British Standard

BRITISH STANDARD

BS 5896:1980

Specification for

High tensile steel wire and strand for the prestressing of concrete

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Cooperating organizations

The Iron and Steel Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

British Cast Iron Research Association
British Constructional Steelwork Association
British Internal Combustion Engine Manufacturers' Association
British Ironfounders' Association
British Railways Board
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The organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

British Steel Corporation
British Precast Concrete Federation Ltd.
Cement and Concrete Association
Concrete Pipe Association
Department of the Environment (PSA)
Prestressing Equipment Manufacturing Association

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Contents

Foreword

This British Standard, prepared under the direction of the Iron and Steel Standards Committee, supersedes BS 2691:1969 "*Steel wire for prestressed concrete*" and BS 3617:1971 "*Seven-wire steel strand for prestressed concrete*" both of which are now withdrawn. The standard closely follows the appropriate parts of Euronorm 138 "Prestressing steels", but some minor changes have been made in order to make it applicable to the requirements of the United Kingdom. Requirements for high tensile alloy steel bars for the prestressing of concrete are specified in BS 4486.

Certification. Attention is drawn to the certification facilities described on the inside back cover of this standard.

A British Standard does not purport to include all the 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 14, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This British Standard specifies requirements for high tensile strength steel wire and seven-wire strand that are to be used for the prestressing of concrete, and is applicable only to material in the condition as supplied by the manufacturer. Requirements for other materials that may be associated with the steel in a prestressing tendon are not specified in this standard.

The types of prestressing steel, the associated methods of manufacture, and general requirements are specified in section 1. The specific properties for each type of prestressing steel are specified in sections 2 and 3.

2 References

The titles of the publications referred to in this standard are listed on the inside back cover.

3 Definition

For the purposes of this British Standard the following definition applies.

consignment

any quantity of material prepared at any one time for delivery to one location

4 Types of prestressing wire and strand

4.1 Cold-drawn wire. Cold-drawn wire is produced in coil form from hot rolled rod treated to make it suitable for cold drawing. The surface is smooth and may be covered by a residue of drawing lubricant.

By subsequent mechanical processes the wire may be indented or crimped and a final stress-relieving treatment is carried out on the wire in one of the following ways:

a) stress-relieving by heating to a suitable temperature for a short time to improve certain mechanical properties;

b) a similar stress-relieving heat treatment carried out under plastic deformation, for example under conditions of longitudinal strain, additionally to improve the relaxation characteristics.

4.2 Strand. Strand is made from cold-drawn wires. The seven-wire strand consists of a straight core wire around which are spun six helical wires in one layer.

Strand is given a final stress-relieving treatment in the same way as for cold-drawn wire and is wound into coil form. Drawn strand is strand that has been drawn through a die and given a stress-relieving treatment before winding into coil form.

5 Steel making

The steel may be made by any process except that the air and mixed air/oxygen bottom blown processes shall not be used.

The chemical composition shall be related to the type of product and its size and tensile strength. If required by the purchaser, a chemical analysis of the steel shall be provided by the supplier. The cast analysis shall not show more than 0.040 % sulphur or more than 0.040 % phosphorus.

6 Properties of prestressing steels

6.1 Introduction. The properties specified in **6.2**, **6.3** and **6.4** are significant and those to be determined for the appropriate type of inspection are given in clause **7**. The specific type of test for each product is specified in sections 2 and 3.

6.2 Geometrical properties. The geometrical properties are defined by a nominal dimension, characteristic of the section, with specified tolerances.

Where this is insufficient or inappropriate, it is permitted to define the geometrical properties by nominal cross section with specified tolerances and appropriate details of the configuration of the wire or strand (see sections 2 and 3).

6.3 Mechanical properties

6.3.1 *Specified characteristic value.* In this standard specified characteristic values are shown as either:

specified characteristic breaking loads and specified characteristic 0.1 % proof loads; or

specified characteristic tensile strength and specified characteristic 0.1 % proof stress.

For prestressing steel the specified characteristic value is the lower limit of the one sided statistical tolerance interval for which there is a 95 % probability that at least 95 % of the values will be equal to or greater than this lower limit. For the practical application of this criterion it is arbitrarily assumed that the distribution is normal (see BS 2846-3).

In manufacturer's inspection the criterion may be considered to be met if, in each homogeneous production lot, not more than 5 % of the test results are less than the specified characteristic value and no test result is less than 95 % of this value.

6.3.2 *Maximum standard deviation.* For the statistical interpretation of data (see **8.4**) a maximum standard deviation is given for the tensile strength and 0.1 % proof stress, or breaking load and 0.1 % proof load, in sections 2 and 3 for each product.

The maximum standard deviation for each product is the maximum value of the standard deviation based on the entire production of each product of one manufacturer for a sufficiently long period using the same process and technique.

Specified characteristic values associated with maximum standard deviations indicate the desired level and degree of consistency of the property under consideration.

