

BS 5896:2012



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High tensile steel wire and strand for the prestressing of concrete – Specification

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Summary of pages

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 May 2012. It was prepared by Technical Committee ISE/104, *Concrete reinforcing and prestressing steels*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 5896:1980, which is withdrawn.

Relationship with other publications

This standard has been revised to follow BS EN 10138-1 (in preparation). Definitions, symbols, steelmaking and manufacturing processes, routine inspection and testing, test methods, identification of the manufacturer and technical class and verification of mechanical properties in the case of dispute may be taken from BS EN 10138-1, when published.

CEN Derogation from standstill

The European Committee for Standardization (CEN) have granted derogation from standstill to permit BSI to publish this British Standard as a UK national standard. This derogation is to enable the continued production of steel products for the prestressing of concrete, incorporating the latest products on the UK market, and for reasons of product safety and has been granted until publication of the BS EN 10138 series.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard specifies general requirements for uncoated high tensile strength steel products, which are used widely for the prestressing of concrete and are also used for other tensile applications in the construction field. The standard applies only to products as supplied by the producer.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 10020, *Definition and classification of grades of steel*

BS EN 10027-1, *Designation systems for steels – Part 1: Steel names*

BS EN 10027-2, *Designation systems for steels – Part 2: Steel numbers*

BS EN ISO 15630-3, *Steel for the reinforcement and prestressing of concrete – Test methods – Part 3: Prestressing steel*

BS EN ISO 16120-1, *Non-alloy steel wire rod for conversion to wire – Part 1: General requirements*

BS EN ISO 16120-4, *Non-alloy steel wire rod for conversion to wire – Part 4: Specific requirements for wire rods for special applications*

3 Terms and definitions

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

3.1 product type

specific delivery form of prestressing steel

NOTE See Table A.1.

3.2 wire rod

hot rolled steel delivered in coils, used for cold working treatments such as wire drawing

3.3 wire

product manufactured by cold working wire rod that is in a suitable metallurgical condition for cold working and which is given a final thermo-mechanical treatment

NOTE The surface of the wire is plain or indented. It may be covered by a residue of drawing lubricant. The wire is wound into large diameter coils (see 10.3) or delivered in bundles of cut lengths.

3.4 strand

product consisting of a number of cold drawn wires spun together in the same direction and with the same lay length that is given a final thermo-mechanical treatment and is then wound into large diameter coils (see 10.3)

NOTE The common types of strands are as follows:

- a) 7-wire strand: a straight core wire around which are spun six wires in one layer;
- b) 7-wire compacted strand: 7-wire strand that has been drawn through a die, or compressed by other means, before the final thermo-mechanical treatment;

- c) *7-wire indented strand: strand produced from indented wires. The central wire of 7-wire indented strand may be plain with no indentations.*

3.5 unit of manufacture

quantity of product of the same nominal diameter, surface configuration and technical class (strength class) that is manufactured according to specified manufacturing conditions

NOTE The physical limits on the unit of manufacture depend on each product type, see 8.2.2.1.

3.6 unit of product

quantity of product coming from a subdivision of a unit of manufacture, generally in the form as delivered to a customer

NOTE The physical limits on the unit of product depend on each product type, see 8.2.2.1.

3.7 unit of inspection

quantity of product coming from a unit of manufacture and presented at any one time for examination and release purposes

NOTE The physical limits on the unit of inspection depend on each product type, see 8.2.2.1.

3.8 consignment (delivery batch)

total amount of the product in the same delivery to a customer, which may consist of products coming from several units of manufacture

3.9 characteristic value

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

NOTE In the context of this British Standard the characteristic value is (unless otherwise indicated) the lower limit of the statistical tolerance interval at which there is a 95% probability ($1 - \alpha = 0.95$) 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.

3.10 inspection

conformity evaluation by observation and judgement accompanied as appropriate by measurement, testing or gauging

3.11 product family

group of products of the same type and same technical class (strength class) (see Annex A)

NOTE Their surface configuration may vary, e.g. plain or indented.

3.12 factory production control

permanent internal production control exercised by the manufacturer

3.13 standard properties

properties prescribed in this British Standard as part of the factory production control requirements for every unit of inspection

3.14 special properties

properties prescribed in this British Standard that are not determined as part of the factory production control requirements for every unit of inspection

3.15 maximum value

value which no test result shall exceed

3.16 minimum value

value below which no test result shall fall

3.17 production or manufacturing site

site at which the product is produced

3.18 testing laboratory

laboratory carrying out the various tests required to evaluate the products

NOTE It may be located at the manufacturer's production area, located on the manufacturer's site or located remote to the manufacturer's site independent to the manufacturer.

3.19 heat of steel

quantity of steel corresponding to the same single melting operation identified by a single number so designated by the steel manufacturer(s)

3.20 median

average value of the third and fourth test result from the ordered series of results of six corrosion tests

3.21 threshold level

quantitative expression of the behaviour of a construction product, for an action to which it is subject or which it generates under the intended use conditions

3.22 threshold value

quantitative expression of the limiting value of a construction product, for an action to which it is subject or which it generates under the intended use conditions

3.23 indentation length

length of individual indentations measured in the direction of the wire axis

3.24 indentation depth

maximum depth of individual indentations measured radially from wire surface

3.25 indentation spacing

distance between the centre of two successive indentations measured (or taken) in the direction of the wire axis (see Figure 2 and Figure 3)

3.26 average diameter

average of the diameters measured in two perpendicular directions, one of which is the maximum diameter found by inspection

3.27 ovality

difference between maximum and minimum diameters

4 Symbols

The symbols used in this British Standard and the corresponding designations are given in Table 1.

