

BS 4449 : 1988

British Standard Specification for
**Carbon steel bars for the
reinforcement of concrete**

Barres en acier au carbone pour l'armature du béton — Spécifications

Stäbe aus unlegiertem Stahl zur Bewehrung von Beton

BSI

STANDARDS

Foreword

This British Standard has been prepared under the direction of the Iron and Steel Standards Committee and is a revision of BS 4449 : 1978 incorporating the requirements of BS 4461 : 1978. Both standards are withdrawn.

This document has been produced to provide a single product standard for carbon steel bars for the reinforcement of concrete and the opportunity has been taken to revise the text to reflect developments in steelmaking and processing practices. The standard applies equally to hot rolled and cold worked steel bars.

Fatigue requirements have been included for the first time.

Certification requirements have been included to align with Euronorm 80 'Reinforcing steel (not for pre-stressing). Technical delivery conditions'. These provide separate testing regimes for manufacturers covered by a certification scheme and those not covered by a certification scheme.

Information to be supplied by the purchaser is given in appendix G.

Product testing and certification. Attention is drawn to the provision in this British Standard of a facility for third party certification of product conformity with this British Standard based on testing and continuous product surveillance coupled with assessment of a supplier's quality systems against BS 5750 : Part 2 : 1987.

Enquiries as to the availability of third party certification schemes and of competent test laboratories will be forwarded by BSI to the Association of Certification Bodies. If a third party certification scheme does not already exist, users should consider approaching an appropriate body from the list of Association members.

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

Contents

	Page
Foreword	Inside front cover
Committees responsible	Back cover
Specification	
1 Scope	2
2 Definitions	2
3 Sizes	2
4 Cross-sectional area and mass	3
5 Length	3
6 Steelmaking process	3
7 Chemical composition	3
8 Bond classification of deformed bars	4
9 Routine inspection and testing	4
10 Mechanical properties	4
11 Fatigue properties of deformed bar	5
12 Retests	5
13 Verification of characteristic strength	5
14 Marking	5
Appendices	
A Determination of the effective cross-sectional area of deformed bars	6
B Bond classification of deformed bars (bond test)	6
C Inspection, testing and certification	8
D Method of test for fatigue properties of deformed bars	11
E Tensile test multiplying factors	12
F Recommended formulae for calculating projected rib area	12
G Information to be supplied by the purchaser	13
Tables	
1 Preferred nominal sizes	2
2 Cross-sectional area and mass	3
3 Tolerance on mass	3
4 Chemical composition of steel grades: cast analysis	3
5 Maximum carbon equivalent values: cast analysis	3
6 Maximum deviations in chemical composition on product analysis	4
7 Tensile properties	5
8 Percentage total strain	8
9 Bend test formers	9
10 Rebend test formers	9
11 Acceptability index (k) as a function of the number (n) of the test results (for a reliable failure rate of 5 % (pass = 0.95) at a probability of 90 % ($1 - \alpha = 0.90$))	10
12 Test stress ranges for nominal bar sizes	12
Figure	
1 Typical mould for bond performance testing	7

Specification

1 Scope

This British Standard specifies requirements for weldable steel bars for the reinforcement of concrete. It covers plain round steel bars in grade 250 and deformed high yield steel bars in grade 460.

The weldability requirements for both grades of steel are specified in terms of the carbon equivalent value.

Appendix C includes a testing facility for material covered by a third party product certification scheme and a testing facility for material not covered by a third party product certification scheme.

Steel bars for use as lifting hooks are not included in this standard.

Steel bars produced by re-rolling finished products or by rolling material whose metallurgical history is not known and fully documented are excluded from this standard.

NOTE 1. Flash welds in lengths of bar are permissible. However, for some purposes, purchasers may require bars without flash welds. If so this information should be supplied to the manufacturer (see appendix G).

NOTE 2. All steels complying with this British Standard are of weldable quality. Welding procedures and consumables appropriate to the particular grade and quality should be used.

NOTE 3. A British Standard for welding steel reinforcement is in preparation.

NOTE 4. The titles of publications referred to in this standard are listed on page 13.

2 Definitions

For the purposes of this British Standard the following definitions apply.

2.1 bar. A steel product of plain round or deformed cross section.

2.2 hot rolled deformed bar. A bar which has been so shaped during hot rolling that it complies with either the geometrical or performance test classification given in clause 8.

2.3 cold worked deformed bar. A bar which has been cold worked to comply with the property requirements of this standard and complies with either the geometrical or performance test classification given in clause 8.

2.4 nominal size. The diameter of a circle with an area equal to the effective cross-sectional area of the bar.

NOTE. See clause 3 and appendix A.

2.5 yield stress. The stress measured during the tensile test when the total extension of the gauge length is that specified for the grade.

2.6 coil. A continuous as-rolled bar in the form of a coil.

2.7 length. A piece of nominally straight bar cut to a specified length.

2.8 bundle. Two or more coils or a number of lengths properly bound together.

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

2.10 longitudinal rib. A uniform continuous protrusion parallel to the axis of the bar, before twisting in the case of cold worked bars.

