British Standard

BRITISH STANDARD

BS 6744:2001

Stainless steel bars for the reinforcement of and use in concrete — Requirements and test methods

ICS 77.140.15, 91.080.40

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee ISE/9, Steel for concrete reinforcement, to Subcommittee ISE/9/1, Bars, wire and fabric for concrete reinforcement, upon which the following bodies were represented:

British Cement Association

British Coatings Federation Ltd.

British Precast Concrete Federation Ltd.

Concrete Society

Department of the Environment, Transport and the Regions — Highways Agency

Electricity Association

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UK Certification Authority for Reinforcing Steels

UK Steel Association

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Contents

Foreword

This British Standard has been prepared by Technical Subcommittee, ISE/9/1.

This British Standard supersedes BS 6744:1986 which is withdrawn.

This revision contains new grades and strength levels not in the 1986 revision. Informative annexes have been used to give guidance on grade selection, magnetic properties, coefficients of thermal expansion and third party certification. As far as is possible, the revision has been written to reflect the requirements of BS 4449, *Specification for carbon steel bars for the reinforcement of concrete*.

Annex A, Annex C, Annex D, Annex E and Annex F are normative. Annex B, Annex G, Annex H, Annex I and Annex J are informative.

A British Standard does not purport to include all necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 23 and a back cover.

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1 Scope

This British Standard specifies requirements and describes methods of test for solid stainless steel bars used for the reinforcement of, and use in, concrete. It covers plain round steel bars in grade 200 and ribbed and plain steel bars in grades 500 and 650.

This Standard applies to bars in which the ribs have been formed by the cold working or hot rolling processes. This Standard also applies to plain bars.

Stainless steel bars produced from material whose metallurgical history is not known and fully documented are excluded from this standard.

2 Normative references

The following normative documents contain provisions which, through references in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 8666, *Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete*.

BS EN 10002 (all parts), *Tensile testing of metallic materials*.

BS EN 10021, *General technical delivery requirements for steel and iron products*.

BS EN 10045-1, *Charpy impact test on metallic materials — Part 1: Test method (V- and U-notches)*.

BS EN 10088-1, *Stainless steels — Part 1: List of stainless steels*.

BS EN 10088-3, *Stainless steels — Part 3: Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes*.

BS EN 10221, *Specification for surface quality classes for hot-rolled bars and rods — Technical delivery conditions*.

BS EN ISO 3651-2, *Determination of resistance to intergranular corrosion of stainless steels — Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels — Corrosion test in media containing sulfuric acid*.

ISO 10606, *Steel for the reinforcement of concrete — Determination of percentage total elongation at maximum force*.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this British Standard the terms, definitions and symbols given in BS EN 10088-1 and the following apply.

3.1.1
bar

product of plain round or ribbed cross-section

3.1.2
cold worked ribbed bar

ribbed bar that has been cold worked to meet the property and geometrical requirements of this British Standard

3.1.3
hot rolled ribbed bar

ribbed bar that has been hot worked to meet the property and geometrical requirements of this British Standard

3.1.4
nominal diameter, ***d***
diameter of a circle with an area equal to the effective cross-sectional area of the bar

NOTE See clauses **5** and **6**.

3.1.5
coil
continuous as-rolled bar in the form of a coil

3.1.6
length
piece of nominally straight bar cut to a specified length

3.1.7
bundle
two or more coils or a number of lengths properly bound together

3.1.8
batch
any quantity of bars of one size, from one cast and grade, whether in coils or bundles, produced by one manufacturer or supplier, presented for examination at any one time

3.1.9
longitudinal rib
uniform continuous protrusion parallel to the axis of the bar

3.1.10
transverse rib
any rib on the surface of the bar other than a longitudinal rib

3.1.11
rib height, ***a***
distance from the highest point of the rib (transverse or longitudinal) to the surface of the core (see Figure C.2)

3.1.12
rib spacing, ***c***
distance between the centres of two consecutive transverse ribs, measured parallel to the axis of the bar (see Figure C.1)

3.1.13
relative rib area, f_R
area of the projections of all ribs on a plane perpendicular to the longitudinal axis of the wire, or bar, or rod, divided by the wire length and the nominal circumference

3.1.14
transverse rib inclination, β
angle between the axis of the transverse rib and the longitudinal axis of the bar (see Figure C.3)

3.1.15
transverse rib flank inclination, α
angle between the rib flank and the longitudinal axis of the bar (see Figure C.2)

3.1.16
cast (heat) analysis
chemical analysis representative of the cast (heat) determined by the steelmaker at his discretion in a manner of his choice

3.1.17
product analysis
chemical analysis carried out on a sample of the product

3.1.18
manufacturer
organization that produces reinforcing steel, including steelmakers, re-rollers and cold workers

3.1.19
supplier
organization supplying reinforcing steel to an end user

NOTE The product may be supplied in straight lengths or fabricated in accordance with BS 8666.