The maximum standard deviations specified are intended for application in:

a) manufacturer's inspection for the verification of the degree of consistency of the production; and

b) acceptance tests of material not covered by a certification scheme, for comparison with the standard deviation of the sample in accordance with **8.4**.

6.3.3 *Breaking load.* The specified breaking load value is the characteristic breaking load, defined in **6.3.1**.

Tensile stress, if required, shall be calculated from the load and the actual or nominal area as specified for each product.

6.3.4 *Proof load.* The specified proof load value is the characteristic 0.1 % proof load, defined in **6.3.1**.

Proof stress, if required, shall be calculated from the load and the actual or nominal area as specified for each product.

6.3.5 *Elongation.* The percentage elongation under maximum load shall be determined on a gauge length appropriate to the product.

6.3.6 *Ductility.* The prestressing steel shall be proved to have suitable ductility by means of reverse bending or constriction or both, depending upon the product, as specified in sections 2 and 3.

6.4 Long-term behaviour

6.4.1 *Isothermal relaxation.* Curves for relaxation of load shall be established at a nominal temperature of 20 °C for a period of 1 000 h from initial stresses of 60 %, 70 % and 80 % of the actual strength, determined on an adjacent test piece (see **A.4**).

6.5 Technological properties

6.5.1 *Wire condition.* The finished material shall be free from defects, which may have occurred at any stage of manufacture, to a degree that would impair the performance as a prestressing tendon.

Longitudinal surface defects are acceptable provided that their depth is less than 4 % of the nominal diameter of the wire.

Rusted steels, apart from those with a thin film of rust, shall not be supplied.

NOTE Coatings for specific purposes are to be applied to the surface of the steel only if previously agreed between the purchaser and the manufacturer. Such coatings are not specified in this standard.

6.5.2 *Welds.* The limitations on the presence of welds for each product are specified in sections 2 and 3.

7 Inspection

7.1 General. Procedures for the following are specified in this clause:

Manufacturer's inspection.

Material covered by a certification scheme.

The manufacturer's testing records covering the output as a whole shall be accessible to the purchaser or other authorized person.

7.2 Manufacturer's inspection

7.2.1 The manufacturer shall carry out an inspection for those items in the following list that are appropriate to the product. The unit quantity for sampling and the frequency of each test are specified for each product in sections 2 and 3, except for tests on long-term behaviour. Relaxation tests shall be carried out periodically on the minimum number of pieces necessary to verify the established data.

1) The appropriate geometrical properties
2) Wire condition
3) Breaking load or tensile strength
4) Proof load or proof stress
5) Elongation at maximum load
6) Load-extension diagram
7) Ductility (constriction)
8) Ductility (reverse bend)
9) Relaxation

NOTE For special purposes, test evidence may be required on fatigue and stress corrosion (see Appendix B).

7.2.2 Products with satisfactory test results shall be considered to comply with the requirements of this standard.

7.3 Material covered by a certification scheme. Where the manufacturer and his products are required to be approved under a certification scheme acceptable to the purchaser, control procedures shall be carried out to the satisfaction of the certifying authority.

The manufacturer's inspection shall be in accordance with **7.2**.

7.4 Test certificates. Each consignment shall be accompanied by a test certificate containing:

a) all the information necessary to identify the consignment;

b) a summary of test results from the manufacturer's records.

NOTE On request, purchasers may obtain from the manufacturers maximum and minimum load-extension diagrams (showing maximum and minimum values of modulus of elasticity), covering the testing of material used to make up a consignment.

7.5 Compliance. A consignment shall be deemed to comply with the requirements of this standard on the basis of the manufacturer's test certificate, normally without the need for further testing. This does not preclude the purchaser's option to carry out further tests to verify that the specified properties have been attained.

8 Material not covered by a certification scheme

8.1 Documentation. Documentary evidence of the manufacturer's ability to comply with the requirements of this standard is required as follows.

The manufacturer shall provide a survey of his recent inspection tests for all the properties appropriate to the product specified in this standard. If the manufacturer has not previously or recently supplied material complying with the requirements of this standard, by agreement with the purchaser recent data on material to a similar specification may be submitted.

It is permissible for data on long-term behaviour normally covered by periodical testing to be taken from manufacturer's records of tests on recent production of similar material (see **7.2**).

8.2 Inspection of consignments. Each separate consignment shall be subject to inspection by the manufacturer in accordance with **7.2**, with the exception of the tests for long-term behaviour (see **6.4**).

8.3 Test certificates. Each consignment shall be accompanied by a test certificate containing:

a) all the information necessary to identify the consignment;

b) all the test results obtained in testing the consignment (see **8.2**);

c) maximum and minimum load-extension diagrams covering the testing of materials used to make up the consignment;

d) cast analysis of the steel.

8.4 Acceptance. If the purchaser is satisfied with the manufacturer's ability to supply material to the specification (see **8.1**), but wishes to have further or independent inspection in addition to that given by the manufacturer's test certificate, the details shall be agreed at the time of ordering the material.

Such purchasers' acceptance tests for the same properties shall be made on a sample selected in accordance with the appropriate requirements for each product (see sections 2 and 3).