Table 1 Symbols and corresponding designations

Symbol	Unit	Designation
a	mm	Depth of the indentations
A_{gt}	%	Specified minimum value of percentage total elongation at maximum force
c	mm	Indentation spacing
C_v	kN	Specified characteristic value for maximum force or 0.1% proof force
d	mm	Nominal diameter of the product
d_{sw}	mm	Nominal diameter of a constitutive wire of a strand
D	%	Maximum permitted value of the average coefficient of reduction of the maximum force in the deflected tensile test
D_i	mm	Minimum internal diameter of a coil of wire or strand
E	GPa	Modulus of elasticity
f	Hz	Frequency of load cycles in the axial load fatigue test
F_m	kN	Specified characteristic value of maximum force
$F_{m'_{max}}$	kN	Specified maximum value of maximum force
$F_{p0.1}$	kN	Specified characteristic value of 0.1% proof force
F_{ma}	kN	Actual maximum force, in the tensile test, determined on a test piece adjacent to the test piece submitted to special property test
F_{up}	kN	Upper force in the axial load fatigue test
F_r	kN	Force range in the axial load fatigue test
l	mm	Length of indentation
k	—	Coefficient function of the number of test results
L_0	mm	Original gauge length of the extensometer for the determination of A_{gt}
m	g	Mass of the test piece
M	g/m	Nominal mass per metre of the product
m_r	kN	Average value of the test results for maximum force or 0.1% proof force
n	—	Number of test results for maximum force or 0.1% proof force
r	mm	Mandrel radii for bend test machine
R_m	MPa	Nominal tensile strength
s	kN	Estimated standard deviation of the test results for maximum force or 0.1% proof force
S_n	mm ²	Nominal cross-sectional area of the product
α	—	Statistically reliable failure rate
σ	—	Force ratio, i.e. the ratio of the actual maximum force divided by the actual 0.1% proof force, as determined in the tensile test

NOTE 1 MPa = 1 N/mm²

5 Classification and designation

5.1 Classification

All steels covered by this British Standard shall be classified as special steels according to BS EN 10020.

5.2 Designation

The products covered by this British Standard shall be designated as given in this specification.

6 Information to be obtained by the manufacturer

The following information shall be obtained by the manufacturer at the time of enquiry and order:

- designation of the product in accordance with 5.2;
- the packaging and protection requirements and in the case of products supplied in bundles, the maximum mass of the individual bundle;
- the requirements concerning information to accompany the delivery (e.g. delivery note, type of inspection document [see BS EN 10204], copies of force/extension diagrams);
- special requirements for labeling;
- strand lay direction;
- nominal depth of indentations for indented wire.

7 Requirements

7.1 General

7.1.1 Steel making processes

The steel may be made by any process, except that air or mixed air-oxygen bottom blown processes shall not be used.

7.1.2 Primary incoming materials

The primary products (billets, wire rod) shall be manufactured according to 7.1.1 and associated processes which will ensure products fully conform to requirements. The wire rod shall conform to BS EN ISO 16120-1 and BS EN ISO 16120-4.

7.1.3 Freedom from defects

The finished product shall be free from any defects likely to impair its performance.

Products with rusted steel shall not be supplied unless the rust is a thin film. The underlying steel surface shall appear to be smooth to the unaided eye.

7.1.4 Welds

Wire shall contain no welds in the product as supplied by the manufacturer. Strands with normal production lengths may contain welds made in the individual wires before cold drawing, but shall not contain any welds made during or after cold drawing. Not more than one weld in any component wire shall be permitted in any 50 m of strand.

7.2 Standard properties

7.2.1 Geometrical properties

The geometrical properties shall be defined by a nominal diameter (d), a nominal cross-sectional area (S_n) and a nominal mass per metre (M). In addition, for indented wire, geometrical properties shall be defined by the nominal dimensions of indentations and for strands, geometrical properties shall be defined by the lay length.

The requirements for the surface configuration of the product and the product straightness shall be as given in Clause 11 and Clause 12.

7.2.2 Mechanical properties

NOTE These requirements apply to both strand and wire.

7.2.2.1 The standard mechanical properties are:

- the maximum force;
- the 0.1% proof force;
- the total percentage elongation at maximum force;
- the ductility properties appropriate to the product type (i.e. percentage reduction of area and resistance to reverse bending);
- the force ratio.

7.2.2.2 The specified values of the standard mechanical properties for technical (strength) classes shall be as specified in this standard. Tensile properties shall be recorded as force in force units. Where stress is used for designation purposes, calculation of stress shall be based on the nominal cross-sectional area of the product.

7.2.2.3 The specified maximum force is the specified characteristic value of maximum force (F_m).

7.2.2.4 The maximum value of maximum force ($F_{m,max}$) shall not be greater than 1.15 times the specified maximum force (F_m) for wire and strands.

7.2.2.5 The specified proof force value is the specified characteristic 0.1% proof force ($F_{p0.1}$).

7.2.2.6 The specified minimum value of percentage total elongation at maximum force (A_{gt}) shall not be lower than 3.5%.

7.2.2.7 The pre-stressing steel shall be proved to have suitable ductility by means of the test(s) applicable to the specific product type. These tests shall be:

- a) for wires, the reverse bend test and examination of the constriction at break, see Table 9 and Table 10;

NOTE When bend testing type T2 indented wire it is a mandatory requirement that the wire is inserted in the machine such that the indents are 90° to the bending plane.

- b) for strand, the examination of the constriction at break, see Table 13.