3.1.20
purchaser
organization that purchases the product for use in reinforced concrete production

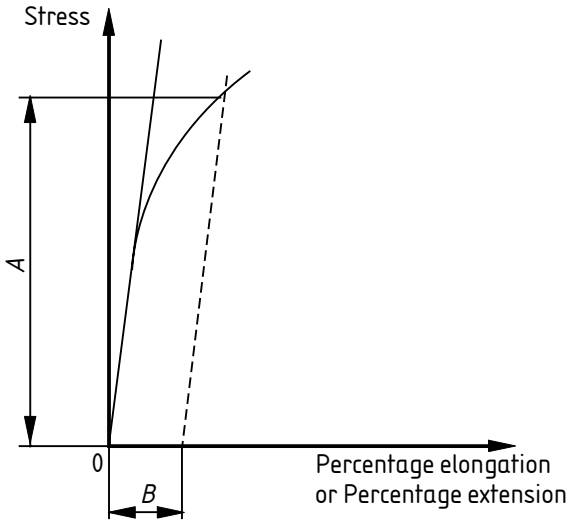
3.1.21
0.2 % proof strength, $R_{p0.2}$
stress at which a non-proportional extension is equal to 0.2 % of the extensometer gauge length (L_e) (see Figure 1)

3.1.22
characteristic strength

value of the proof stress, having a prescribed probability of not being attained in a hypothetical unlimited test series

the characteristic value is the lower limit of the one-sided statistical tolerance interval at which there is a 90 % probability (i.e. 1-α = 0.90) that 95 % (p = 0.95) of the values are at or above this lower limit

this definition refers to the long term quality level of production



Key

A = Proof strength, non-proportional extension ($R_{p0.2}$ MPa)

B = Specified percentage non-proportional extension (0.2 %)

Figure 1 — 0.2% proof test

3.2 Table of symbols

The symbols used in this British Standard are described in Table 1.

Table 1 — Symbols

Symbol	Unit	Description	Clause(s)
d	mm	Nominal diameter of the bar	**3.1.4**, **10.3.2**, **C.3.2**, **D.1.4**, **F.2**
$R_{p0,2}$	MPa	0,2 % proof strength, non-proportional extension	**5.3**
R_m	MPa	Tensile strength	**12.1**, **D.1.4**, **I.2.3**, **I.2.4**
A_5	%	Percentage elongation after fracture	**12.1**, **D.1.4**, **I.2.3**, **I.2.4**
A_{gt}	%	Percentage total elongation at maximum force	**12.1**, **D.1.4**, **I.2.3**, **I.2.4**
c_v		Characteristic value	**3.1.22**, **I.2.4**
M_{mR}	kg/m	Mass per metre run of bar	**A.1**
M	kg	Mass of bar sample	**A.1**, **A.2**
L	m	Length of bar sample	**A.1**, **A.2**
ρ	kg/dm^3	Density	**A.1**, **A.2**
M'	kg	Mass of bar sample after removal of ribs	**A.2**
m		Average of a population of results	**I.1.2**, **I.2.4**
k		Acceptability index	**I.1.2**, **I.2.4**
σ		Standard deviation of a population of results	**I.1.2**, **I.2.4**
A	mm^2	Cross-sectional area of the bar	**A.1**
a	mm	Maximum height of transverse rib	**3.1.11**, **10.3.2**, **C.2.1**
a'	mm	Height of longitudinal rib	**C.2.2**, **C.3.2**
$a_{1/4}$	mm	Rib height at the quarter-point	**C.3.3**
a_m	mm	Rib height at the mid-point	**C.3.3**
$a_{3/4}$	mm	Rib height at the three-quarters point	**C.3.3**
c	mm	Transverse rib spacing	**3.1.12**, **10.3.2**, **C.2.3**, **C.3.2**
P	mm	Pitch for cold-twisted bars	**C.2.4**
Σf_i	mm	Part of the circumference without rib	**C.2.5**
β	°	Angle between the axis of a transverse rib and the bar axis	**3.1.14**, **10.3.2**, **C.2.6**, **C.3.2**
α	°	Transverse rib flank inclination	**3.1.15**, **10.3.2**, **C.2.7**
f_R	—	Relative rib area	**3.1.13**, **10.2**, **C.3.1**, **C.3.2**, **C.3.3**, **C.3.4**
F_R	mm^2	Area of the longitudinal section of one rib	**C.3.2**
n, m, q, p	—	Indices used in calculations of f_R and F_R	**C.3.2**
λ	—	Empirical factor in empirical formula for f_R	**C.3.3**

4 Designation

4.1 The steel designation numbers used in this standard shall be defined in accordance with BS EN 10088-1.

4.2 The products covered by this British Standard shall be designated in the following sequence:

a) the description of the product form (e.g. plain round or ribbed bar or coil);

b) the number of this British Standard (BS 6744:2001);

c) the nominal dimensions of the product (see clause **5** and **6.2**);

d) the BS EN 10088-1 steel designation number (see Table 4);

e) the strength grade (see Table 6).

EXAMPLE

In accordance with this British Standard, a ribbed bar with a nominal diameter of 20 mm, a nominal length of 12 000 mm, steel designation number 1.4301, and strength grade 500:

Ribbed bar BS 6744:2001-20×12000-1.4301, 500.

5 Standard sizes

The range of sizes of bars in all grades shall be from 3 mm to 50 mm.

NOTE 1 The range of standard sizes is given in Table 2.

Table 2 — Standard sizes

Grade	Nominal sizes mm
200[a]	3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 25, 30, 35, 40, 50
500	3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 25, 32, 40, 50
650	3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 20, 25
[a] Plain only	

NOTE 2 Other sizes may be made available on request.

6 Dimensions, mass and tolerances

6.1 Effective cross-sectional area and mass per metre run

The effective cross-sectional area and mass per metre run of the bars shall be calculated using the method described in Annex A.

The values for the nominal cross-sectional area and nominal mass per metre run of individual bars shall be as given in Table 3.

The tolerances on mass per metre run shall be in accordance with Table 4.

NOTE The values for the nominal mass per metre run are calculated from the values of the nominal cross-sectional area using density values in BS EN 10088-1.