Analysis of the results of the breaking load (or tensile strength) and proof load (or proof stress) tests made on the sample shall show compliance with the specified characteristic values and maximum standard deviation. Statistical interpretation of data shall be in accordance with Table 3 of BS 2846-3:1975 and Table E of BS 2846-4:1976 both for one sided tolerance interval of 0.95 and for confidence level of 0.95.

For all other properties, all test results shall show compliance with the requirements of this standard.

Where sufficient data is available on long-term behaviour (see **6.4**), these properties shall be excluded from purchaser purchaser's acceptance tests.

9 Test methods

The methods of test employed shall be in accordance with Appendix A.

10 Delivery conditions

10.1 Identification. Each coil of wire or strand shall carry a label stating the following information or such other details as may be agreed between the purchaser and the manufacturer:

a) the number of this standard and the appropriate section number (2 or 3), e.g. BS 5896-2;

b) the product (wire or strand);

c) the specified characteristic breaking load (or equivalent nominal tensile strength);

d) the nominal diameter;

e) in the case of wire, the type of surface (smooth, indented or crimped);

f) the class of relaxation (relax 1 or relax 2);

g) the coil number related to test certificate;

h) the manufacturer's name and plant;

10.2 Coil size. Unless otherwise agreed, the coil size shall be in accordance with **16.2** (for wire), and **22.2** (for strand).

The diameter of the coil shall be sufficiently large to ensure that the material can be uncoiled without difficulty. A maximum curvature of the prestressing steel is specified in **16.3** (for wire) and **22.3** (for strand).

11 Transport and storage

Prestressing steels in transport and storage shall be protected against damage and contamination.

12 Information to be supplied by the purchaser

When ordering material to this standard the purchaser shall state:

a) the number of this standard and the appropriate section number (2 or 3), e.g. BS 5896-2;

b) the type of material (as drawn or straightened wire, or seven-wire strand);

c) specified characteristic breaking load (or equivalent nominal tensile strength);

d) nominal diameter;

e) wire surface (smooth, indented or crimped);

f) class of relaxation (relax 1 or relax 2);

g) packing and protection requirements.

Section 2. Specific requirements for cold-drawn wire

13 Introduction

Section 2 gives specific requirements for round cold-drawn high tensile steel wire, either plain, or indented or crimped, supplied in coils, either:

a) as drawn on the wiredrawing machine in coils of internal diameter approximating to that of the wire-drawing capstan; or

b) straightened and stress-relieved with two classes of relaxation. The straightened wire may be supplied in cut lengths.

14 Designation

The wire shall be ordered in accordance with clause **12** and be designated as follows:

a) BS 5896-2;

b) wire;

c) nominal tensile strength;

d) nominal diameter;

e) D = as drawn; P = straightened;

f) E = smooth, I = indented, C = crimped (see **15.2.3**);

g) class of relaxation (relax 1 or relax 2).

Example

Straightened indented wire of nominal diameter 7 mm and nominal tensile strength 1 770 N/mm^2, with class 1 relaxation is designated:

BS 5896-2 wire-1770-7-PI-relax 1

15 Manufacture

15.1 Material. The wire shall be manufactured from non-alloy steel (high carbon content) in accordance with **4.1**, clause **5**, **6.5**, **15.2** and **15.3**.

15.2 Type of deformation

15.2.1 *General.* When indented or crimped wire is specified, the type of deformation shall be agreed between the purchaser and the manufacturer. The examples given in **15.2.2** and **15.2.3** are for information purposes.

15.2.2 *Indentations.* Figure 1 indicates the preferred arrangement of indentations. The nominal dimensions of the indentations related to nominal wire diameter are as shown in Figure 1 and Table 1. Other forms of indentation are permissible.

15.2.3 *Crimps.* Figure 2 indicates two methods of crimping, helical and uni-planar. The total wave height (excluding the wire diameter) and pitch of crimping are as shown in Figure 2 and Table 2. Other forms of crimping are permissible.

15.3 Welds. There shall be no welds in the wire as supplied to the purchaser.

16 Delivery by the manufacturer

16.1 General. Delivery conditions shall be in accordance with clause **10**, clause **12**, **16.2** and **16.3**.

16.2 Coil diameter. The nominal internal diameter of mill coils shall be agreed between the purchaser and the manufacturer.

Straightened wire, after stress-relieving, shall be wound into large diameter coils. The preferred coil diameters are given in Table 3.

The manufacturer shall state the coil size on the test certificate.

16.3 Curvature of straightened wire. When a length of wire is lying free on a flat surface, the maximum bow height from a base line 1 m in length, measured from the inside of the curve, shall not be greater than 30 mm for all wire diameters.

17 Inspection

17.1 General. The inspection procedures shall be in accordance with clauses **7**, **8** and **9** and **17.2**, **17.3** and **17.4**.

17.2 Unit of production for sampling. The unit of production, from which a test piece is selected, is the amount of wire manufactured from one original coil of rod.