7.3 Special properties

7.3.1 General

The special properties of prestressing steels are:

- mandatory: isothermal relaxation and stress corrosion resistance.
- optional: fatigue behaviour and deflected tensile test for plain strands $12.5 \text{ mm} \leq d \leq 15.7 \text{ mm}$ nominal diameter.

7.3.2 Isothermal stress relaxation

The losses by relaxation of force shall be established at a nominal temperature of 20 °C, for a period of 1 000 h from an initial force of 70% and 80% of the actual maximum force (F_{ma}), determined by a tensile test on an adjacent test piece and shall be lower than or equal to the maximum value specified in this standard.

NOTE If verification of established values is required, tests of 120 h extrapolated to 1 000 h may be accepted, provided that proof of a satisfactory correlation between 1 000 h tests and extrapolation of 120 h tests can be demonstrated.

Two samples shall be taken and tested, from different units of manufacture, for every size within a product family.

All sizes produced shall be tested over a 5 year period.

7.3.3 Fatigue behaviour

Products shall withstand without failure two million force cycles under conditions of stable upper force (F_{up}) and frequency (f) where the stable upper force is defined by 80% of the actual maximum force (F_{ma}) determined in a tensile test on an adjacent test piece. The force range (F_r) shall be in accordance with the values specified in Table 2.

Two samples shall be taken and tested, from different units of manufacture, for every size within a product family.

All sizes produced shall be tested over a 5 year period.

7.3.4 Deflected tensile behaviour

The maximum permitted deflection percentage reduction value (D) for plain strands with nominal diameter $12.5 \text{ mm} \leq d \leq 15.7 \text{ mm}$ shall be in accordance with the value specified in this standard.

Tests shall be carried out on customer request.

7.3.5 Stress corrosion resistance

The minimum individual and median values of six life-time to failure tests shall be determined using a solution of ammonium thiocyanate specified in BS EN ISO 15630-3. These values shall be in accordance with the values specified in this standard.

All diameters produced within a product family shall be tested over a 5 year period.

Table 2 Force ranges for various types of prestressing steels in the axial load fatigue test

Product	Force range F_r in newtons
Plain wire	$200S_n$
Indented wire	$180S_n$
Plain strand	$200S_n$
Indented strand	$180S_n$

8 Evaluation of conformity

8.1 General

The conformance of prestressing steel to the requirements of this British Standard shall be demonstrated by manufacturer's inspection.

8.2 Manufacturer's inspection

8.2.1 General

Prestressing steels according to this British Standard shall be produced under a permanent system of factory production control which shall ensure the same level of confidence in the conformity of the finished product, whatever the manufacturing process.

The system of factory production control shall include evaluation of the property requirements given in 8.2.2.

NOTE Manufacturers that have a factory production control system that meets the requirements of BS EN ISO 9001 and addresses the requirements of this British Standard are recognized as satisfying the factory production control requirements of this standard.

8.2.2 Sampling and testing

8.2.2.1 Unit of manufacture, unit of product, unit of inspection

NOTE Definitions are illustrated in Table 3.

8.2.2.1.1 Wire

The unit of manufacture is the wire product from a single rod coil.

The unit of product is the coil of wire or bundle of lengths as delivered to the customer.

NOTE 1 The unit of product is either the unit of manufacture or a smaller coil cut from a unit of manufacture.

Cut lengths in a bundle shall be produced from the same steel heat.

NOTE 2 At the transition between two heats, one bundle may contain cut lengths from these two heats.

The unit of inspection shall be composed of units of manufacture from the same steel heat manufactured at any one time.

8.2.2.1.2 Strand

The unit of manufacture is the product of one set of coils of wire placed in the stranding machine.

NOTE Such a unit of manufacture is often designated as mother coil.

The unit of product is the coil of strand as delivered to the customer.

The unit of inspection shall be composed of all units of product coming from the same unit of manufacture.

Table 3 Definition of unit of manufacture, unit of product and unit of inspection

Type of product	Unit of manufacture	Unit of product	Unit of inspection
Wire	Wire produced from one coil of wire rod	For coils: the unit of manufacture or a smaller coil cut from a unit of manufacture. For cut lengths: a bundle from the same steel heat	All the units of products coming from the same heat of steel
Strand	A mother strand coil	A coil cut from a single mother coil	All the units of products coming from the same unit of manufacture

8.2.2.1.3 Frequency of sampling and inspection for factory production control

The finished product shall be sampled and tested at least in accordance with Table 4 and Table 5 for wire and strand respectively.

Table 4 Minimum frequency of sampling and testing for factory production control of wire

Property	Frequency of sampling and testing
Maximum force	One test every unit of manufacture
Visual inspection of tensile test fracture ^{A)}	
Diameter ^{B)}	
0.1% proof force	One test every five units of manufacture
Force ratio	
Total percentage elongation at maximum force	
Reverse bending	
Straightness	
Indentation depth	
Mass per metre (for indented wire) ^{C)}	

^{A)} In case of doubt about the type of rupture, the percentage of reduction in area shall be checked (see Table 10).

^{B)} Diameter checks on wire for indenting shall be checked prior to the indent rollers.

^{C)} Where the wire diameter on a plain round wire is ± 0.01 times the nominal diameter and has an ovality ≤ 0.05 mm, no checks by weighing are necessary. See 11.3.2.2.

Table 5 Minimum frequency of sampling and testing for factory production control of strand

Property	Frequency of sampling and testing
Maximum force	A test from the beginning and a test from the end of the unit of manufacture and one further test at an intermediate point if the number of units of product is greater than two
0.1% proof force	
Force ratio	
Total percentage elongation at maximum force	
Straightness	
Visual inspection of tensile test fracture ^{A)}	
Indentation depth ^{B)}	One test per unit of manufacture
Mass per metre	
Lay length	
Diameter relationship core to outer wires (plain and indented 7-wire strands only)	

^{A)} In case of doubt about the type of rupture, the percentage of reduction in area for individual wires shall be checked (see Table 13).

