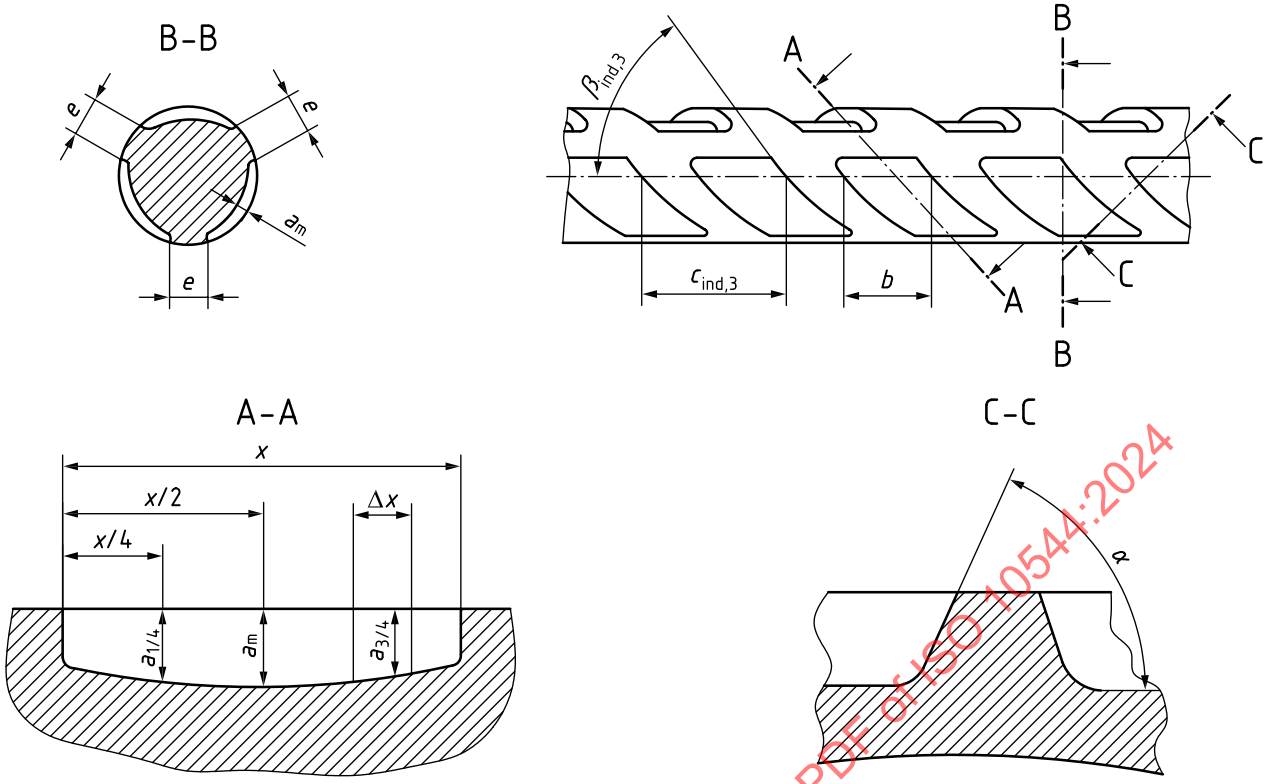
0,035 for 4 mm ≤ d ≤ 6 mm;

0,040 for 6 mm < d ≤ 12 mm;

0,056 for 12 mm < d ≤ 18 mm.

Table 3 — Ranges for the indentation parameters

Nominal diameter	Nominal indentation dimension					
	Depth	Spacing	Ratio	∑e	Angle	Angle
d mm	a_m mm	C mm	b/c	mm	α °	β_{ind} °
≥4,0 ≤18,0	≥0,03 d ≤0,15d	≥0,4 d ≤1,2 d	≥0,50	≤0,75 d	≥45,0	≥40,0 ≤75,0



Key

a_m depth at centre of indentation
$a_{1/4}$ and $a_{3/4}$ depth at ¼ and ¾ of the indentation
b indentation width
$c_{ind,3}$ indentation spacing
e gap between indentation rows
α protrusion flank inclination
$\beta_{ind,3}$ indentation inclination

Figure 4 — Example of indented wire with three rows

In the area of marking, deviations from the requirements of this subclause may occur (see 10.1).

6 Chemical composition

The steel shall not contain quantities of the given elements higher than those specified in Table 4.