Table 3 — Nominal cross-sectional area and nominal mass per metre run

Nominal size	Nominal cross-sectional area	Nominal mass per metre run		
		Steel designation		
		1.4301	1.4436 1.4429	1.4462
mm	mm^2	kg	kg	kg
3	7.1	0.056	0.057	0.055
4	12.6	0.100	0.101	0.098
5	19.6	0.155	0.157	0.153
6	28.3	0.224	0.226	0.221
7	38.5	0.304	0.308	0.300
8	50.3	0.397	0.402	0.392
10	78.5	0.620	0.628	0.612
12	113.1	0.893	0.905	0.882
14	153.9	1.216	1.231	1.200
16	201.1	1.589	1.609	1.569
20	314.2	2.482	2.514	2.451
25	490.9	3.878	3.927	3.829
30	706.9	5.585	5.655	—
32	804.2	6.353	6.434	—
35	962.1	7.601	7.697	—
40	1256.6	9.927	10.053	—
50	1963.5	15.512	15.708	—

Table 4 — Tolerances on mass per metre run

Nominal size mm	Tolerances on mass per metre run %
3 to 6	±9.0
7 to 12	±6.0
over 12	±4.5

6.2 Length

6.2.1 The nominal length of bars shall be agreed at the time of enquiry and order.

NOTE 1 The preferred length is 6 m.

NOTE 2 Bar lengths available are:

≤ 20 mm up to 12 m;
> 20 mm up to 9 m.

6.2.2 Unless otherwise agreed at the time of enquiry and order, the permissible deviation from the nominal length shall be $^{+100}_{0}$ mm.

7 Steelmaking process

Unless a special steelmaking process is agreed when ordering, the steelmaking process for steels conforming to BS EN 10088 shall be at the discretion of the manufacturer.

8 Chemical composition

8.1 Cast analysis

The chemical composition of the steel, based on cast analysis, shall be in accordance with Table 5.

In cases of dispute, the appropriate methods of test given in BS EN 10088-3 shall be used.

Table 5 — Stainless steel bar chemical composition (cast analysis) % by mass

BS EN 10088-1 Steel Designation Number	C max.	Si max.	Mn max.	S max.	Cr min./max.	Ni min./max.	Mo min./max.	P max.	N max.
1.4301[a]	0.07	1.0	2.0	0.03	17.0/19.5	8.0/10.5	—	0.045	≤ 0.11
1.4436[a]	0.05	1.0	2.0	0.015	16.5/18.5	10.5/13.0	2.5/3.0	0.045	≤ 0.11
1.4429	0.03	1.0	2.0	0.015	16.5/18.5	11.0/14.0	2.5/3.0	0.045	0.12/0.22
1.4462	0.03	1.0	2.0	0.015	21.0/23.0	4.5/6.5	2.5/3.5	0.035	0.10/0.22
1.4501[b]	0.03	1.0	1.0	0.015	24.0/26.0	6.0/8.0	3.0/4.0	0.035	0.20/0.30
1.4529[b]	0.02	0.50	1.0	0.010	19.0/21.0	24.0/26.0	6.0/7.0	0.030	0.15/0.25

[a] Nitrogen content of these steels may be increased to 0.22 % max.
[b] These designations are available on request but are only required for special applications, see Annex B for guidance.

8.2 Product analysis

The maximum deviations in product analysis from the values specified for cast analysis shall be in accordance with those given in BS EN 10088-3.

9 Surface quality

All bars shall be free from defects or other surface contamination which can be shown to adversely affect the corrosion or mechanical properties of the steel specified in this Standard.

If more exact requirements for surface quality are necessary, these shall be agreed at the time of enquiry and order, where appropriate, on the basis of BS EN 10221.

10 Surface geometry

10.1 General

Bars shall have either a ribbed or plain surface.

Measurement of geometrical characteristics shall be in accordance with Annex C.

NOTE The stainless steel products covered by this British Standard are characterized by their surface geometry, which enables them to bond with the concrete.

10.2 Relative rib area

The relative rib area, f_R, shall be regarded as the ruling criterion for the bond performance of ribbed products. The value of f_R as a function of the nominal size, as determined in accordance with **C.3**, shall be in accordance with Table 6.

Table 6 — Minimum relative rib area, f_R

Nominal size mm	f_R min.
≤ 6	0.039
6.5 to 8.5	0.045
9 to 10.5	0.052
11 to 50	0.056

10.3 Geometry of rib

10.3.1 *General*

The products shall have two or more rows of parallel transverse ribs, equally distributed around the perimeter with a uniform spacing over the entire length.

NOTE Longitudinal ribs may be present or not.

10.3.2 *Transverse ribs*

10.3.2.1 Transverse ribs shall have a crescent shape and shall merge smoothly into the core of the product (unless the same product properties can be achieved by other special surface configurations).

10.3.2.2 The projection of the ribs shall extend over at least 80 % of the periphery of the product, which shall be calculated from the nominal size and the transverse ribless parameter in accordance with **C.2.5**.

10.3.2.3 The rib flank inclination, α, measured in accordance with **C.2.7**, shall be greater than or equal to 45° and radiused at the transition to the core of the product (see Figure C.2).

10.3.2.4 The angle of rib inclination, β, measured in accordance with **C.2.6**, shall be between 35° and 75° (see Figure C.1).

10.3.2.5 The rib height, a, measured in accordance with **C.2.1**, shall be 0.05d to 0.10d (see Figure C.2), the rib spacing, c, measured in accordance with **C.2.3**, shall be 0.5d to 1.0d (see Figure C.1).

10.3.3 *Longitudinal ribs*

Where longitudinal ribs are present, their height, measured in accordance with **C.2.2**, shall not exceed 0.15d.

Minor deviations from the values given in **10.3.2** and **10.3.3** shall be permitted provided that the specifications for the relative rib area according to Table 6 are satisfied.