2.11 transverse rib. Any rib on the surface of the bar other than a longitudinal rib.

2.12 flash weld. Resistance butt weld in which the components are progressively advanced towards each other while the current, confined to localized points of contact, causes expulsion of molten metal. When welding temperature is reached, upset force is applied.

2.13 manufacturer. An organization that produces reinforcing steel including steelmakers, re-rollers and cold workers (twisting or drawing).

2.14 supplier. Any organization supplying reinforcing steel to an end user.

NOTE. The product may be supplied in lengths or coil or fabricated in accordance with BS 4466.

2.15 characteristic strength. That value of the yield stress below which fall not more than 5 % of the test results.

3 Sizes

3.1 Range

The range of nominal sizes of bars in both grades shall be from 6 mm to 50 mm.

NOTE. The preferred nominal sizes of bars are given in table 1.

Grade	Nominal size
	mm
250	8, 10, 12, 16
460	8, 10, 12, 16, 20, 25, 32, 40
NOTE 1. If a bar smaller than 8 mm is required, the recommended size is 6 mm.	
NOTE 2. If a bar larger than 40 mm is required, the recommended size is 50 mm.	

3.2 Tolerance

The deviation of any cross-sectional dimension, other than those of ribs, from its nominal size, shall not exceed 8 %.

4 Cross-sectional area and mass

The cross-sectional area and mass of the bars shall be calculated on the basis that these steels have a mass of 0.00785 kg/mm² per metre run.

The values for the nominal cross-sectional area shall be as given in table 2. The mass of individual bars shall be as given in table 2, subject to the tolerances given in table 3.

For bars where the effective cross-sectional area is determined as in A.2.2, the nominal mass per metre run shall equate to the gross mass per metre run.

The total cross-sectional area and total mass of two or more bars shall be calculated pro-rata on the basis of the values for an individual bar. All cross-sectional areas derived from the values in table 2 shall be expressed to three significant figures.

Nominal size	Cross-sectional area	Mass per metre run
mm	mm ²	kg
6*	28.3	0.222
8	50.3	0.395
10	78.5	0.616
12	113.1	0.888
16	201.1	1.579
20	314.2	2.466
25	490.9	3.854
32	804.2	6.313
40	1256.6	9.864
50*	1963.5	15.413

*These are non-preferred sizes.

Nominal size	Tolerance on mass per metre run
mm	%
6	± 9
8 and 10	± 6.5
12 and over	± 4.5

5 Length

Each bar shall be cut to ± 25 mm of the length specified by the purchaser.

Where a minimum length is requested it shall be subject to a tolerance of $\begin{matrix} +50 \\ -0 \end{matrix}$ mm.

Where a maximum length is requested it shall be subject to a tolerance of $\begin{matrix} +0 \\ -50 \end{matrix}$ mm.

6 Steelmaking process

The steel shall be made by refining molten iron in a top-blown basic oxygen converter or by melting in a basic-lined electric arc furnace.

7 Chemical composition

7.1 Cast analysis

The chemical composition of the steel based on cast analysis shall be in accordance with table 4.

The two grades shall have a carbon equivalent value, based on cast analysis, not exceeding the maximum values given in table 5.

The following formula shall be used to calculate the carbon equivalent value where the individual values are calculated as percentages.

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

In cases of dispute the appropriate methods of test given in BS 6200 : Part 3 or Handbook 19 shall be used.

Element	Grade 250	Grade 460
	% max	% max
Carbon	0.25	0.25
Sulphur	0.060	0.050
Phosphorus	0.060	0.050
Nitrogen	0.012	0.012

NOTE 1. The maximum value for nitrogen does not apply if the chemical composition shows a minimum aluminium content of 0.020 % or if sufficient other nitrogen binding elements are present.

NOTE 2. Nitrogen is not normally quoted on a release certificate.

Grade	Maximum carbon equivalent value
	%
250	0.42
460	0.51

7.2 Product analysis and permitted deviations

7.2.1 The product analysis may vary from the cast analysis due to heterogeneity arising during casting and solidification. The maximum deviations on product analysis from the values specified for cast analysis (see tables 4 and 5) shall be as given in table 6.

Element	Deviation above the specified maximum given in tables 4 and 5
Carbon	% 0.02
Sulphur	0.005
Phosphorus	0.005
Total nitrogen	0.001
Carbon equivalent value	0.03

7.2.2 Samples for product analysis shall be taken in accordance with either the appropriate method of BS 6200 : Part 3 or Handbook 19.

7.2.3 Any bar which on product analysis falls outside the limits of maximum deviation from the specified composition range for a specified element given in table 6 shall be deemed not to comply with this standard.

7.2.4 In the event of a single sample falling outside the maximum deviations on the product analysis given in table 6, further samples shall be selected for check analysis from the remainder of the batch, as follows:

(a) at least two samples from the same cast for delivered masses up to 5 t;

(b) at least five samples from the same cast for delivered masses up to 20 t;

(c) at least eight samples for delivered masses over 20 t.

If any of these further samples are proved to be outside the maximum deviation for any element given in table 6 the batch shall be deemed not to comply with this standard.