Table 4 — Chemical composition — Maximum values in percentage by mass

	C	Si	Mn	P	S	Cu	N[a]	C_{eq}
Cast analysis (Product analysis)	0,25 (0,27)	0,60 (0,65)	1,60 (1,70)	0,045 (0,050)	0,045 (0,050)	0,80 (0,85)	0,012 (0,013)	0,50 (0,52)
[a] A higher nitrogen content may be used if sufficient quantities of nitrogen-binding elements are present.								

The carbon equivalent, C_{eq}, is calculated in accordance with Formula (2).

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + V + Mo}{5} + \frac{Cu + Ni}{15} \quad (2)$$

Where C, Mn, Cr, V, Mo, Cu and Ni are percentages by mass of the respective elements of the steel.

In the case of dispute about analytical methods, the chemical composition shall be determined by an appropriate referee method. See list of methods in ISO/TR 9769.

7 Mechanical properties

7.1 Tensile properties

The tensile properties shall be in accordance with Table 5.

At least 95 % of the population under consideration shall have tensile properties equal to or above the characteristic value specified.

No single test result shall be less than 95 % of the characteristic value given in Table 5.

7.2 Bending properties

After testing, none of the test pieces shall show fractures or cracks visible to the naked eye.

7.3 Rebending properties

By agreement between manufacturer and purchaser, the rebend test may replace the bend test.

The rebend test is used to verify the ageing properties of bent wires.

After testing, none of the test pieces shall have fractures or cracks visible to the naked eye.

8 Testing of mechanical properties

The testing shall be done on wires in the straightened condition. The test pieces may not be aged if the product performance is guaranteed. If aging is required, the aging method shall conform with ISO 15630-1.

8.1 Tensile test

The tensile properties shall be determined in accordance with ISO 6892-1. The test piece shall have an original gauge length of 5 times the nominal diameter. The free distance between the grips shall be not less than 180 mm.

For calculation of proof stress and tensile strength, the nominal cross-sectional area of the wire shall be used.

Table 5 — Two examples of steel grades characteristic values for proof stress at 0,2 % non-proportional elongation, tensile strength and elongation after fracture on a gauge length of 5 times the nominal diameter

Steel grade[c]	Proof stress $R_{p\,0,2}$ N/mm^2	Tensile strength R_m N/mm^2	$R_m/R_{p\,0,2}$	Elongation [a] A %	Total elongation at maximum force (A_{gt}) %
CRB500	500	550	1,03	12	2,5
CRB540H[b]	540	600	1,05	14	5,0

[a] By agreement between purchaser and supplier, a total elongation at maximum force (Agt) shall be used instead of A.

[b] “CRB” ”H”, are the initial letters of "Cold rolled "," Ribbed "," Bar" and "High elongation”. The next 3 digits is the specified characteristic value of proof strength at 0,2 % non-proportional elongation.

[c] The mechanical properties of the wires after artificially aged treatment shall meet the requirements of this table.

Alternative steel grades may be agreed between the manufacturer and purchaser at the time of ordering.

8.2 Bend test

The bend test shall be carried out in accordance with ISO 15630-1.

The test piece shall be bent to an angle between 160° and 180° over a mandrel of the diameter specified in Table 6.

The mandrel diameter for intermediate sizes shall be that of the next lower size in Table 6.

Table 6 — Mandrel diameter to be used for the bend test

Dimensions in millimetres

Nominal diameter of wire, *d*	4	5	6	7	8	9	10	12	14	16	18
Mandrel diameter, *D*	3*d*										6*d*

8.3 Rebend test

The rebend test shall be carried out in accordance with ISO 15630-1. The test piece shall be bent over a mandrel of the diameter specified in Table 7.

The angle of bend, before heating (aging) shall be 90°, and the angle of rebend shall be 20°. Both angles shall be measured before unloading.

The mandrel diameter for intermediate sizes shall be that of the next lower size in Table 7.

Table 7 — Mandrel diameter to be used for the rebend test

Dimensions in millimetres

Nominal diameter of wire, *d*	4	5	6	7	8	9	10	12	14	16	18
Mandrel diameter, *D*	5*d*										8*d*

9 Designation

Wire shall be designated in the following order:

— reinforcing steel;

— a reference to this document, i.e. ISO 10544:—;

— steel grade;

— nominal diameter, in millimetres;

— surface configuration (plain, indented or ribbed).

EXAMPLE Reinforcing steel ISO 10544 – CRB540H - 8 mm ribbed

10 Marking

10.1 Marking on the wire

Indented and ribbed wire should have an identification of the manufacturer introduced during rolling. Examples are shown in Annex A.

10.2 Marking of bundles or coils

Each bundle or coil of at least 500 kg shall have a label stating the manufacturer, the number of this document, nominal diameter, cast number or reference related to test record, and country of origin.