^{B)} Indentation depth is measured on component wires prior to stranding.

8.2.2.2 Evaluation of test results of a unit of inspection

The unit of inspection shall be deemed to conform to the requirements of this British Standard if all the results of tests are greater than or equal to the characteristic value for the mechanical properties, lower than the maximum value for maximum force and within the tolerances of the geometrical properties. If these conditions are not met then the following procedure shall apply.

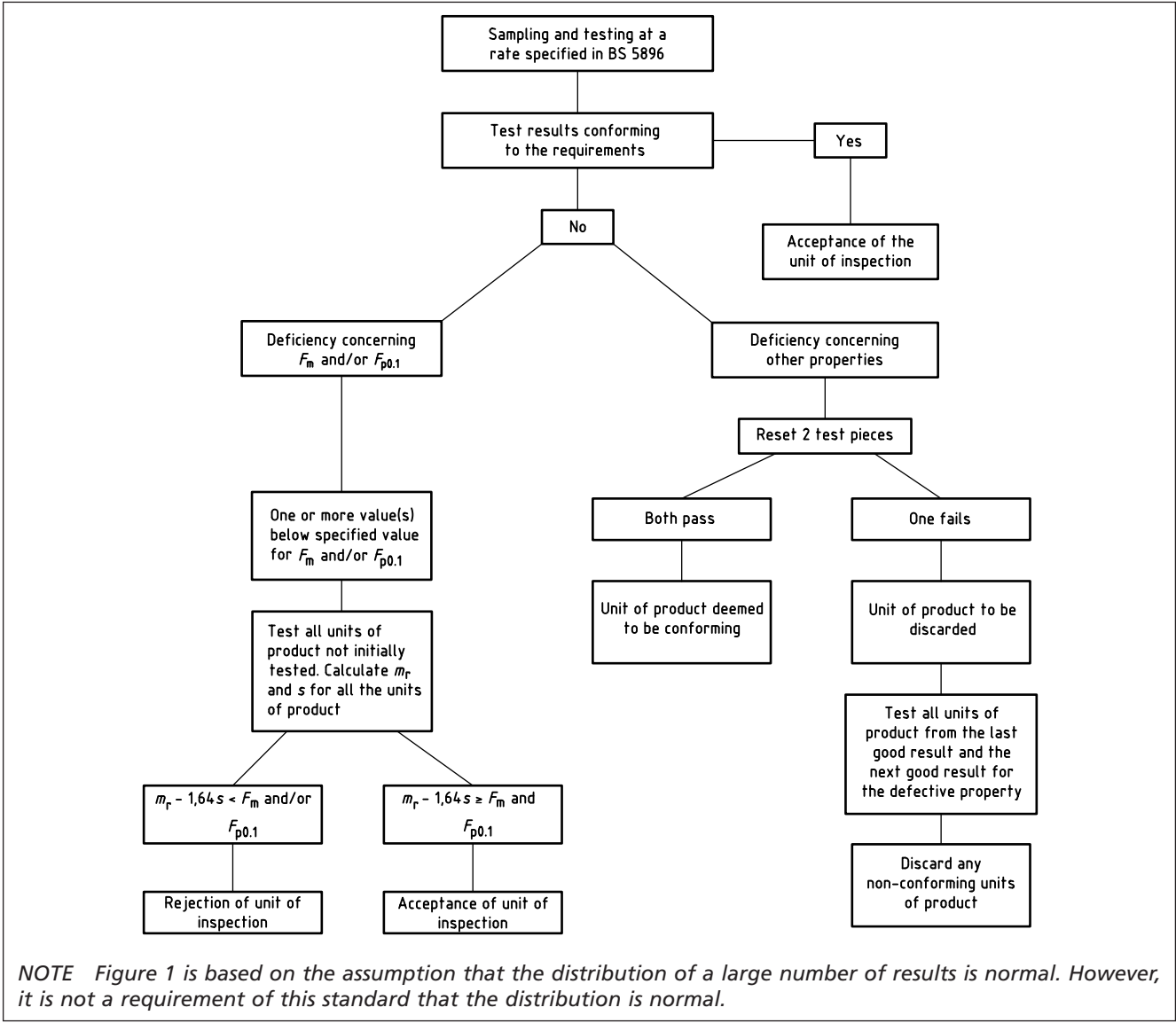
- a) When one or more results for maximum force and/or 0.1% proof force are below the corresponding characteristic value(s), all units not initially tested in the unit of inspection shall be tested. The mean value of all individual results from the unit of inspection for either parameter shall be calculated. The unit of inspection shall be deemed to conform to this standard if the mean values calculated are equal to or greater than the characteristic value plus 1.64 times the standard deviation. See Figure 1.

- b) When results for other properties specified by a minimum and or a maximum value do not conform to specifications then two additional samples shall be taken from the unit of product concerned by each failed result and these shall be tested for the property concerned. If the two additional results conform to the specification then the unit of product shall be deemed to conform to this standard.

If one or more of these additional tests does not conform to the specifications, the unit of product concerned shall be rejected. In addition, all units of product from the last good result until the next good result shall be tested for the defective properties.

All units of product with non-conforming results shall be rejected and the producer shall immediately take measures to determine the reason and rectify any faults.