8 Bond classification of deformed bars

8.1 General

Deformed bars shall be classified either as type 1 or as type 2 as follows:

(a) in accordance with their surface shape, as specified in 8.2; or

(b) for bars which do not comply with the surface shape bond classifications of 8.2, in accordance with 8.3.

8.2 Bond classification by surface shape

Bond classification by surface shape shall be as follows.

Type 1 A plain square twisted bar or a plain chamfered square twisted bar, each with a pitch of twist not greater than 14 times the nominal bar size.

Type 2 A bar with transverse ribs with a substantially uniform spacing not greater than 0.8ϕ for as-rolled deformed bars or 1.2ϕ for cold twisted bars, having a mean area of ribs (per unit length) above the core of the bar projected on a plane normal to the axis of the bar not less than $0.15 \phi \text{ mm}^2/\text{mm}$, where ϕ is the nominal bar size (in mm).

NOTE. Recommended formulae for the calculation of the projected rib area are given in appendix F.

8.3 Bond classification by performance

The performance tests described in appendix B shall be conducted by a competent test laboratory (see foreword). The bond classification established by the laboratory and given on the test report shall be regarded as final.

9 Routine inspection and testing

Routine inspection and testing shall be carried out as described in appendix C and shall include the manufacturer's inspection (see C.1); and either:

(a) for material covered by a third party certification scheme, the requirements of C.2; or

(b) for material not covered by a certification scheme, the requirements of C.3.

10 Mechanical properties

NOTE. All bars should be free from defects, e.g. seams, porosity, segregation, non-metallic inclusions etc., which can be shown to adversely affect the mechanical properties.

10.1 Tensile properties

10.1.1 The tensile properties of the steel obtained from test specimens selected, prepared and tested in accordance with appendix C shall comply with 10.1.2 and 10.1.3. The specified tensile properties apply to the delivery condition or the accelerated aged condition.

NOTE 1. The treatment condition of the test specimens is at the manufacturer's discretion.

In cases of dispute, the test shall be carried out on test specimens in the accelerated aged condition.

NOTE 2. The method for accelerated ageing is given in appendix C.

10.1.2 The specified characteristic strength and elongation of the two strength grades of steel shall be as given in table 7.

10.1.3 The tensile strength shall be either:

(a) at least 10 % greater than the actual yield stress measured in the tensile test in accordance with appendix C; or

(b) between 5 % and 10 % greater than the actual yield stress measured in the tensile test in accordance with appendix C. In this case the actual yield stress shall be not less than the value determined from the following formula, in N/mm^2 :

$$A (2.1 - B)$$

where

A is either 250 or 460 according to the grade concerned;

B is the ratio of measured tensile strength to actual yield strength.

Table 7. Tensile properties		
Grade	Specified characteristic strength (<i>cv</i>)	Minimum elongation on gauge length $5d^*$
	N/mm^2	%
250	250	22
460	460	12

**d* is the nominal size of the test piece.

NOTE. The method of calculation of the effective cross-sectional area of deformed bars is given in appendix A.

10.2 Bend test

The method of bend testing shall be as given in appendix C. The test specimens shall withstand being bent through 180° round a former of the diameter specified in table 9. For the purposes of this test, the presence of any mill scale shall be ignored. The test specimens shall show no sign of fracture on visual examination.

10.3 Reband test

When test specimens selected and prepared in accordance with appendix C are subjected to the test described in that appendix the test specimens shall show no sign of fracture or irregular bending deformation.

11 Fatigue properties of deformed bar

Deformed bars shall be subjected to type testing as described in appendix D to determine the fatigue characteristics of a particular geometrical shape. Thereafter the characteristics shall be confirmed by periodic testing on a three yearly cycle.

For both type and periodic testing, deformed bars shall endure 5×10^6 cycles of stress.

12 Retests

If any test specimen fails to meet the tensile strength, elongation, bend or reband test requirements, two additional test specimens shall be taken from different bars of the same batch and shall be subjected to the test or tests which the original specimen failed. If both additional test specimens pass the retests the batch from which they were taken shall be deemed to comply with this standard. If either of them fails, the batch shall be deemed not to comply with this standard.

13 Verification of characteristic strength

13.1 Where the characteristic strength of the material is in dispute it shall be verified by selecting and testing three test specimens from different bars in the batch. If any one test result is less than the characteristic strength specified in table 7 the requirements of 13.2 shall apply. If the three valid test results have an actual yield stress equal to or greater than the characteristic strength specified in table 7, the batch shall be deemed to comply with this standard.

13.2 When one or more of the test results in 13.1 fall below the characteristic strength specified in table 7, 10 specimens shall be selected from different bars in the batch.

If any one test result is less than 93 % of the characteristic strength specified in table 7, both the test specimen and the test method shall be carefully examined. If there is a local fault in the specimen or reason to believe that an error has occurred in the test, the bar from which the test specimens was taken shall be disregarded and the test result shall be ignored.

If the valid test results have an actual yield stress equal to or greater than 93 % of the characteristic strength specified in table 7, the batch shall be deemed to comply with this British Standard.