11 Conditions of supply

11.1 Ribbed bar shall be supplied in coil or straight lengths, or fabricated in accordance with BS 8666 in the following conditions:

a) hot rolled and descaled;

b) hot rolled, descaled and cold worked.

11.2 Plain bar shall be supplied in coil or straight lengths, or fabricated in accordance with BS 8666 in the following conditions:

a) hot rolled and descaled;

b) hot rolled, descaled and cold worked;

c) hot rolled and bright finished.

12 Mechanical and physical properties

12.1 Tensile properties

The 0.2 % proof strength, $R_{p0.2}$, stress ratio, $R_m/R_{p0.2}$, and elongation at fracture, A_5, of the steel obtained from test samples selected, prepared and tested in accordance with Annex D, shall be as specified in Table 7.

For routine testing the 0.2 % proof strength shall be considered a minimum value. For determination of long term quality level, the values given in the table shall be for the characteristic strength (see **3.1.22**).

Table 7 — Tensile properties

Grade	0.2 % proof strength, $R_{p0.2}$ MPa	Stress ratio, $R_m/R_{p0.2}$ (min.)	Elongation at fracture, A_5 (min.) %	Total elongation at maximum force, A_{gt} (min.) %
200	200	1.10	22	5
500	500	1.10	14	5
650	650	1.10	14	5

[a] R_m is the ultimate tensile strength.
[b] 1 MPa = 1 N/mm².

12.2 Total elongation at maximum force, A_{gt}

The total elongation at maximum force, A_{gt}, shall be determined in accordance with ISO 10606.

Measurements shall be made and recorded and shall be made available for inspection, but if the total elongation is below the minimum value specified in Table 7, this shall not be a cause for non-conformity with this British Standard

12.3 Bend test

When test samples, selected and prepared in accordance with Annex E, undergo the bend test described in Annex E, the test samples shall show no sign of fracture or irregular bending deformation.

12.4 Fatigue test

Ribbed bar shall be subjected to type testing as described in Annex F to determine the characteristics of a particular geometric shape and grade. The fatigue characteristics shall be verified every five years or after 1 000 tonnes produced for each size and grade manufactured, whichever is sooner.

The batch shall be deemed to conform to this British Standard if all five test samples endure 5×10^6 cycles of stress.

12.5 Additional test requirements

12.5.1 *General*

BS EN 10088-1 steel designations 1.4462, 1.4529 and 1.4501 shall undergo further testing in accordance with **12.5.2** and **12.5.3** to ensure the absence of detrimental metallurgical phases in the finished condition. The results shall be quoted on the test certificate.

12.5.2 *Charpy impact test*

Three impact tests shall be performed for each batch. Impact testing shall be carried out in accordance with BS EN 10045-1 on test pieces with a V-notch. The average obtained from three test pieces shall be considered to be the test result (see also BS EN 10021). The values obtained shall conform to BS EN 10088 for the appropriate grade.

NOTE Charpy impact tests should only be performed on bar diameters 16 mm and above.

12.5.3 *Intergranular corrosion test*

The resistance to intergranular corrosion shall be tested in accordance with BS EN ISO 3651-2, at a frequency of one test per batch.

13 Retests

If any test sample fails to meet the stress ratio, proof strength, elongation to fracture or bend test requirements (see clause **12**), two additional test samples shall be taken from different bars of the same batch and subjected to the test or tests in which the original sample failed. If both additional test samples pass the test or tests, the batch from which they were taken shall be deemed to conform to this standard. If either of them fails, the batch shall be deemed not to conform to this standard.

14 Product identification

14.1 Product marking

Ribbed bars shall be identified by rolled-on legible marks on the surface at intervals not greater than 1.5 m to indicate the origin of manufacture.

14.2 Product labelling

Each bundle of bar, or each coil shall have a label attached containing the following information:

— reference to this British Standard;
— specification;
— grade;
— size;
— cast number;
— batch reference;
— name of the manufacturer.

Annex A (normative)
Determination of the effective cross-sectional area and mass per metre run of ribbed bars

A.1 Uniform cross-sectional area

For bars where the configuration is such that, by visual inspection, the cross-sectional area is substantially uniform along the length of the bar, the effective cross-sectional area A (in mm^2) shall be equal to the gross cross-sectional area.

Determine the mass per metre run by weighing and measuring to a precision of ±0.5 %, a length of bar not less than 0,5 m. The mass per metre run, M_{mR} (in mm^2), is given by the equation:

$$M_{mR} = \frac{M}{L}$$

where

M is the mass of the bar in kg;

L is the length of the bar in m.

Calculate the effective cross-sectional area by weighing and measuring to a precision of ±0.5 %, a length of not less than 0.5 m. The cross-sectional area, A (in mm^2), is given by the equation:

$$A = \frac{M}{\rho L} \times 1\,000$$

where

M is the mass of the bar in kg;

L is the length of the bar in m;

ρ is the density of the grade from BS EN 10088-1 in kg/dm^3.

All cross-sectional area and mass per metre run shall be expressed to three significant figures.

A.2 Variable cross-sectional area

For a bar where the cross-sectional area varies along its length, weigh a sample not less than 0.5 m long (M) and measure it to a precision of ±0.5 % in the as-manufactured condition. Reweigh the sample after the transverse ribs have been removed (M').

Where the difference between the two masses (M-M') is less than 3 % of M', determine the effective cross-sectional area in accordance with **A.1**.

Where the difference between the two masses (M-M') is equal to or greater than 3 %, determine the effective cross-sectional area A (in mm^2) from the following equation:

$$A = \frac{103M'}{\rho L} \times 1\,000$$

where

M' is the mass of the bar with the transverse ribs removed in kg;

L is the length of the bar in m;

ρ is the density of the grade from BS EN 10088-1 in kg/dm^3.