11 Testing and inspection

11.1 General

Testing and inspection of reinforcement shall be performed either:

— in accordance with the requirements for the evaluation of conformity during production, see 11.2; or

— in accordance with testing of a specific delivery, see 11.3.

11.2 Evaluation of conformity during production

This clause specifies requirements for the evaluation of conformity during production.

NOTE ISO 10144 specifies scheme requirements for the certification for the continuous production of steel bars for the reinforcement of concrete in order to verify the conformity with requirements specified in product standards, such as ISO 6935-1 and this document.

11.3 Testing of a specific delivery

Provisions regarding the nature, extent and evaluation of acceptance tests on deliveries of cold-reduced wire not subject to a certification scheme are given in 11.4 and 11.5.

Testing of a specific delivery shall be performed in accordance with 11.4.

By agreement between manufacturer and purchaser, 11.5 may be used.

11.4 Verification of conformity

11.4.1 Organization

The tests shall be organized and carried out in accordance with an agreement between purchaser and manufacturer.

11.4.2 Extent of sampling and testing

For the purpose of testing, the delivery shall be subdivided into test units with a maximum mass of 50 t or a fraction thereof. Each test unit shall consist of products of the same nominal diameter from the same cast. When required by the purchaser, the chemical composition (cast analysis) shall be stated in the test report.

Test pieces shall be taken from each test unit as follows:

— two test pieces from different coils or straightened wires for testing the chemical composition (product analysis);

— fifteen test pieces (if appropriate 60 test pieces; see 11.4.3.1) from different coils or straightened wires for testing all other properties specified in this document.

11.4.3 Evaluation of the results

11.4.3.1 Inspection by variables

For properties which are specified as characteristic values, the following shall be determined:

a) all individual values, x_i of the 15 test pieces (for n = 15);

b) the mean value, m_{15} (for n = 15);

c) the standard deviation, s_{15} (for n = 15).

The test unit corresponds to the requirements if the condition stated below is fulfilled for all properties:

$$m_{15} - 2{,}33 \times s_{15} \geq f_k$$

where

f_k is the required characteristic value;

2,33 is the value for the acceptability index, k, for n = 15 for a failure rate of 5 % (p = 0,95) at a probability of 90 % (1 - α = 0,90).

If the condition stated above is not fulfilled, the index

$$k' = \frac{m_{15} - f_k}{s_{15}}$$

is determined from the test results available. Where $k' \geq 2$, testing can be continued. In this case, 45 further test pieces shall be taken and tested from different coils or straightened wires, so that a total of 60 test results are available (n = 60).

The test unit shall be considered to conform with the requirements if the condition stated below is fulfilled for all properties:

$$m_{60} - 1{,}93 \times s_{60} > f_k$$

where 1,93 is the value for the acceptability index, k, for n = 60 for a failure rate of 5 % (p =0,95) at a probability of 90 % (1- α = 0,90).

11.4.3.2 Inspection by attributes

When testing properties specified as maximum or minimum values, all results determined on the 15 test pieces shall conform with the requirements of this document. In this case the test unit shall be considered to conform with the requirements.

The tests can be continued when at most 2 results not conforming to conditions occur. In this case 45 further test pieces from different coils or straightened wires in the test unit shall be tested, so that a total of 60 test results are available. The test unit conform with the requirements if at most 2 of the 60 results do not conform to the conditions.

11.4.3.3 Chemical composition

Both test pieces shall conform with the requirements in Clause 6.

11.5 Verification of guaranteed minimum values

Tests shall be carried out in accordance with the following.

— For the purpose of testing, the delivery shall be subdivided into test units with a maximum mass of 50 t or a fraction thereof. Each test unit shall consist of products of the same nominal diameter from the same cast. When required by the purchaser, the chemical composition (cast analysis) shall be stated in the test report.

— For each mechanical property specified, one test shall be carried out for each test unit. Each individual test result shall meet the requirements specified in Clause 7.

— If a test result does not meet the requirements, retests may be carried out, in accordance with ISO 404.

— The manufacturer shall submit a test report stating that products of the delivery satisfy the mechanical properties specified in Clause 7, and a confirmation that the other requirements of this document are fulfilled.

12 Test report

The test report shall contain at least the following information:

a) a reference to this document, i.e. ISO 10544:2024;

b) works producing the steel wire;

c) designation of the wire in accordance with Clause 9;

d) number on the bundle;

e) name of the organization carrying out the test, if appropriate;

f) date of testing;

g) mass of the test unit;

h) test results.