If one or more valid test results is less than 93 % of the characteristic strength specified in table 7, the batch shall be deemed not to comply with this British Standard.

14 Marking

Deformed 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.

Appendices

Appendix A. Determination of the effective cross-sectional area of deformed 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 , shall be the gross cross-sectional area, in millimetres squared, determined by weighing and measuring to a precision of $\pm 0.5\%$ a length of not less than 0.5 m and calculated as follows:

$$A = \frac{M}{0.00785L}$$

where

M is the mass of the bar (in kg);

L is the length of the bar (in m).

A.2 Variable cross-sectional area

A.2.1 For a bar where the cross-sectional area varies along its length, a sample not less than 0.5 m shall be weighed (M) and measured to a precision of $\pm 0.5\%$ in the as-manufactured condition, and after the transverse ribs have been removed it shall be reweighed (M').

A.2.2 Where the difference between the two masses ($M - M'$) is less than 3% of M' , the effective cross-sectional area shall be obtained as in A.1.

A.2.3 Where the difference between the two masses ($M - M'$) is equal to or greater than 3% of M' , the effective cross-sectional area A , in millimetres squared, shall be calculated as follows:

$$A = \frac{1.03M'}{0.00785L}$$

where

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

L is the length of the bar (in m).

For routine test purposes a nominal ratio of effective to gross cross-sectional area of bars covered by A.2.3 shall be stated and used by the manufacturer.

Appendix B. Bond classification of deformed bars (bond test)

B.1 Principle

The principle of the test is to show that deformed bars, claimed to be equal to those satisfying the classification given in 8.2, will hold for a given time the specified characteristic strength (see table 7) in a pull-out test with a free end slip not greater than 0.2 mm.

B.2 Selection of test specimens

For a range of sizes of bar which are geometrically similar in shape, tests shall be carried out on two sizes, preferably 20 mm and the largest available size. The surface shape of the bars to be tested shall comply with the manufacturer's published specification, and shall be as near to the minimum amount of deformation as is possible. Six specimens of each size shall be tested.

B.3 Test prisms

For each of the specimens prepare a concrete test prism having a square cross section of 150 mm side for bars up to and including 20 mm size, and 250 mm side for bars over 20 mm size. The length of prism, L , in millimetres, shall be calculated as follows:

$$L = \frac{f_y \phi}{21} \text{ for deformed type 1 bars and}$$

$$L = \frac{f_y \phi}{28} \text{ for deformed type 2 bars}$$

where

f_y is the specified characteristic strength of the steel (in N/mm^2);

ϕ is the nominal bar size (in mm).

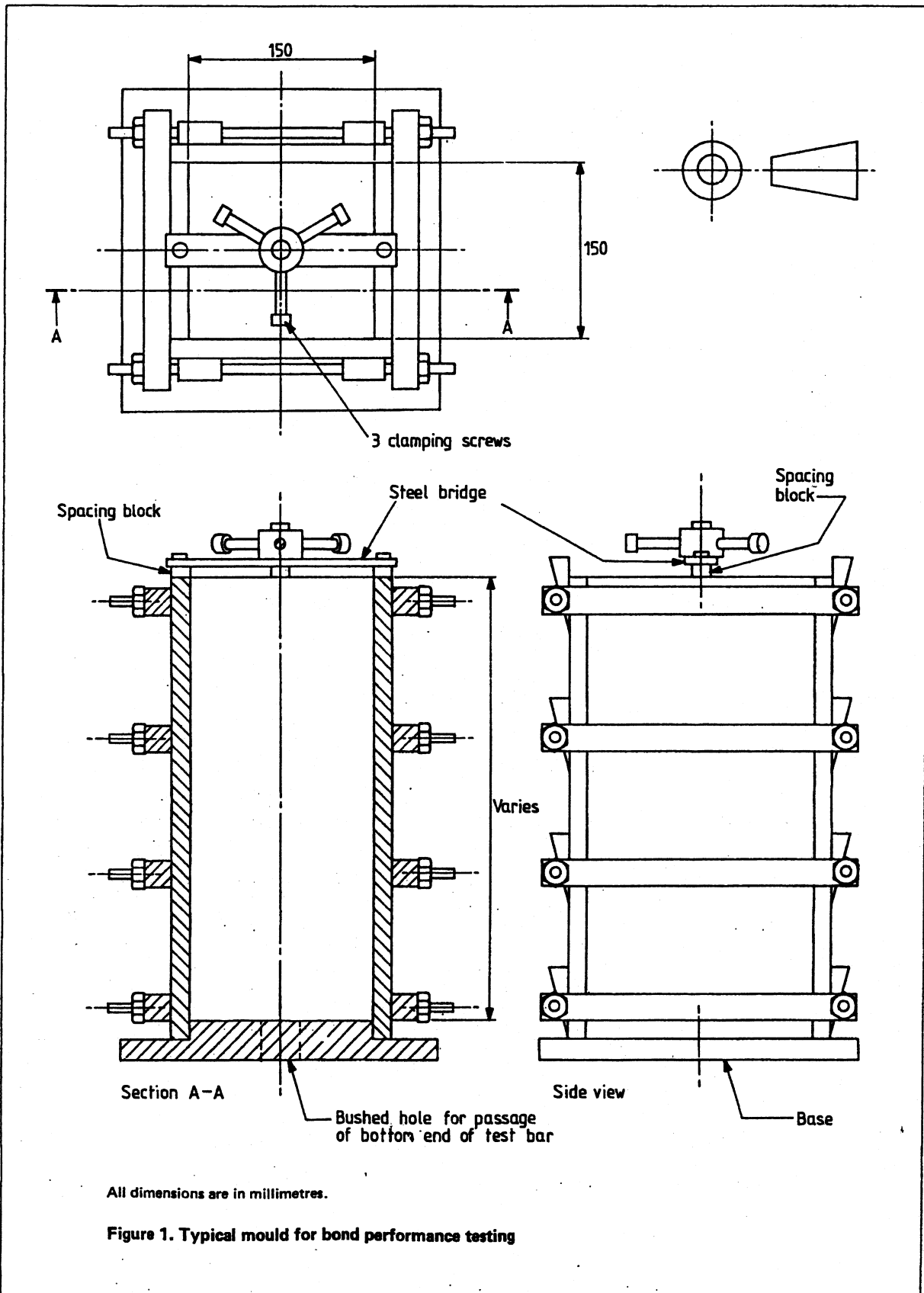
Prepare the prisms using a mortar mix that gives a concrete having a cube strength of between 40 N/mm^2 and 45 N/mm^2 at the time of the pull-out test. Support the test bar so that it is rigidly embedded in and passes completely through the prism of concrete along its longitudinal axis. Reinforce the prism along the embedded length with a helix of 6 mm diameter plain mild steel having a pitch of 25 mm, the outer diameter of the helix being 5 mm less than the side of the square section. A typical mould is shown in figure 1.