17.3 Sample size and frequency for each test

17.3.1 *Manufacturer's inspection* (see **7.2**). Tests for property nos. 1, 2, 3 and 7 shall be carried out on every unit.

Tests for property nos. 4, 5, 6 and 8 shall be carried out on one unit in five.

The tests to be carried out depend upon the type of wire, see Table 4 and Table 5.

17.3.2 *Purchaser's acceptance testing for non-certified material* (see **8.4**).

17.3.2.1 The consignment shall be divided into inspection lots of 50 t and a test piece shall be selected from each unit in a random selection of fifteen units of production in the inspection lot.

17.3.2.2 If there are less than fifteen units in the consignment, then each coil of wire in the consignment shall be tested.

17.3.2.3 Tests for property nos. 1 to 8, appropriate to the type of wire (see Table 4 and Table 5), shall be carried out on each test piece.

17.4 Retests

17.4.1 *Tests for compliance with specified characteristic values* (see **6.3.1**). No retests are permitted, except where there has been a malfunction in the test procedure.

17.4.2 ***Tests for compliance with all other mechanical properties***

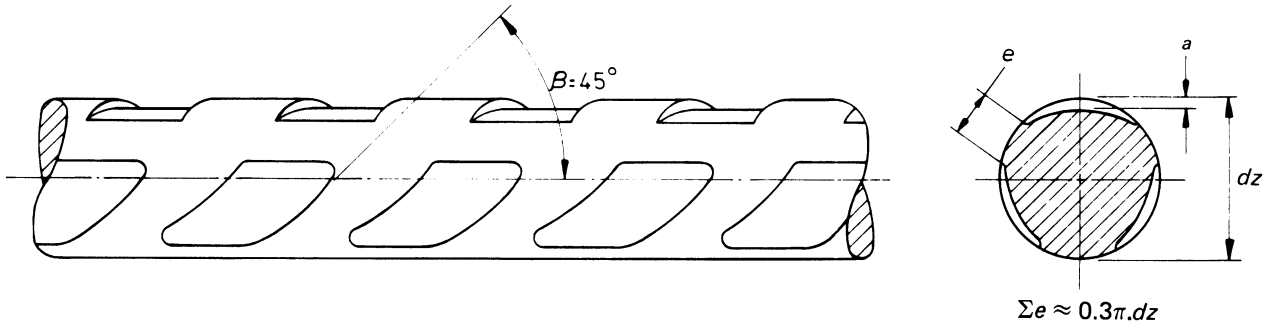
17.4.2.1 *Manufacturer's inspection.* If any test piece fails any of the specified tests, two additional test pieces shall be taken from the same unit of production. These test pieces shall be subjected to the same test or tests that the original test piece failed. If both test pieces pass the tests then that unit of production shall be deemed to comply with the requirements of this standard. If one of the retest pieces fails then the unit of production shall be deemed not to comply with the requirements of this standard.

17.4.2.2 *Purchaser's testing of non-certified material.* In the case of material inspected according to **17.3.2.1**, if any test piece fails, the purchaser's inspection lot shall be deemed not to comply with the requirements of this standard until the same test or tests have been satisfactorily completed on a further random selection of fifteen units of production in the lot.

In the case of material inspected according to **17.3.2.2**, if any test piece fails, the corresponding coil shall be rejected.

Table 1 — Nominal dimensions of indentations

Nominal wire diameter d	Depth a	Length	Pitch
mm	mm	mm	mm
5.0 and below	0.12 ± 0.05	3.5	5.5
Over 5.0	0.15 ± 0.05	5.0	8.0



NOTE One line of indentations is at a contrary angle to the others.

Figure 1 — Indentations

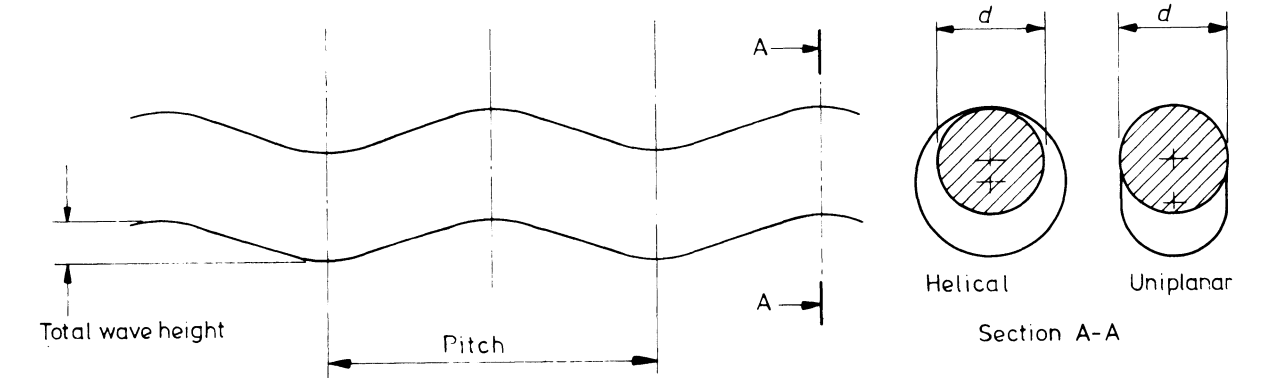


Figure 2 — Crimps

Table 2 — Crimp dimensions

Type of crimp	Pitch	Total wave height (excluding the wire diameter)	
		Helical	Uniplanar
Short pitch	5*d* to 10*d*	5 % *d* to 10 % *d*	10 % *d* to 20 % *d*
Long pitch	8*d* to 12*d*	6 % *d* to 12 % *d*	12 % *d* to 25 % *d*