Annex B (informative)
Guidance on grade selection to prevent corrosion

It is assumed that corrosion resistance is of primary concern when stainless steel reinforcement is specified. This revision of BS 6744:1986 has increased the scope of stainless steel alloys considered appropriate for the reinforcement and use in concrete. The range of alloys covered reflects the materials that are currently available in the United Kingdom.

Corrosion resistance, and therefore the durability of the different grades varies with composition and service environment. It is assumed that designers will not necessarily have detailed knowledge of the individual grades and their suitability for different applications. Therefore, Table B.1 below provides some general guidance related to the suitability of the different grades for a range of service conditions. This table can be used for both new structures and the repair and/or strengthening of existing structures.

Table B.1 — Guidance on the use of stainless steel reinforcement for different service conditions

Grade in accordance with BS EN 10088-1	Service condition			
	For structures or components with either a long design life, or which are inaccessible for future maintenance	For structures or components exposed to chloride contamination with no relaxation in durability design (e.g. concrete cover, quality or water proofing treatment requirements)	Reinforcement bridging joints, or penetrating the concrete surface and also subject to chloride contamination (e.g. dowel bars or holding down bolts)	Structures subject to chloride contamination where reductions in normal durability requirements are proposed (e.g. reduced cover, concrete quality or omission of water proofing treatment)
1.4301	1	1	5	3
1.4436	2	2	1	1
1.4429	2	2	1	1
1.4462	2	2	1	1
1.4529	4	4	4	4
1.4501	4	4	4	4

Key

1 – Appropriate choice for corrosion resistance and cost.

2 – Over-specification of corrosion resistance for the application.

3 – May be suitable in some instances: specialist advice should be obtained.

4 – Grades suitable for specialist applications which should only be specified after consultation with corrosion specialists.

5 – Unsuitable for the application.

Annex C (normative)
Measurement of the geometrical characteristics

C.1 Test equipment

The geometrical characteristics shall be measured with an instrument of a resolution of at least:

a) 0.02 mm for the height of transverse of longitudinal ribs;

b) 0.05 mm for the gap between two adjacent transverse ribs rows;

c) 0.5 mm for the measurement of the distance between transverse ribs when determining the transverse rib spacing (see **10.3.2.5**);

d) one degree for the inclination between the transverse rib and the longitudinal axis of the bar.

C.2 Test procedure (see Figure C.1 and Figure C.2)

C.2.1 *Heights of transverse ribs*

C.2.1.1 *Maximum value, a*

The maximum height of transverse ribs, a, shall be determined as the mean of at least three measurements per row of the maximum height of individual transverse ribs not used for the identification of the bars.

C.2.1.2 *Value at a given position*

The height of transverse ribs at a given position, e.g. at the quarter-point or at the mid-point or at the three-quarters point, respectively designated $a_{\frac{1}{4}}$, a_{m}, and $a_{\frac{3}{4}}$, shall be determined as the mean of at least three measurements in this position per row on different transverse ribs not used for the identification of the bars.

C.2.2 *Height of longitudinal ribs, a´*

The height of longitudinal ribs, $a´$, shall be determined as the mean of at least three measurements of the height of each longitudinal rib at three different positions.

C.2.3 *Transverse rib or indentation spacing, c*

The spacing of the transverse ribs, c, shall be determined from the length of the measuring distance divided by the number of the rib spacings in between.

For the purposes of this British Standard, the measuring distance shall be the interval between the centre of a rib and the centre of another rib on the same row of the product, determined in a straight line and parallel to the longitudinal axis of the product. The length of the measuring distance shall be:

a) at least 10 ribs gaps;

b) one pitch length for cold-twisted products.

C.2.4 *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 generatrix for each longitudinal rib.

C.2.5 *Transverse ribless perimeter, Σf_{i}*

The transverse ribless perimeter, Σf_{i}, shall be determined as the sum of the average gap between ribs of two contiguous rib rows, for each rib row. The average gap shall be determined from at least three measurements.

C.2.6 *Transverse rib angle, β*

The transverse rib angle, β, to the bar axis shall be determined as a mean of the individual angles measured for each row of ribs.

C.2.7 *Transverse rib flank inclination, α*

The transverse rib inclination, α, shall be determined as the mean of the individual inclination on both sides of the rib, measured as indicated in Figure C.2 on at least two different transverse ribs per row not used for the identification of the bars.

C.3 Determination of the relative rib area, f_{R}

C.3.1 *General*

The determination of the relative rib area, f_{R}, shall be carried out using the results of measurements made according to clause **C.2**.

C.3.2 *Calculation of f_R (see Figure C.3)*

The relative rib area is defined by the following:

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

where

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

m is the number of transverse rib inclinations per row;

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

d is the nominal diameter of the bar;

c is the transverse rib spacing;

a' is the height of the longitudinal rib;

P is the pitch for cold twisted bars;

β is the angle between the axis of the transverse rib and the bar axis;

F_R is the area of the longitudinal section of one rib and can be calculated using the following formula:

$$F_R = \sum_{n=1}^{p}(a_{s,i}\Delta l)$$

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 should only be taken into account up to a value of 30 % of the total value of f_R.

C.3.3 *Simplified formulae*

Where the general formula given in **C.3.2** is not strictly applied by using special devices, a simplified formula may be used.