B.4 Apparatus

Mount the test specimen in the testing device in such a manner that the bar is pulled axially from the prism. Arrange the test piece such that the end of the bar at which the pull is applied is that which projected from the top end of the prism as cast. Place plaster bedding or rubber or plywood packing between the top end of the prism and the surface of the testing device bearing on it. Mount a suitable dial gauge in such a manner that the gauge records the relative slip between the unloaded end of the bar and the bottom end of the prism as cast.

B.5 Procedure

During a period of approximately 2 min, steadily increase the axial force in the bar protruding from the top end of the prism until the tensile stress in the bar attains the specified characteristic strength f_y (see table 7) for the grade of steel from which the bars are made. Maintain this stress for a further 2 min then record the free end slip of the bar.



B.6 Free end slip

If the average free end slip of the six bars tested exceeds 0.2 mm they shall not qualify for that classification.

B.7 Test report

The test report shall contain the following information:

- (a) mill of manufacture;
- (b) bar size;
- (c) rib geometry;
- (d) concrete cube strength;
- (e) the bond classification determined.

NOTE. Further information may be included by agreement.

Appendix C. Inspection, testing and certification

C.1 Manufacturer's inspection

C.1.1 General

All units of continuous production shall be tested in accordance with C.1.2 to C.1.8.

C.1.2 Selection of test specimens

The unit of production from which test specimens are selected shall be the cast.

Test specimens shall be either at least 600 mm long or 20 times the nominal size, whichever is the greater. The rate of testing shall be:

- (a) for casts of 100 t or less: 3 tensile tests, 1 bend test and 1 rebend test;
- (b) for casts greater than 100 t: 3 tensile tests, 1 bend test and 1 rebend test and an additional tensile, bend and rebend test for each 30 t or part of 30 t.

C.1.3 Condition of test specimens

C.1.3.1 The tensile, bend and rebend tests shall be carried out on straight bars in the delivery or accelerated aged condition. Bars with a nominal diameter of 40 mm or less shall not be machined.

NOTE. At the option of the manufacturer or supplier and in order to simulate natural ageing, test specimens may be subjected to a temperature of 100 °C for a period of not more than 2 h, provided that both the tensile and rebend test samples are so treated and the fact is recorded on the test certificates.

C.1.3.2 In the case of 50 mm hot rolled grade 460 bars, where a tensile testing machine of adequate capacity is not available, the bars may be machined to 40 mm diameter for tensile testing providing that there are multiplying factors predetermined by testing similar specimens of such bars as-rolled and machined (see appendix E).

C.1.4 Tensile test

Determine the tensile strength, yield stress and elongation of the steel by the methods described in BS 18 except where otherwise stated below, but using an extensometer calibrated in accordance with grade D of BS 3846.

Use a strain rate corresponding to a rate of loading not exceeding 10 N/mm² per second approaching the yield stress.

The yield stress shall be derived from the load on the specimen corresponding to an increase measured by the extensometer of percentage total strain specified in table 8 on any convenient gauge length.

Specified characteristic strength	Percentage total strain
N/mm ²	%
250	0.33
460	0.43

NOTE. It is recommended that test pieces be lightly scribed at one diameter (d) or 10 mm centres, whichever is more convenient, throughout their length, and that a gauge length be selected that is as nearly symmetrical about the fracture as possible and is clear of the machine grips.