Table 3 — Nominal internal diameter of coil

Nominal wire diameter *d*	Coil diameter
mm	m
4.0 and 4.5	1.25
5.0	1.5
6.0 and 7.0	2.0

18 Properties

18.1 Data. The designations, data for information and required properties are given in Table 4 and Table 5, subject to the qualifications given in **18.2**, **18.3** and **18.4**.

18.2 Geometrical properties of smooth wire. Where the diameter measurements of smooth round wire (taken in two directions at right angles in the same plane) show an ovality of not more than one half of the total diameter tolerance, no checks on section by weighing shall be necessary.

18.3 Indented wire

18.3.1 *Diameter.* The nominal diameter of indented wire is the diameter of the smooth wire having the same nominal cross-section. The actual diameter of indented wire shall not be subject to checking.

18.3.2 *Cross section.* The actual cross section of indented wire shall be calculated from the mass, in accordance with the method described in **A.1**.

18.3.3 *Depth of indentation.* The depth of indentation shall be measured on one unit of production in ten.

18.4 Crimped wire. The total wave height of the crimp (excluding the wire diameter) and the pitch shall be measured on one unit of production in ten.

Table 4 — Dimensions and properties of cold-drawn wire

Nominal diameter (see note 1)	Nominal tensile strength (see notes 1 and 3)	Nominal 0.1 % proof stress (see notes 2 and 3)	Nominal cross-section (see note 2)	Nominal mass (see note 2)	Tolerance on			Specified characteristic breaking load (see notes 6 and 7)	Specified characteristic 0.1 % proof load (see notes 4, 6 and 7)	Load at 1 % elongation (see notes 4, 6 and 7)	Minimum elongation at max. load L_o = 200 mm	Ductility tests			Relaxation		
					Dia.	Cross-sectional area	Mass					Constriction at break	Reverse bends		Initial load (% of actual breaking load)	Max. relaxation after 1 000 h	
													Min. number	Bend radius		Relax class 1	Relax class 2
mm	N/mm^2	N/mm^2	mm^2	g/m	mm	mm^2	g/m	kN	kN	kN				mm			
7 7	1 570 1 670	1 300 1 390	38.5	302	± 0.05	± 0.55	± 4.3	60.4 64.3	50.1 53.4	51.3 54.7	For all wires 3.5 %	For all wires: a ductile break visible to the naked eye	4 for smooth wires 3 for indented wires	20	For all wires 60 % 70 % 80 %	For all wires 4.5 % 8 % 12 %	For all wires 1.0 % 2.5 % 4.5 %
6 6	1 670 1 770	1 390 1 470	28.3	222	± 0.05	± 0.47	± 3.7	47.3 50.1	39.3 41.6	40.2 42.6				15			
5 5	1 670 1 770	1 390 1 470	19.6	154	± 0.05	± 0.39	± 3.1	32.7 34.7	27.2 28.8	21.8 29.5				15 15			
4.5	1 620	1 350	15.9	125	± 0.05	± 0.35	± 2.7	25.8	21.4	21.9				15			
4 4	1 670 1 770	1 390 1 470	12.6	98.9	± 0.04	± 0.25	± 2.0	21.0 22.3	17.5 18.5	17.9 19.0				10			

NOTE 1 The nominal diameter and nominal tensile strength are for designation purposes only.

NOTE 2 The nominal 0.1 % proof stress, nominal cross-section and nominal mass are for information only.

NOTE 3 The nominal tensile strength is calculated from the nominal cross-section and the specified characteristic breaking load (see note 7).

NOTE 4 The specified characteristic 0.1 % proof load is approximately 83 % of the specified characteristic breaking load. By agreement, alternatively the characteristic load at 1 % elongation may be specified, which is approximately 85 % of the specified characteristic breaking load.

NOTE 5 The modulus of elasticity is to be taken as 205 + 10 kN/mm^2, unless otherwise indicated by the manufacturer.

NOTE 6 The maximum standard deviations are:

tensile strength: 55 N/mm^2, or the equivalent value expressed as a load (see **6.3.2**)

0.1 % proof stress: 60 N/mm^2, or the equivalent value expressed as a load (see **6.3.2**).

NOTE 7 In view of the close tolerance on diameters and areas, specified characteristic loads have been specified rather than stresses.