Figure 1 Evaluation of tests results and a unit of inspection testing route



8.2.2.3 Assessment of the long-term quality level

The results of tests on all units of inspection of the continuous production shall be collated by product family and statistically evaluated for maximum force and 0.1% proof force using data based on a 6 months operation (or a 12 months operation if the production quantity is limited and the number of values is below 60).

The following requirement shall be satisfied for maximum force and 0.1% proof force.

$$m_r - ks \geq C_v$$

NOTE See Table 6 for coefficient k .

Table 6 Coefficient k as a function of a number (n) of the test results for a reliable failure rate of 5% ($p = 0.95$) at a probability of 95%

n	k	n	k
5	4.21	30	2.22
6	3.71	40	2.13
7	3.40	50	2.07
8	3.19	60	2.02
9	3.03	70	1.99
10	2.91	80	1.97
11	2.82	90	1.94
12	2.74	100	1.93
13	2.67	150	1.87
14	2.61	200	1.84
15	2.57	250	1.81
16	2.52	300	1.80
17	2.49	400	1.78
18	2.45	500	1.76
19	2.42	1 000	1.73
20	2.40		

8.2.2.4 Evaluation, reporting and action

The results of the manufacturer's long term quality level assessment shall be evaluated every six months.

If the results show that the production does not conform to the requirements, appropriate corrective measures shall be taken. The measures will depend on the type and significance of the deficiencies noted but shall include:

- intensification of supervision (increase the frequency of testing);
- suggestion to change the conditions of production.

9 Test methods

All test methods shall be in accordance with BS EN ISO 15630-3.

10 Delivery conditions

10.1 Identification

Each coil or bundle of wire or strand shall carry a label giving:

- the designation of the product given in this standard;
- the coil/strand number;
- the manufacturer's name and manufacturing site.

10.2 Delivery information

Each consignment shall be provided with information containing:

- all the information necessary to identify the units of product within the consignment;
- all information previously agreed with the purchaser (see Clause 6).

NOTE In the case of the force/extension diagram as every unit of product might not be tested, this diagram may be of the closest unit tested to the product unit concerned.

10.3 Dimensions of product

Where the product is supplied in coil form, the minimum internal diameter of the coil D_i shall be such that 90% of the 0.1% proof force is not exceeded.

$$\text{i.e. } \frac{D_i}{d} \geq \left(\frac{S_n \times E}{0.9 \times F_{p0.1}} \right) - 1 \text{ for wire}$$

$$\text{or } \frac{D_i}{d_{sw}} \geq \left(\frac{S_n \times E}{0.9 \times F_{p0.1}} \right) - 1 \text{ for strand}$$

NOTE For specific applications, coil diameters lower than D_i may be agreed between the purchaser and supplier.

Where the product is supplied in straight lengths, the maximum mass of the bundle, as well as the nominal length and its tolerances, shall be agreed at the time of ordering with the purchaser.

10.4 Packaging and handling

Where the product is supplied in a coil form then these coils shall be formed in such a way that the material is held firmly by restraining bands or ties. In case of reopening the coils, special caution shall be taken to contain the inherent energy to avoid personal injuries.

Where the product is supplied in straight lengths then the material shall be held firmly by retaining ties and supported to avoid any degradation of straightness.

Packaging for all products shall be selected to ensure no damage or collapse occurs during transportation.

NOTE Agreements between producers and purchasers at the time of order may be made to define particular conditions of packaging consistent with the likely conditions to be encountered by the products before application (e.g. core, packing paper, paperboard, protection by water soluble oil film, etc.).

10.5 Transport and storage

Prestressing steels in transport and storage shall be protected against damage and contamination, particularly from substances or liquids which are likely to produce or facilitate corrosion.

11 Wire requirements

11.1 Designation

11.1.1 The steel names shall be allocated in accordance with BS EN 10027-1; the steel numbers shall be allocated in accordance with BS EN 10027-2.

11.1.2 The designation shall consist of:

- the number of this standard;
- the steel name consisting of:
 - the letter Y for prestressing steel;
 - the nominal tensile strength in MPa;
 - the letter C for cold drawn wire;
- the nominal diameter of the wire in mm (see Table 9);
- Type of indent (T1 or T2).

EXAMPLE

	<i>BS 5896</i>	<i>Y</i>	<i>1770</i>	<i>C</i>	<i>5.0</i>	<i>T1</i>
<i>Standard</i>	<i>X</i>					
<i>Prestressing steel</i>		<i>X</i>				
<i>Nominal tensile strength (MPa)</i>			<i>X</i>			
<i>Cold drawn wire</i>				<i>X</i>		
<i>Nominal diameter (mm)</i>					<i>X</i>	
<i>Type of indent</i>						<i>X</i>
<i>i.e. BS5896 Y1770C-5.0 – T1</i>						

11.2 Manufacture of indented wire: type of indentation

For indented wire, the dimensions of the indentations shall be in accordance with: Table 7 and Figure 2; Table 8 and Figure 3; or as agreed with the customer.

For wire with indentations of Type T1 one line of indentations shall be at a contrary angle to the others.

The nominal depth of indents shall be chosen within the limits given in Table 7 and Table 8.