For elongation values, regard the test results 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 comply with 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, or;
- (b) if the relevant end of the gauge length used for measuring elongation is $2d$ or less away from the face of the testing machine grips.

Calculate the stresses using the effective cross-sectional area of the bar determined by weighing as described in appendix A.

C.1.5 Evaluation of tensile test results

C.1.5.1 The following requirements on the individual values (x) and on the average value (m) of the cast shall be met in assessing the characteristic strength.

- (a) $x \geq 0.93 \times cv$, where cv is the characteristic strength specified in table 7.
- (b) $m \geq cv + a$, where $a = 10 \text{ N/mm}^2$.

NOTE. It is not necessary to assess the mean value m of the cast if all individual values of x are equal to or greater than the characteristic strength cv .

C.1.5.2 Each individual value for the tensile strength shall comply with the requirements of 10.1.3 and each individual value of the elongation shall comply with the requirements of 10.1.2.

C.1.6 Bend and rebend tests

C.1.6.1 Bend test. The test shall be carried out on test specimens at 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 test shall be conducted either:

- (a) on a power bending machine in which the test specimen is adequately supported by plain smooth surfaces or rolls which do not offer resistance to longitudinal movement of the test piece, or;
- (b) on a 3-point hydraulic bending machine.

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

The maximum bending rate shall be 3 r/min or equivalent.

The test specimens shall withstand being bent through 180 ° round a former of the diameter specified in table 9. There shall be no transverse rupture of the surface of the metal. For the purposes of this test, the presence of any mill scale shall be ignored.

Grade	Diameter of former
250	Twice the nominal size of the bar
460	Three times the nominal size of the bar

C.1.6.2 Rebend test. Subject the test specimens to the following sequence of operations:

- (a) bend the test specimen through 45 ° using the method of bending described in C.1.6.1 round a former of diameter as specified in table 10;
- (b) immerse the test specimen in boiling water (100 °C) for not less than 30 min;
- (c) allow the test specimen to cool to a temperature between 5 °C and 30 °C and bend it back towards its original shape (partially restraightened) by a steadily applied force through at least 23 ° on the same bending machine as used in (a) above.

Grade	Diameter of former
250	Twice the nominal size of the bar
460	Five times the nominal size of the bar

C.1.6.3 Failure in relation to rib damage. In the event of failure, if there is any damage to the ribs caused by carrying out the initial bending, the test shall be considered invalid, and the test shall be repeated on another specimen.

NOTE. Damage to the ribs may be avoided by the use of an aluminium sheet insert placed between the specimen and the former. The maximum thickness of the aluminium sheet insert is 6 mm.

C.1.7 Cross-sectional area and mass

All individual values determined in the tensile test shall comply with the requirements of clause 4.

C.1.8 Chemistry

The cast analysis shall comply with the chemical composition requirements of clause 7.

C.1.9 Test records

The manufacturer shall maintain a record of the test results for a period of 10 years from the date of testing. These shall be made available for inspection, on request, by the purchaser or his representative.

C.2 Material covered by a third party product certification scheme

(see foreword)

C.2.1 Consistency of production

For the purpose of determining the consistency of the manufacturer's production the long term quality level shall be assessed at regular intervals. No conclusion regarding compliance with this British Standard shall be made on the basis of this assessment.

C.2.2 Determination of the long term quality level

C.2.2.1 Extent of testing. The yield stress results obtained on all casts for each size shall be collated at intervals of 3 months or after at least 200 results have been obtained. These shall be used to determine the long term quality level.

C.2.2.2 Evaluation. The average value m , shall satisfy the following requirements:

$$m > cv + k \sigma$$

where

σ is the standard deviation of the population;

cv is the characteristic strength (in N/mm^2);

k is the acceptability index for which values are given in table 11.

Table 11. Acceptability index (k) as a function of the number (n) of the test results (for a reliable failure rate of 5 % (pass = 0.95) at a probability of 90 % ($1 - \alpha = 0.90$))

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

C.2.3 Test certificates

C.2.3.1 Certificate of compliance. A certificate of compliance shall be issued by a supplier when requested. This shall state:

- (a) that the material supplied complies with and has been tested at the frequency specified in this standard;
- (b) the address at which the record of test results is available for inspection.

The certificate shall include the approval number issued by the Certifying Authority.

C.2.3.2 Manufacturer's certificate. In the case of material delivered to a supplier, the manufacturer shall issue a certificate of routine testing stating the following.

- (a) The cast number and cast analysis. The cast analysis shall include all specified elements and those used for the calculation of the carbon equivalent value.
- (b) The carbon equivalent value.
- (c) The individual results of the tensile, bend and rebend tests on specimens taken from the material. The tensile test results shall include the effective cross-sectional area.
- (d) In the case of deformed bars, the rolled on mill mark.

The certificate shall include the approval number issued by the Certifying Authority.

C.3 Material not covered by a third party product certification scheme

C.3.1 General

Material not covered by a third party product certification scheme shall be assessed by acceptance tests on each batch. Sampling and testing shall be carried out by an organization independent of the producer at the producer's works or in the stockholder's yard.