Examples of simplified formulae are as follows:

a) trapezium formula

$$f_R = \left(a_{\frac{1}{4}} + a_m + a_{\frac{3}{4}}\right)(\pi d - \sum f_i)\frac{1}{4\pi dc} + \frac{1}{P}qa'$$

b) Simpson's formula

$$F_R = \left(2a_{\frac{1}{4}} + a_m + a_{\frac{3}{4}}\right)(\pi d - \sum f_i)\frac{1}{6\pi dc} + \frac{1}{P}qa'$$

c) parabola formula

$$F_R = \frac{2a_m}{3\pi dc}(\pi d - \sum f_i)\frac{1}{P}qa'$$

d) empirical formula

$$f_R \text{ or } f_P = \lambda\frac{a_m}{c}$$

where

$a_{\frac{1}{4}}$ is the rib height at the quarter point;

a_m is the rib height at the midpoint;

$a_{\frac{3}{4}}$ is the rib height at the three quarters point;

d is the nominal diameter;

Σf_i is the part of the circumference without the rib;

c is the transverse rib spacing;

P is the pitch for cold-twisted bars;

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

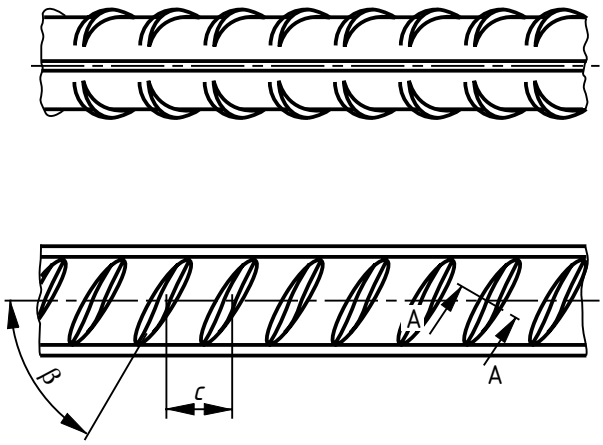
a' is the height of the longitudinal rib;

λ is an empirical factor that may be shown to relate f_R to $\frac{a_m}{c}$ for a particular bar profile.

The values $a_{\frac{1}{4}}$, a_m, and $a_{\frac{3}{4}}$ shall be determined in accordance with **C.2.1.2**. Σf_i shall be determined in accordance with **C.2.5**.

C.3.4 ***Formula used for the calculation of*** f_R

The formula used for the calculation of f_R shall be stated in the test report.



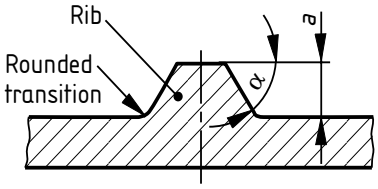
Key

A-A is the section of the bar detailed in Figure C.3;

β is the angle between the axis of the transverse rib and the bar axis;

c is the transverse rib spacing (mm).

Figure C.1 — Example of bar showing rib geometry

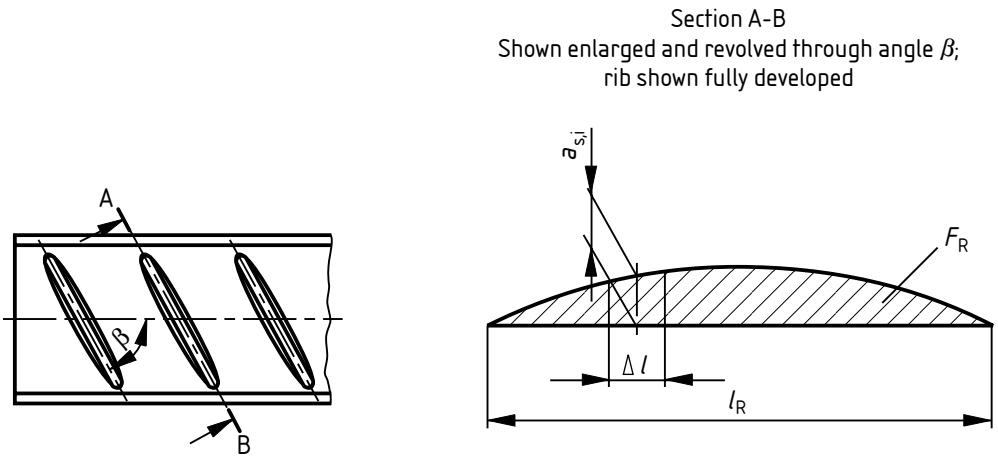


Key

a is the maximum height of the transverse rib;

α is the transverse rib flank inclination.

Figure C.2 — Rib flank inclination, α, and rib height, a (section A-A from Figure C.1)



Key

A-B is the section shown enlarged and revolved through angle β;

β is the angle between the axis of the transverse rib and the bar axis;

$a_{s,\,i}$ is the average height of a portion, i, of a rib subdivided into p parts of length, Δl;

l_R is rib length (in mm);

F_R is the area of the longitudinal section of the rib (mm^2).

Figure C.3 — Determining the area of the longitudinal section of a rib

Annex D (normative)
Inspection and testing

D.1 Manufacturer's inspection

D.1.1 *General*

All units of continuous production shall be tested in accordance with **D.1.2**, **D.1.3**, **D.1.4**, **D.1.5** and **D.1.6**.

D.1.2 *Selection of test samples*

Where it is possible to perform full section testing, the test samples shall be at least 300 mm long. Where it is not possible to perform full section testing, test samples shall be prepared in accordance with BS EN 10002-1. The type of test sample used shall be stated on the manufacturer's statement of results.

D.1.3 *Condition of test samples*

The tensile tests shall be carried out on straight bars in delivery condition.

D.1.4 *Tensile test*

The tensile strength, R_m, 0.2 % proof strength, $R_{p0.2}$, elongation at fracture, A_5, and the total elongation at maximum force, A_{gt}, shall be determined by the methods described in BS EN 10002.