Table 7 Specified indentation dimensions for indent type T1 (also known as triple indent)

Nominal wire diameter	Range of nominal depths of indentation, <i>a</i>		Depth tolerance on chosen nominal depth	Length <i>l</i>	Spacing <i>c</i>
	From	To			
≤5.0	0.06	0.13	±0.03	3.5 ±0.5	5.5 ±0.3
>5.0 to ≤7.0	0.09	0.16	±0.04	5.0 ±0.3	8.0 ±0.3

Figure 2 Indentation type T1

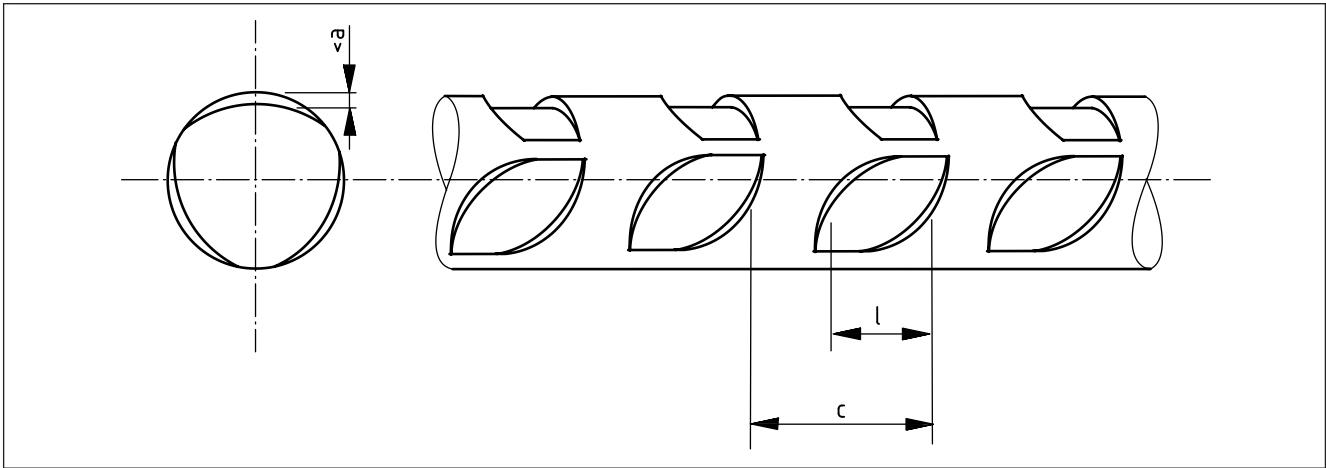
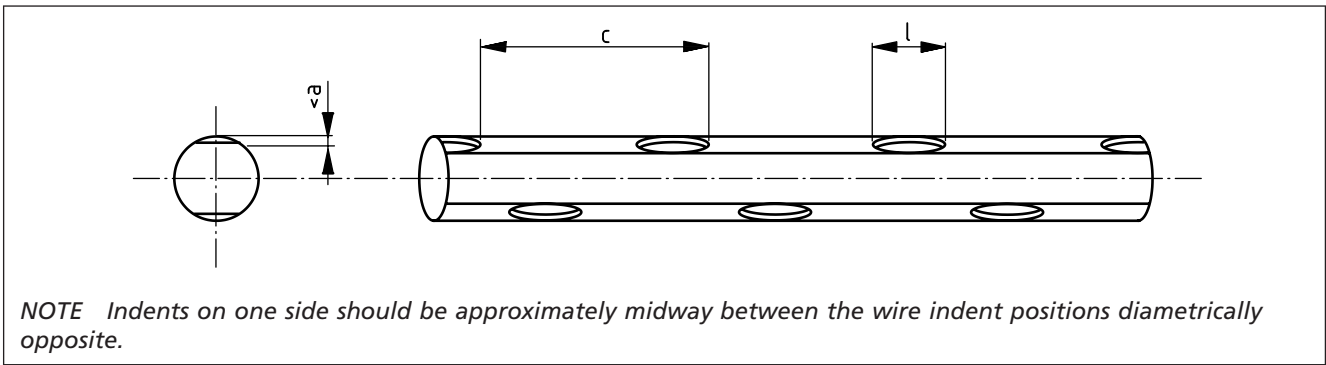


Table 8 Specified indentation dimensions for indent type T2 (also known as Belgian indent)

Nominal wire diameter	Range of nominal depths of indentation, <i>a</i>		Depth tolerance on chosen nominal depth	Length <i>l</i>	Spacing <i>c</i>
	from	to			
5.0	0.06	0.16	±0.04	5.0 ±1.0	8 to 18
7.0	0.06	0.16	±0.04	5.4 ±1.0	10 to 20

Figure 3 Indentation type T2



11.3 Requirements

11.3.1 General

The technical classes covered by BS 5896 shall possess nominal and specified properties as specified in Table 9 and Table 10.

11.3.2 Geometrical properties

11.3.2.1 General

The nominal diameter d , the cross-sectional area S_n and the mass per metre M shall be as given in Table 9.

11.3.2.2 Plain round wire

Where the average measured diameter is no greater than 1% from the nominal diameter and has an ovality ≤ 0.05 mm, no checks by weighing shall be necessary.

11.3.2.3 Straightness

Straightness shall be determined in accordance with BS EN ISO 15630-3. The maximum bow height from a base line 1 m in length, measured from the inside of the curve, shall be no greater than 25 mm for all wire diameters.

NOTE Alternative agreements on straightness including for cut lengths using the method in BS EN ISO 15630-3 may be made between producer and purchaser at the time of ordering.