Table 5 — Dimensions and properties of cold-drawn wire in mill coil

Nominal diameter (see note 1) mm	Nominal tensile strength (see notes 1 and 4) N/mm^2	Nominal cross-section (see note 2) mm^2	Nominal mass (see note 2) g/m	Tolerance on			Specified characteristic breaking load (see notes 5 and 6) kN	Specified characteristic load at 1 % elongation (see notes 3, 5 and 6) kN	Ductility tests			Relaxation	
				Dia. mm	Cross-sectional area mm^2	Mass g/m			Constriction at break	Reverse bends		Initial load (% of actual breaking load)	Max. relaxation after 1 000 h
										Min. number	Bend radius mm		
5	1 570	19.6	154	± 0.05	± 0.39	± 3.1	30.8	24.6	For all wires: a ductile break visible to the naked eye	4 for smooth wires 3 for indented wires	15	For all wires 60 % 70 %	For all wires 8 % 10 %
5	1 670						32.7	26.2					
5	1 770						34.7	27.8					
4.5	1 620	15.9	125	± 0.05	± 0.35	± 2.7	25.8	20.6			15		
4	1 670	12.6	98.9	± 0.04	± 0.25	± 2.0	21.0	16.8			10		
4	1 720						21.7	17.4					
4	1 770						22.3	17.8					
3	1 770	7.07	55.5	± 0.04	± 0.25	± 1.5	12.5	10.0			7.5		
3	1 860						13.1	10.5					

NOTE 1 The nominal diameter and nominal tensile strength are for designation purposes only.

NOTE 2 The nominal cross-section and nominal mass are for information only.

NOTE 3 In order to prove the suitability of this material, which is only used in certain applications, e.g. railway sleepers, there is a requirement for a load at 1 % total elongation to be at least 80 % of the specified characteristic breaking load.

NOTE 4 The nominal tensile strength is calculated from the nominal cross-section and the specified characteristic breaking load (see note 6).

NOTE 5 The maximum standard deviation are:

tensile strength: 55 N/mm^2, or the equivalent value expressed as a load (see **6.3.2**);

stress at 1 % elongation: 60 N/mm^2, or the equivalent value expressed as a load (see **6.3.2**).

NOTE 6 In view of the close tolerance on diameters and areas, specified characteristic loads have been specified rather than stresses.

Section 3. Specific requirements for strand

19 Introduction

Section 3 gives specific requirements for high tensile steel wire strand that has been given a stress relieving heat treatment to produce either of two classes of relaxation.

The strand may be:

a) seven-wire standard strand,

b) seven-wire super strand,

c) seven-wire drawn strand.

20 Designation

The strand shall be ordered in accordance with clause **12** and be designated as follows:

a) BS 5896-3;

b) seven-wire strand, e.g. standard, super or drawn strand;

c) nominal tensile strength;

d) nominal diameter;

e) class of relaxation (relax 1 or relax 2).

Example

Seven-wire super strand, nominal diameter 12.9 mm and nominal tensile strength 1 770 N/mm^2, class 2 relaxation is designated

BS 5896-3 super strand-1770-12.9-relax 2.

21 Manufacture

21.1 Material. The strand shall be manufactured from non-alloy steel (high carbon content) wire in accordance with **4.2**, clause **5**, **6.5** and **21.2** to **21.6**.

21.2 Stranding process. The diameter of the straight centre wire of seven-wire strand shall be at least 2 % greater than the diameter of the outer helical wires. The latter shall be tightly spun around the centre wire with a lay length or pitch of between 12 times and 18 times the nominal strand diameter. The preferred direction of lay of the outer wires is right hand.

21.3 Defects. Longitudinal surface defects are acceptable provided their depth is less than 4 % of the nominal size of the component wires.

21.4 Welds. The normal production lengths may contain welds made in the individual wires before drawing, but shall not contain any welds made during or after wiredrawing. Not more than one weld in any component wire shall be permitted in any 50 m of strand.

21.5 Stress-relieving heat treatment. The strand shall be subjected to a low temperature heat treatment as a continuous linear process by uncoiling and running the strand through any suitable form of heating, as described in **4.1**. The strand shall be rewound into coils or on to reels.

Strand-forming operations and the stress-relieving treatment shall ensure either that the wires do not unravel when the strand is cut, or that they may be put back into position without difficulty.

21.6 Drawn strand. The seven-wire strand before drawing shall comply with the requirements of **21.4**, and after drawing and the stress relieving treatment shall have a lay length of 14 times to 18 times the nominal strand diameter.

22 Delivery by the manufacturer

22.1 General. Delivery conditions shall be in accordance with clauses **10** and **12** and **22.2** and **22.3**.

22.2 Coil size. The preferred coil dimensions are as follows.

Internal diameter:	800 ± 60 mm or 950 ± 60 mm.
Width:	600 ± 50 mm or 750 ± 50 mm.

The manufacturer shall state the coil size on the test certificate.

22.3 Curvature of strand. When a length of seven-wire strand is lying free on a flat surface, the maximum bow height from a base line 1 m in length, measured to the inside of the curve, shall not be greater than 25 mm.