NOTE It is recommended that:

a) test pieces are lightly scribed at one diameter, d, or at 10 mm centres (whichever is the more convenient) throughout their length;

b) for the measurement of A_5, a gauge length clear of the machine grips and as nearly symmetrical about the fracture as possible is selected.

For elongation values, the test results shall be regarded as valid, irrespective of the position of the fracture, provided that the minimum elongation specified in Table 7 has been obtained.

Where the minimum elongation is not obtained, the sample shall be deemed not to conform to this British Standard, except in the following cases, where the test results shall be considered invalid:

a) if the distance between the fracture and the nearer gauge mark is less than one third of the gauge length;

b) if the relevant end of the gauge length used for measuring the elongation is $2d$ or less from the face of the machine grips.

The stresses shall be calculated using the effective cross-sectional area of the bar, determined in accordance with Annex A.

D.1.5 *Test records*

The manufacturer shall maintain a record of the test results for ten years from the date of testing. The records shall be available for inspection, on request by the purchaser or purchaser's representative.

D.1.6 *Test certificate*

The test certificate shall state:

a) that the products conform to this British Standard, and have undergone the tests specified in this British Standard at the specified frequency;

b) the address at which the records of the tests are available for inspection;

c) the cast number, batch reference and cast analysis, including all specified elements in **8.1**;

d) the results of the tensile test, including the effective cross-sectional area;

e) results of the bend test;

f) results of Charpy impact test and intergranular corrosion test where applicable;

g) for ribbed bars, the rolled-on mill mark;

h) approval number issued by the certifying authority (if applicable).

NOTE *Assessed capability*. Users of this British Standard are advised to consider the desirability of product certification against the requirements of this British Standard and the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body (see Annex I).

Annex E (normative)
Bend test

E.1 The units of production from which test samples are selected shall be the batch. Test samples shall be selected from each batch at a frequency of one per ten tonnes.

E.2 The test shall be carried out on test samples having a temperature between 5 °C and 30 °C and in such a way as to produce a continuous and uniform bending deformation (curvature) at every section of the bend. The method of bending shall be one of the following:

a) on a power bending machine in which the test sample is adequately supported by plain smooth surfaces or rolls which do not offer resistance to longitudinal movement of a test piece;

b) on a three-point hydraulic bending machine.

The chosen machine shall be serviceable and capable of imparting constant loading to the sample and be without impact effect.

The rate of application of the load shall not exceed 3 revolutions/min or equivalent.

E.3 The test sample shall be bent through 180° using one of the methods of bending described in **E.1** round a former of maximum diameter as given in Table E.1.

Table E.1 — Bend test formers

Nominal size of the bar	Maximum diameter of former
≤ 16 mm	Three times the nominal size of the bar
>16 mm	Six times the nominal size of the bar

Annex F (normative)
Method of test for fatigue properties of ribbed bars

F.1 Fatigue testing

The fatigue properties for each defined bar shape and process route shall be established at an applicable testing laboratory, initially by testing two sizes selected from the top and bottom of the product size range.

Testing shall be carried out on bars in the commercially straight condition using the test stress ranges in Table F.1.

Table F.1 — Fatigue test stress ranges

Bar size mm	Stress range MPa
Up to and including 16	200
Over 16 up to and including 20	185
Over 20 up to and including 25	170
Over 25 up to and including 32	160
Over 32 up to and including 40	150

F.2 Sampling

Samples shall be taken from a batch at random. The bars shall not exhibit isolated defects that are not characteristic of the product. Samples shall have a minimum length of 30d and a minimum free length of 10d, where d is the nominal diameter of the sample. Each test unit shall comprise five test samples.

F.3 Test procedure

Samples shall be tested in air under axial tensile loading, using tapered grips and a suitable gripping medium. The stress ratio shall be 0.2 and the frequency shall not exceed 120 Hz. A sine wave form shall be used. Testing shall be carried out under load control and stresses shall be calculated on the nominal area.

The test shall be considered invalid if a sample fails the test due to a defect unique to the sample, or if failure occurs in an area adjacent to the testing machine grips. In these cases a further sample shall be tested.

F.4 Retests

F.4.1 If two or more samples fail to endure 5×10^6 cycles, and the test is valid (see **F.3**), the batch shall be deemed not to conform to this British Standard.

F.4.2 If one sample fails the test, a further five test samples shall be selected from the same batch. If one or more of these samples fail, the batch shall be deemed not to conform to this British Standard.

Annex G (informative)
Comparison of similar specifications

The following table provides comparison between the designation systems used in current and former British Standards and American steel specifications.

Table G.1 — Comparison between the designation systems used in current and former British Standards and American steel specifications

BS EN 10088	British Standard	American Standard
1.4301	304 S31	AISI 304N
1.4436	316 S33	AISI 316
1.4429	316 S63	AISI 316LN
1.4462	318 S13	UNS 31803
1.4529	No equivalent	UNS NO8367
1.4501	No equivalent	UNS S32750

Annex H (informative)
Guidance on magnetic properties

Austenitic stainless steels are generally considered to be non-magnetic. However, after cold working some magnetic permeability may be evident. Conversely, duplex stainless steels (1.4462 and 1.4501) are considered to be magnetic.

Relative magnetic permeability, μ_r, is defined as the ratio of the magnetic flux density produced in the material relative to that produced in free space by the same magnetizing force. Therefore, the lowest achievable relative magnetic permeability is 1.

The relative magnetic permeability for stainless steel decreases in the designation in the order 1.4301 > 1.4436 > 1.4429 > 1.4529. However, as noted above, the magnetic permeability is directly affected by the manufacturing route. Therefore, where low magnetic permeability is of importance ($\mu_r \approx 1.005$), the purchaser should agree the specific supply condition and chemical composition with the manufacturer at the time of order.