Table 9 Dimensions and properties of wires

Steel designation		Nominal ^{A)}				Specified				
Steel name	Steel number	Diameter, <i>d</i>	Cross-sectional area ^{B)} <i>S_n</i>	Tensile strength, <i>R_m</i>	Mass per metre, <i>M</i>	Permitted deviation on mass per metre	Bend radii for reverse bend test ^{C)}	Characteristic value of maximum force, <i>F_m</i>	Maximum value of maximum force, <i>F_m</i> ^{max}	Characteristic value of 0.1% proof force, <i>F_{p0.1}</i> ^{D)}
Y1570C	1.1350	mm	mm ²	MPa	g/m	%	mm	kN	kN	kN
		7.0	38.5	1 570	300.7	±2	20	60.4	69.5	53.2
Y1620C	1.1349	4.5	15.9	1 620	124.2	±2	15	25.8	29.7	22.7
		4.0	12.6	1 670	98.4	±2	10	21.0	24.2	18.5
		5.0	19.6		153.1		15	32.7	37.6	28.8
		6.0	28.3		221.0		15	47.3	54.4	41.6
		7.0	38.5	1 770	300.7	±2	20	64.3	73.9	56.6
		4.0	12.6		98.4		10	22.3	25.6	19.6
		5.0	19.6		153.1		15	34.7	39.9	30.5
		6.0	28.3	1 860	221.0	±2	15	50.1	57.6	44.1
		5.0	19.6		153.1		15	36.5	42.0	32.5

^{A)} The modulus of elasticity may be taken to be 205 GPa (kN/mm²).

^{B)} The nominal mass per metre is calculated from the cross-sectional area and a density of 7.81 kg/dm³.

^{C)} See Table 10 for bend limits.

^{D)} The specified characteristic value of the 0.1% proof force is calculated as 88% of the specified characteristic value of the maximum force, except Y1860C which is 89%.

Table 10 Additional test requirements; prestressing wire only

Property		Specification
Force ratio σ	$D \geq 4.0$ mm	1.05 to 1.17
Total minimum percentage elongation at maximum force, A_{gt} with $L_0 \geq 100$ mm		3.5%
Reduction in area at break		Ductile break visible to the unaided eye ^{A)}
Minimum number of reverse bends	– for plain wire	4
	– for indented wire	3
Maximum relaxation at 1 000 h	For initial force 70% F_{ma}	2.5%
	corresponding to: 80% F_{ma}	4.5%
Fatigue force range F_r with upper limit F_{up} equal to 80% actual max. force (F_{ma})	– for plain wire	≥ 200 MPa $\times S_n$ for $\geq 2 \times 10^6$ cycles
	– for indented wire	≥ 180 MPa $\times S_n$ for $\geq 2 \times 10^6$ cycles
Stress corrosion resistance at 80% actual max. force (F_{ma})	For plain and indented wire	Minimum (h)
		Median (h)
		2.0
		5.0

^{A)} Ruptures in “arrow-head” are prohibited. In case of dispute, the percentage reduction of area shall be determined and the value shall be $\geq 25\%$ for plain wire and $\geq 20\%$ for indented wire.

12 Strand requirements

COMMENTARY ON CLAUSE 12

The following clause gives specific requirements for technical classes of high tensile steel wire strand, which has been given a stress relieving heat treatment and may be in the plain, indented or compacted condition, i.e.:

- 7-wire strand;
- 7-wire indented strand;
- 7-wire compacted strand.

12.1 Designation

12.1.1 For the steel grades covered by this standard, the steel names shall be allocated in accordance with BS EN 10027-1; the steel numbers shall be allocated in accordance with BS EN 10027-2.

12.1.2 The designation shall consist of:

- the number of this standard i.e. BS 5896;
- the steel name consisting of:
 - the letter Y for prestressing steel;
 - the nominal tensile strength in MPa;
 - the letter S for strand;
 - the number 7 to indicate the number of wires in the strand;
- where appropriate, the letter G to indicate compacted strand;
- the nominal diameter of the strand in mm (see Table 14);
- where necessary the letter I to indicate indented.

EXAMPLE

	BS 5896	Y	1860	S	7	15.7	I
Specification number	X						
Prestressing steel		X					
Nominal tensile strength (MPa)			X				
Strand				X			
Number of wires					X		
Nominal diameter (mm)						X	
Indented							X
i.e. BS5896-Y1860S7-15.7-I							

NOTE The steel number can be used instead of the steel name, i.e. BS 5896-1.1366-15.7-I.

12.2 Manufacture of strand; stranding process

12.2.1 7-wire strand

The strand shall include a straight central wire, called a core or king wire, around which are spun six wires in one layer. The outer wires shall be tightly spun around the central wire with a lay length between 14 and 18 times the nominal strand diameter; the lay can be left or right handed (customer specific). The diameter of the central wire shall be at least 3.0% greater than the diameter of the outer helical wires.

12.2.2 Indented strand

Indentation of wires in a 7-wire strand shall be completed before stranding. The outer wires shall be tightly spun around the central wire with a lay length between 14 and 18 times the nominal strand diameter; the lay can be left or right handed (customer specific). The diameter of the central wire shall be at least 3.0% greater than the diameter of the outer helical wires.

The dimensions of the indentation shall be in accordance with Table 11. One line of indentations shall be at a contrary angle to the others.

NOTE The centre wire of indented 7-wire strand is normally plain.

12.2.3 7-wire compacted strand

NOTE 7-wire compacted strand is seven-wire strand, which after stranding, has been compacted by drawing or rolling before stress relief treatment.

The straight central wire shall be at least equal to the diameter of the outer helical wires. The strand before compaction shall have a lay length of 14 to 18 times the nominal strand diameter. The diameter of the central wire shall be at least 3.0% greater than the diameter of the outer helical wires.

Table 11 Specified indentation

Dimensions in mm				
Nominal strand diameter	Nominal depth	Depth tolerance	Length	Spacing
<i>d</i>	<i>a</i>	mm	<i>l</i>	<i>c</i>
≤12	0.06	±0.03	3.5 ±0.5	5.5 ±0.5
>12	0.07	±0.03	3.5 ±0.5	5.5 ±0.5

12.3 Requirements

12.3.1 General

Nominal and specified properties shall be in accordance with Table 12 and Table 13.