23 Inspection

23.1 General. The inspection procedures shall be in accordance with clauses **7**, **8** and **9**, as appropriate, and **23.2**, **23.3** and **23.4**.

23.2 Unit of production for sampling. The unit of production from which a test piece is selected is the manufacturing length of strand of mass equivalent to seven original rod coils.

23.3 Sample size and frequency for each test

23.3.1 *Manufacturer's inspection* (see **7.2**). Tests for property nos. 1, 2, 3, 5 and 7 shall be carried out on every unit, except that for property no. 5 it is only necessary to confirm that the minimum specified value has been achieved. The actual value of elongation at maximum load shall be determined on one unit in three.

Tests for property nos. 4 and 6 shall be carried out on one unit in three.

23.3.2 ***Purchaser's acceptance testing for non-certified material*** (see **15.3**)

23.3.2.1 The consignment shall be divided into inspection lots of 100 t. A test piece shall be selected from each unit in a random selection of fifteen units of production in the inspection lot.

23.3.2.2 If there are less than fifteen units in the consignment, then each coil of strand in the consignment shall be tested.

23.3.2.3 Tests for property nos. 1 to 7 shall be carried out on each test piece.

23.4 Retests

23.4.1 *Tests for compliance with specified characteristic values* (see **6.3.1**). No retests are allowed, except where there has been a malfunction in the test procedure.

23.4.2 ***Tests for compliance with all other mechanical properties***

23.4.2.1 *Manufacturer's inspection.* If any test piece fails any of the specified tests, two additional test pieces shall be taken from the same unit of production. These test pieces shall be subjected to the same test or tests in which the original test piece failed. If both test pieces pass the tests then that unit of production shall be deemed to comply with the requirements of this standard. If one of the retest pieces fails then the unit of production shall be deemed not to comply with the requirements of this standard.

23.4.2.2 *Purchaser's testing of non-certified material.* In the case of material inspected according to **23.3.2.1**, if any test piece fails, the purchaser's inspection lot shall be deemed not to comply with the requirements of this standard until the same test or tests have been satisfactorily completed on a further random selection of fifteen units of production in the lot.

In the case of material inspected according to **23.3.2.2**, if any test piece fails, the corresponding coil shall be rejected.

24 Properties

24.1 Data. The designations, data for information and required properties are given in Table 6.

24.2 Diameter. The diameter of seven-wire strand shall be measured across a diametrically opposite pair of outer wires.

In case of dispute a rope gauge shall be used for the measurement.

The diameter shall be within the limits given in Table 6.

Table 6 — Dimensions and properties of strands

Type of strand (see note 1)	Nominal dia. (see note 1)	Nominal tensile strength (see note 1)	Nominal steel area (see note 2)	Nominal mass (see note 2)	Tolerance on			Specified characteristic breaking load (see notes 6 and 7)	Specified characteristic 0.1 % proof load (see notes 4, 6 and 7)	Load at 1 % elongation (see notes 4, 6 and 7)	Minimum elongation at max. load $L_o \geq 500$ mm	Constriction at break	Relaxation		
					Dia.	Cross-sectional area	Mass						Initial load (% of actual breaking load)	Max. relaxation after 1 000 h	
														Relax class 1	Relax class 2
	mm	N/mm^2	mm^2	g/m	mm	mm^2	g/m	kN	kN	kN					
7-wire standard	15.2	1 670	139	1 090	+ 0.4 – 0.2	For all strands + 4 % – 2 %	For all strands + 4 % – 2 %	232	197	204	For all strands 3.5 %	For all strands ductile wire breaks visible to the naked eye	For all strands 60 %	For all strands 4.5 %	For all strands 1.0 %
	12.5	1 770	93	730				164	139	144			70 %	8 %	2.5 %
	11.0	1 770	71	557	+ 0.3 – 0.15			125	106	110			80 %	12 %	4.5 %
	9.3	1 770	52	408				92	78	81					
7-wire super	15.7	1 770	150	1 180	+ 0.4 – 0.2			265	225	233					
	12.9	1 860	100	785				186	158	163					
	11.3	1 860	75	590	+ 0.3 – 0.15			139	118	122					
	9.6	1 860	55	432				102	87	90					
	8.0	1 860	38	298				70	59	61					
7-wire drawn	18.0	1 700	223	1 750	+ 0.4 – 0.2			380	323	334					
	15.2	1 820	165	1 295				300	255	264					
	12.7	1 860	112	890				209	178	184					

NOTE 1 The type of strand, nominal diameter and nominal tensile strength data are given for designation purposes only.

NOTE 2 The nominal steel area and nominal mass data are given for information only.

NOTE 3 The nominal tensile strength is calculated from the nominal steel area and the specified characteristic breaking load (see note 7).

NOTE 4 The specified characteristic 0.1 % proof load is approximately 85 % of the specified characteristic breaking load. Alternatively, by agreement between the manufacturer and the purchaser, the characteristic load at 1 % elongation may be specified, which is approximately 88 % of the specified characteristic breaking load.

NOTE 5 The modulus of elasticity is to be taken as 195 ± 10 kN/mm^2, unless otherwise indicated by the manufacturer.