Annex I (informative)
Third party certification

I.1 Material covered by a third party product certification scheme

I.1.1 *Consistency of production*

To determine the production consistency of the manufacturer, the long term quality level should be regularly assessed. However, no conclusion regarding product conformity to this British Standard should be made on the basis of this assessment.

I.1.2 *Determination of the long term quality level*

I.1.2.1 *Extent of testing*

The 0.2 % proof stress results obtained on all casts for each size should be collated every six months. The results should be used to determine the long term quality level.

I.1.2.2 *Evaluation*

The average proof stress, m, should satisfy the following:

$$m \geq c_v - k\sigma$$

where

c_v is the characteristic strength (in MPa);

k is the acceptability index (see Table I.1);

σ is the standard deviation of the population.

Table I.1 — Acceptability index, k, as a function of the number of test results, n, for a reliable failure rate of 5 % (pass = 0.95) at a probability of 90 % (1 - α = 0.90)

n	k
5	3.40
6	3.09
7	2.89
8	2.75
9	2.65
10	2.57
11	2.50
12	2.45
13	2.40
14	2.36
15	2.33
16	2.30
17	2.27
18	2.25
19	2.23
20	2.21
30	2.08
40	2.01
50	1.97
60	1.93
70	1.90
80	1.89
90	1.87
100	1.86
150	1.82
200	1.79
250	1.78
300	1.77
400	1.75
500	1.74
1000	1.71
∞	1.64

I.2 Acceptance testing

I.2.1 *General*

The production consistency of the manufacturer, and the long-term quality level, may be determined by more extensive acceptance testing on each batch. Sampling and testing should be carried out at the producer's works or in the stockholder's yard.

I.2.2 *Extent of sampling and testing*

For testing purposes, the batch should be divided into test units each with a maximum mass of 10 t. Each test unit should comprise products of the same steel grade and nominal diameter from the same batch. The manufacturer should certify that all products in the test unit originate from the same batch.

Test samples should be taken from each test unit as follows:

a) 15 samples or (if appropriate) 60 samples (see **I.2.4**), from different bars, for testing in accordance with **I.2.3**a) and **I.2.3**b);

b) two test samples, from different bars, for testing in accordance with **I.2.3**c).

Preparation of the test samples should be carried out as described in **D.1**.

I.2.3 *Properties to be tested*

Samples selected in accordance with **I.2.2** should be tested for the following.

a) **Inspection by variables:**

1) tensile strength R_m;

2) 0.2 % proof stress $R_{p0.2}$;

3) elongation after fracture A_5;

4) total elongation at maximum force A_{gt}.

b) **Inspection by attributes:**

1) deviations from the nominal cross-section;

2) surface geometry;

3) bend test.

c) **Chemical composition according to product analysis:**

1) all elements listed in clause **8** to be analysed.

d) **Fatigue properties:**

1) For ribbed bars, the fatigue properties should be determined for each size and defined bar shape in the batch. Sampling and testing should be carried out in accordance with Annex F.

The test procedures should be as described in **D.1**.

I.2.4 *Evaluation of results*

I.2.4.1 *Inspection by variables*

Inspection by variables should be carried out as follows.

a) The following should be determined for the characteristic strength when testing for the properties listed in **I.2.3**a):

1) all individual values for characteristic strength, cv, for the 15 test samples;

2) the mean value for the characteristic strength, m_{15} (for $n = 15$);

3) the standard deviation S_{15} (for $n = 15$).

The test unit shall be deemed to conform to this British Standard if all individual values of $R_m/R_{p0.2}$, the elongation to fracture A_5 and elongation at maximum load A_{gt}, exceed the values in Table 7 and the following condition is fulfilled by the characteristic strength, but see also b):

$$m_{15} - 2.33 \times S_{15} \geq cv$$

b) If the condition for the characteristic strength stated in a) is not fulfilled, a secondary calculation (the acceptability index k) should be determined, where:

$$k = \frac{m_{15} - cv}{S_{15}}$$

If $k \geq 2$, testing should continue. Forty-five further test samples should be taken and tested from different bars in the test unit, so that 60 test results are available ($n = 60$).

The test unit shall be deemed to conform to this British Standard if all individual values of $R_m/R_{p0.2}$, the elongation to fracture A_5 and elongation at maximum load A_{gt}, exceed the values in Table 7 and the following condition is fulfilled by the characteristic strength (1.93 is the value for the acceptability index, k, for $n = 60$, in accordance with Table I.1):

$m_{60} - 1.93 \times S60 \geq cv$

I.2.4.2 *Inspection by attributes*

Inspection by attributes should be carried out as follows. When testing the properties stated in **I.2.3**b), either:

a) all the results determined on the 15 test samples should conform to this British Standard;

b) if a maximum of two of the 15 results do not conform to this British Standard, 45 further test samples should be taken and tested from different bars in the test unit, making 60 results available.

The unit should be deemed to conform to this British Standard if no more than two of the 60 test samples fail the test.

Annex J (informative)
Guidance on coefficients of thermal expansion

It should be noted that the coefficient of thermal expansion of austenitic stainless steels is greater than that of either carbon steel reinforcement or concrete. Table J.1 below provides comparative thermal coefficient of expansion data.

Table J.1 — Comparative thermal coefficient of expansion data

British Standard Steel Designation	Coefficient of thermal expansion × 10^{-6} (20 to 100 °C)
1.4301	16.0
1.4436	16.0
1.4429	16.0
1.4462	13.0
BS 4449, grade 460 (carbon steel)	12.0

Bibliography

BS 4449, *Specification for carbon steel bars for the reinforcement of concrete*.
BS EN ISO 9000 (all parts), *Quality management and quality assurance standards*.

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