C.3.2 Extent of sampling and testing

For the purpose of testing, the delivery is to be subdivided into test units with a maximum mass of 100 tonnes each. Each test unit shall consist of products of the same steel grade and the same nominal diameter from the same cast. The manufacturer or supplier shall confirm in the certification that all products in the test unit originate from one cast.

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

- (a) 15 test specimens (if appropriate 60 test specimens) from different bars for testing in accordance with C.3.3(a) and C.3.3(b);
- (b) 2 test specimens from different bars for testing the chemical composition in the product (see C.3.3(c)).

The preparation of test specimens shall be carried out as described in C.1.

C.3.3 Properties to be tested

The following properties are to be determined in testing the test specimens which have been taken according to C.3.2.

(a) Inspection by variables

- (1) Tensile strength (R_m)
- (2) Yield point (R_e)
- (3) Elongation after fracture (A_5)

(b) Inspection by attributes

- (1) Behaviour in the bend test
- (2) Behaviour in the rebend test
- (3) Deviations from the nominal cross-section
- (4) Bond test

(c) Chemical composition according to the product analysis.

All elements listed in clause 7 and the carbon equivalent are to be determined.

The test procedures shall be as described in C.1.

C.3.4 Evaluation of the results

C.3.4.1 Inspection by variables. Inspection by variables shall be carried out as follows.

(a) The following indices are to be determined when testing for the properties listed in C.3.3(a).

- (1) all individual values x of the 15 test specimens ($n = 15$)
- (2) the mean value m_{15} (for $n = 15$)
- (3) the standard deviations S_{15} (for $n = 15$)

The test unit shall be deemed to comply with the requirements of this British Standard if the condition $m_{15} - 2.23 \times S_{15} \geq cv$ is fulfilled by the characteristic strength.

where

- x is as defined in C.1.5.1;
- m is as defined in C.1.5.1;
- n is the number of test specimens as given in table 11;

2.33 is the value for the acceptability index k ;

cv is the characteristic strength specified in table 7.

(b) If the condition stated in C.3.4.1(a) is not fulfilled, the secondary calculation of the acceptability index

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

is to be determined from the test results available.

Where $k' \geq 2$, testing can be continued. In this case 45 further test specimens shall be taken and tested from different bars in the test unit, so that a total of 60 test results are available ($n = 60$).

The test unit shall be deemed to comply with the requirements of this British Standard if the condition

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

is fulfilled for all properties (1.93 is the value for the acceptability index k for $n = 60$ in accordance with table 12).

C.3.4.2 Inspection by attributes. Inspection by attributes shall be carried out as follows.

(a) When testing the properties listed in C.3.3(b) either all results determined on the 15 test specimens shall comply with the requirements of this British Standard; or

(b) If a maximum of 2 of the 15 results do not comply with the requirements of this British Standard, 45 further test specimens shall be taken and tested from different bars in the test unit, so that a total of 60 test results are available. The test unit shall be deemed to comply with this British Standard if no more than 2 of the 60 test results do not comply with the requirements of this British Standard.

C.3.5 Test report

A test report shall contain the following data:

- (a) Works producing the reinforcing steels
- (b) Nominal diameter
- (c) Grade of reinforcing steel
- (d) Marking on the reinforcing steel
- (e) Cast number
- (f) Date of testing
- (g) Mass of the test unit
- (h) The individual test results for all the properties specified in C.3.3.

Appendix D. Method of test for fatigue properties of deformed bars**D.1 Fatigue testing**

The fatigue properties for each defined bar shape and process route shall be established by a competent test laboratory (see foreword) initially by testing three sizes selected from the top, intermediate and bottom of the preferred size range. The full product size range shall be tested on a three yearly cycle.

Testing shall be carried out in batches on bars in the commercially straight condition. Bars shall be deemed defective or non-defective depending upon their ability to endure 5×10^6 cycles of stress at the stress range given for the relevant bar size in table 12.

D.2 Sampling

For sampling purposes bars shall be formed into batches of 50 bars of a single type and size, manufactured at the same time. Test specimens shall not be taken from bars exhibiting isolated defects which are not characteristic of the product. Each test specimen shall be cut from a bar selected at random and shall have a minimum length of $30d$ and a minimum free length of $10d$ where d is the nominal diameter of the test specimen. The test unit shall comprise five test specimens.

D.3 Test procedure

Test specimens 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. The sine wave form shall be used. Testing shall be carried out under load control and stresses shall be calculated on the nominal area.

The batch shall be deemed to comply with this British Standard provided that the number of cycles of stress specified in clause 11 have been achieved. Where this has not been achieved, the tests shall be considered invalid if the failure initiated from a defect unique to the test specimen or in an area adjacent to the testing machine grips.

D.4 Retests

D.4.1 The batch shall be deemed to comply with this British Standard if all five test specimens endure 5×10^6 cycles of stress.

D.4.2 Where two or more test specimens of the five initially selected fail to endure 5×10^6 cycles, the batch represented shall be deemed not to comply with this British Standard.