NOTE 6 The maximum standard deviations are:

tensile strength: 55 N/mm^2, or the equivalent value expressed as a load;

0.1 % proof stress: 60 N/mm^2, or the equivalent value expressed as a load.

NOTE 7 In view of the close tolerance on mass and areas, specified characteristic loads have been specified rather than stresses.

Appendix A Test methods

A.1 Dimensions

The dimensions shall be measured in accordance with **18.2**, **18.3** and **24.2**. Where the actual cross-sectional area is required, this is to be obtained as follows. Take three test pieces of not less than 500 mm in length and measure the length of each piece to an accuracy of 1 mm. Determine the mass of each test piece to the nearest gram. Calculate the cross-sectional area of each test piece from the following relationship:

$$A = \frac{m}{ld}$$

where

A is the cross-sectional area (in mm^2) of the test piece;

m is the mass (in g) of the test piece;

l is the length (in mm) of the test piece;

d is the density (in g/mm^3) of the product.

The actual cross-sectional area is taken to be the mean of the three values obtained.

Unless otherwise specified for the product, the density shall be taken as 0.00785 g/mm^3.

A.2 Tensile properties

Tensile properties of strand shall be measured in accordance with BS 18-2 and the tensile properties of wire shall be measured in accordance with BS 4545, except where qualified in **A.5**.

A.3 Reverse bend

Reverse bend testing shall be carried out in accordance with BS 4545.

A.4 Relaxation

Relaxation testing shall be conducted under the following conditions.

a) The temperature of the test piece shall be 20 ± 2 °C and the temperature shall be maintained within this range for the duration of the test.

b) The test piece shall not have been subjected to any loading or temperature treatment subsequent to manufacture.

c) The initial load equivalent to 60 %, 70 % or 80 % of the specified characteristic load shall be applied uniformly over a period of not more than 5 min. Thereafter, the gauge length shall be maintained constant and load relaxation readings shall commence one min after application of the total load (for wire) or of the initial load (for strand).

d) Overstressing of the test piece during the loading operation shall not be permitted.

e) The duration of the test shall be 1 000 h.

f) For strand, the test gauge length shall be at least equal to one lay length of the strand.

The above standard conditions of test piece temperature, initial load, overstressing and duration of test may be varied to provide information on other conditions, but such variations shall be quoted against the test result and the test result shall not be stated to be in accordance with this British Standard.

A.5 Strand testing

A.5.1 *Breaking load.* The strand shall be held in grips, which shall not cause excessive damage to the wires. If any wire break occurs at a distance from one of the grips of less than the strand diameter, the test shall be discarded.

A.5.2 *Elongation at maximum load.* The elongation of the strand under maximum load shall be measured on a gauge length of not less than 500 mm by means of a suitable extensometer. The elongation shall be measured prior to fracture of any of the component wires.

Where the extensometer cannot be left on the test piece to failure, the elongation can be measured as follows.

Proceed by the method for measuring load at 1 % extension and continue loading until the extensometer records an elongation equivalent to 3.5 %. At this point, remove the extensometer and note the distance between the testing machine cross-heads. Continue the loading until fracture of one or more wires of the strand occurs and then note the final distance between the cross-heads.

Calculate the difference between the cross-head measurements as a percentage of the original test length between the cross-heads and add this value to the 3.5 % obtained by extensometer.

Appendix B Fatigue and stress-corrosion

Fatigue and stress-corrosion are not specified in this standard, but, if test evidence is requested, note should be taken of the following points.

B.1 Stress-corrosion behaviour

The test method and principles of assessment are to be agreed between the manufacturer and the purchaser or other authority. In general terms, the most favoured method involves testing the wire or strand in straight tension at 80 % of tensile strength, with the test piece completely immersed in a 20 % solution of ammonium thiocyanate at a slightly elevated temperature.

B.2 Fatigue behaviour

Subject to the admission of an occasional failure, the material should withstand two million cycles of stress fluctuating down from a maximum stress of 80 %[1)] of the actual strength, determined on an adjacent test piece. The fluctuating stress range, i.e. twice the stress amplitude, is to be in accordance with Table 7.

Table 7 — Fluctuating stress range

Fluctuating stress range	Product
N/mm^2	
200	straight smooth wire
180	straight indented wire and provisionally crimped wire
195	strand

[1)] Provisionally, wire in mill coil would be tested from a maximum stress of 70 % for the same fluctuating stress as the corresponding type of straight wire.

Publications referred to

BS 18, *Methods for tensile testing of metals.*

BS 18-2, *Steel (general).*

BS 2846, *Guide to statistical interpretation of data.*

BS 2846-3, *Determination of a statistical tolerance interval.*

BS 2846-4, *Techniques of estimation and tests relating to means and variances.*

BS 3518, *Methods of fatigue testing.*

BS 3518-1, *General principles.*

BS 4486, *Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete.*

BS 4545, *Methods for mechanical testing of steel wire.*

Enronorm 138 Prestressing steels.

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