12.3.2 Behaviour during cutting

When the finished strand is cut with a disc cutter, the individual wires either shall not unravel or shall be capable of being repositioned without difficulty.

12.3.3 Straightness

Straightness shall be determined in accordance with BS EN ISO 15630-3. The maximum bow height from a base line 1 m in length, measured from the inside of the curve, shall be not greater than 25 mm for all strand diameters.

NOTE Alternative agreements on straightness for cut lengths using the method in BS EN ISO 15630-3 may be made between producer and purchaser at the time of ordering.

Table 12 7-wire strand – Dimensions and properties

Steel designation		Nominal ^{A)}				Specified			
Steel name	Steel number	Diameter, <i>d</i> mm	Tensile strength, <i>R_m</i> MPa	Cross-sectional area, ^{B)} <i>S_n</i> mm ²	Mass per metre, ^{B)} <i>M</i> g/m	Permitted deviation on mass per metre %	Characteristic value of maximum force, <i>F_m</i> kN	Maximum value of maximum force, <i>F_{m,max}</i> kN	Characteristic value of 0.1% proof force, ^{C)} <i>F_{p0.1}</i> kN
Y1670S7	1.136 4	15.2	1 670	139	1 086	±2	232	267	204
Y1700S7G	1.137 0	18.0	1 700	223	1 742	±2	379	436	334
Y1770S7	1.136 5	9.3	1 770	52.0	406.1	±2	92.0	106	81.0
Y1770S7	1.136 5	11.0	1 770	70.0	546.7	±2	124	143	109
Y1770S7	1.136 5	12.5	1 770	93.0	726.3	±2	165	190	145
Y1770S7	1.136 5	15.7	1 770	150	1 172	±2	266	306	234
Y1820S7G	1.137 1	15.2	1 820	165	1 289	±2	300	345	264
Y1860S7	1.136 6	8.0	1 860	38.0	296.8	±2	70.7	81.3	62.2
Y1860S7	1.136 6	9.3	1 860	52.0	406.1	±2	96.7	111	85.1
Y1860S7	1.136 6	9.6	1 860	55.0	429.6	±2	102	117	89.8
Y1860S7	1.136 6	11.3	1 860	75.0	585.8	±2	140	161	123
Y1860S7	1.136 6	12.5	1 860	93.0	726.3	±2	173	199	152
Y1860S7	1.136 6	12.9	1 860	100	781.0	±2	186	214	164
Y1860S7	1.136 6	15.2	1 860	139	1 086	±2	259	298	228
Y1860S7	1.136 6	15.7	1 860	150	1 172	±2	279	321	246
Y1860S7G	1.137 2	12.7	1 860	112	874.7	±2	208	239	183

^{A)} The modulus of elasticity may be taken to be 195 GPa (kN/mm²).

^{B)} The nominal mass per metre is calculated from the nominal cross-sectional area and a density of 7.81 kg/dm³.

^{C)} The specified characteristic value of the 0.1% proof force is calculated for all grades and diameters as 88% of the specified characteristic value of the maximum force.

Table 13 Additional requirements for prestressing strand

Property			Specification		
Force ratio σ	$d_{sw} \geq 3$ mm		1.05 to 1.17		
	$d_{sw} < 3$ mm		1.03 to 1.17		
Total minimum percentage elongation at maximum force, A_{gt} with $L_0 \geq 500$ mm			3.5%		
Reduction in area at break			Ductile break visible to the unaided eye ^{A)}		
Maximum relaxation at 1 000 h	For initial force	70% F_{ma}	2.5%		
	corresponding to:	80% F_{ma}	4.5%		
Fatigue force range F_r with upper limit F_{up} equal to 80% actual max. force F_{ma}	– for plain strand – for indented strand		≥ 200 MPa $\times S_n$ for $\geq 2 \times 10^6$ cycles ≥ 180 MPa $\times S_n$ for $\geq 2 \times 10^6$ cycles		
Stress corrosion resistance at 80% actual max. force (F_{ma})	for plain and indented strand		Minimum (h)	Median (h)	
		$d_{sw} \geq 3.2$ mm	2.0	5.0	
		$d_{sw} < 3.2$ mm	1.5	3.0	
Maximum D – value of deflected tensile test applies to 7-wire strand with a nominal diameter $12.5 \text{ mm} \leq d \leq 15.7 \text{ mm}$			28%		

^{A)} Ruptures in “arrow-head” are prohibited. In case of dispute, the percentage reduction of area shall be determined and the guideline value shall be $\geq 25\%$ for plain wire and $\geq 20\%$ for indented wire.

Annex A
(normative)

Product families

Table A.1 defines the product families for products defined in this standard.

NOTE Other product families based on steel name and/or nominal diameter are permitted in addition to those listed in Table A.1.

Table A.1 Product families

Type of prestressing steel	Product family number	Products in the product family		Surface configuration	
		Steel name	Nominal diameter mm	Plain	Indented
Cold drawn wire	1	Y1860C	5.0	X	X
	2	Y1770C	4.0 5.0 6.0		
	3	Y1670C	4.0 5.0 6.0 7.0		
	4	Y1620C	4.5		
	5	Y1570C	7.0		
	7-wire strand	6	Y1860S7		
7	Y1770S7	9.3 11.0 12.5 15.7			
8	Y1670S7	15.2			
7-wire strand compacted	9	Y1860S7G	12.7	X	
10	Y1820S7G	15.2			
11	Y1700S7G	18.0			

Bibliography

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 10204, *Metallic materials – Types of inspection documents*

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BS EN ISO 9001, *Quality management systems – Requirements*

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