D.4.3 If one valid test specimen fails, a further five test specimens shall be selected from the batch represented. If one or more of these test specimens fails, the batch shall be deemed not to comply with this British Standard.

Bar size	Stress range
mm	N/mm ²
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

Appendix E. Tensile test multiplying factors

E.1 Hot rolled grade 460 bars of 50 mm diameter may be machined to 40 mm diameter for testing purposes. In this case for each type of bar and pattern of deformations multiplying factors are to be used to convert the test values measured on the machined test specimen to equivalence values for the as-rolled bar.

E.2 For each type of bar and pattern of deformation the multiplying factors are to be determined once and for all by comparative testing of 25 adjacent pairs of test specimens cut from at least 5 bars.

E.3 The tensile tests on the as-rolled test specimens of each pair are to be carried out using an extensometer to record the total extension on the gauge length of 0.5 %. The tensile tests on the machined test specimens are to be carried out using the same testing machine and extensometer.

The multiplying factors shall be calculated as follows:

$$r_y = \frac{Y_a}{Y_m}$$

$$r_u = \frac{T_a}{T_m}$$

$$r_e = \frac{E_a}{E_m}$$

where

Y_a is the yield stress of the as-rolled test piece (in N/mm²);

Y_m is the yield stress of the machined test piece (in N/mm²);

T_a is the tensile strength of the as-rolled test piece (in N/mm²);

T_m is the tensile strength of the machined test piece (in N/mm²);

E_a is the elongation of the as-rolled test piece (in %);

E_m is the elongation of the machined test piece (in %).

The converted test results shall be given on the test certificate.

Appendix F. Recommended formulae for calculating projected rib area

The projected rib area should be calculated for ribbed bars using one of the following equations:

(a) For as-rolled deformed bars the projected rib area R , in millimetres squared per millimetre, from the equation:

$$R = n \left(\frac{1a \sin \beta}{c} \right)$$

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Iron and Steel Standards Committee (ISM/-) to Technical Committee ISM/9, upon which the following bodies were represented:

British Independent Steel Producers' Association
British Precast Concrete Federation Ltd.
British Reinforcement Manufacturers' Association
British Steel Industry
British Steel Industry (Wire Section)
Cement and Concrete Association

Concrete Society
County Surveyor's Society
Department of the Environment (Property Services Agency)
Department of Transport (Highways)
Electricity Supply Industry in England and Wales
Federation of Civil Engineering Contractors
High Yield Bar Development Association
Institution of Civil Engineers
Institution of Structural Engineers
UK Certification Authority Reinforcing Steels

Amendments issued since publication

Amd. No.	Date of issue	Text affected

(b) For cold twisted bars the projected rib area R , in millimetres squared per millimetre, from the equation:

$$R = n \left(\frac{l a \sin \beta}{c} \right) + \frac{N A \pi \phi}{P}$$

where

n is the number of rows of transverse ribs. When more than one pattern of transverse ribs exists, e.g. alternate ribs having different angles or different rib patterns in each row, the first term shall be the sum of the calculated values for each set of ribs.

l is the length of the transverse rib measured at the rib to core interface determined as the average of three measurements on each row or set of transverse ribs (in mm).

a is the height of the transverse rib measured perpendicular to the core of the bar determined as the average of three measurements on each row or set of transverse ribs (in mm) (using Simpsons's rule for approximation under a curve, with rib height measurements at the mid and quarter points, the rib height for each rib profile may be established as a proportion of its mid point height. For transverse ribs of parabolic profile the rib height shall be taken as 2/3 of the mid point height).

β is the angle of the centre line of the transverse rib to the bar axis (in degrees).

c is the centre to centre spacing of transverse ribs determined by dividing the distance, measured parallel to the axis of the bar, between the mid points of two ribs, of the order of ten ribs apart, by the number of rib spaces in between. In the case of twisted bars this will necessitate counting rib spaces in a helical fashion.

N is the number of longitudinal ribs.

A is the height of the longitudinal rib determined as the average of three measurements on each rib (in mm).

P is the pitch of twist measured parallel to the bar axis determined as the average of three measurements (in mm).

ϕ is the nominal bar size.

π is 3.142.

Appendix G. Information to be supplied by the purchaser

The purchaser should give the following basic requirements on the order:

- (a) number and date of this British Standard;
- (b) nominal size of bar;
- (c) length of bar;
- (d) steel grade;
- (e) bond classification;
- (f) any additional requirements.

Publications referred to

BS 18	Method for tensile testing of metals (including aerospace materials)
BS 3846	Methods for calibration and grading of extensometers for testing of metals
BS 4466	Specification for bending dimensions and scheduling of reinforcement for concrete
BS 5750*	Quality systems Part 2 Specification for production and installation
BS 6200	Sampling and analysis of iron, steel and other ferrous metals Part 3 Methods of analysis
Handbook 19	Methods for the sampling and analysis of iron, steel and other ferrous metals
Euronorm 80*	Reinforcing steel (not for pre-stressing) Technical delivery conditions

*Referred to in the foreword only.