



Steel prestressing materials

Part 1: General requirements



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- Austroads
 - Association of Consulting Engineers Australia
 - Australian Chamber of Commerce and Industry
 - Australian Post Tensioning Association
 - Australian Steel Association
 - Australian Wire Industry Association
 - Bureau of Steel Manufacturers of Australia
 - Business New Zealand
 - Cement & Concrete Association of New Zealand
 - Galvanizers Association of Australia
 - Institution of Professional Engineers New Zealand
 - Master Builders Australia
 - National Precast Concrete Association Australia
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-

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Australian Standard®

Steel prestressing materials

Part 1: General requirements

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PREFACE

This Standard was prepared by the Standards Australia/Standards New Zealand Committee BD-084, Reinforcing and Prestressing Materials, to supersede the following Standards:

AS 1310—1987 *Steel wire for tendons in prestressed concrete*

AS 1311—1987 *Steel tendons for prestressed concrete—7-wire stress-relieved strand for tendons in prestressed concrete*

AS 1313—1989 *Steel tendons for prestressed concrete—Cold-worked high-tensile alloy steel bars for prestressed concrete*

This Standard incorporates Amendment No. 1 (November 2018) and Amendment No. 2 (October 2020). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.

Amendment No. 1 to this Standard was prepared by the Australian members of Joint Standards Australia/Standards New Zealand Committee BD-084, Reinforcing and Prestressing Materials. As a consequence of Amendment No. 1, which is published as an Australian-only amendment, the designation of this Standard has been changed from AS/NZS 4672.1:2007 to AS 4672.1:2007.

The objective of this Standard is to provide a single specification for material requirements for as-drawn wire, stress-relieved wire, quenched and tempered wire, strand, and hot-rolled steel bars, intended for use in prestressed concrete structures which have been designed in accordance with AS 3600, *Concrete structures* or NZS 3101.1, *Concrete structures standard*, Part 1: *The design of concrete structures*.

AS/NZS 4672.2, *Steel prestressing materials*, Part 2: *Testing requirements*, provides a method to ensure compliance with this Standard.

This Standard is aligned technically with both ISO 6934, *Steel for the prestressing of concrete* (all parts), and ISO 15630-3, *Steel for the reinforcement and prestressing of concrete—Test methods—Part 3: Prestressing steel*. The Standard is not classed as ‘technically equivalent’ to any of these documents primarily because—

- (a) the procedure for the isothermal relaxation test in ISO 15630-3 was not thought to be adequate (e.g., duration of test, and other testing requirements); and
- (b) differences in both the text and numerical values, although minor in nature, are too numerous to meet the strict definition of ‘technically equivalent’.

Reference has also been made to the European Standards prEN 10138, Parts 1 to 4, *Prestressing steels*, for additional material and information.

The test methods described in this Standard are not generally suitable for crimped wire.

For ease of use, the tables setting out the dimensions, masses and tensile properties have been divided into common sizes readily available and other sizes that may be available from suppliers on special request.

The term force has been used throughout this Standard in place of the term load (which was used previously).

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

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STANDARDS AUSTRALIA

Australian Standard

Steel prestressing materials

Part 1: General requirements

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies requirements for high tensile strength steel tendons to be used for prestressing concrete and for other similar purposes (e.g., masonry structures). It applies only to tendons in the condition as supplied by the manufacturer. It does not cover requirements for anchorage devices (see Note 1) and materials used in conjunction with the prestressing steel in structural components.

The specific properties for each type of prestressing steel are given in Sections 2 to 6, namely:

- (a) Section 2, As-drawn (mill coil) wire.
- (b) Section 3, Stress-relieved wire.
- (c) Section 4, Quenched and tempered wire.
- (d) Section 5, Strand.
- (e) Section 6, Hot-rolled bars with or without subsequent processing.

NOTES:

- 1 Anchorage devices are covered by AS/NZS 1314.
- 2 Advice and recommendations on information to be supplied by the purchaser at the time of enquiry and order are contained in the purchasing guidelines set out in Appendix A.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

A1

1310	Steel wire for tendons in prestressed concrete
1311	Steel tendons for prestressed concrete—7-wire stress-relieved strand for tendons in prestressed concrete
1391	Metallic materials—Tensile testing at ambient temperature
1545	Methods for the calibration and grading of extensometers
2193	Calibration and classification of force-measuring systems
2505	Metallic materials
2505.2	Method 2: Bars, rods and solid shapes—Bend tests
2505.4	Method 4: Wire—Reverse bend test
2706	Numerical values—Rounding and interpretation of limiting values

A1	AS/NZS	
	4672	Steel prestressing materials
	4672.2	Part 2: Testing requirements
A1	BS	
	5896	Specification for high tensile steel wire and strand for the prestressing of concrete
	ISO	
	15630	Steel for the reinforcement and prestressing of concrete—Test methods
	15630-3	Part 3: Prestressing steel

1.3 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

1.3.1 Bar

A product obtained by hot rolling steel and supplied in straight lengths. It may be plain, ribbed or threaded (see Clause 1.3.14). Processed bars are bars which are cold worked or heat-treated. Such bars may have an additional heat treatment, to give the required properties.

1.3.2 Cast analysis

Chemical composition, as determined by analysis, of a sample of the molten steel during casting, taken during the casting process.

1.3.3 Characteristic value

1.3.3.1 Lower characteristic value (C_{vL})

The value of a property having a prescribed (high) probability (p) of being exceeded in a hypothetical unlimited series of standard tests.

NOTE: The probability of a test value being below this value is $(1 - p)$.

1.3.3.2 Upper characteristic value (C_{vU})

The value of a property having a prescribed (high) probability (p) of not being exceeded in a hypothetical unlimited series of standard tests.

NOTE: The probability of a test value being above this value is $(1 - p)$.

1.3.4 Cold-drawn wire

A product derived from a hot-rolled rod by cold working through drawing dies or rollers. The wire is defined by the surface configuration (see Clause 1.3.14) and the following methods of treatment:

- As-drawn (mill coil) wire*—wire in the condition after cold drawing. It may be covered by a residue of drawing lubricant, and is supplied in coils of mean diameter approximately equal to that of the wiredrawing machine capstan.
- Stress-relieved wire*—cold-drawn wire that has been subjected to a stress-relieving heat treatment in a continuous in-line manner. The straightened wire is supplied in large diameter coils or in cut lengths.

1.3.5 Characteristic minimum breaking force

The specified ultimate or breaking force of a wire, strand or bar below which 5% of all actual breaking load test results may fall.

1.3.6 Modulus of elasticity (E)

The slope of the chord between 20% and 70% of the characteristic minimum breaking force and is based on the nominal cross-sectional area of the test piece.

1.3.7 Nominal cross-sectional area (A_n)

Defined for bar, wire and strand as follows:

- (a) *Bar and wire*—the cross-sectional area equivalent to the area of a circular plain bar or wire of nominal diameter.
- (b) *Strand*—the cross-sectional area calculated from the specified value for nominal mass per length, taking the density of steel as 7850 kg/m³.

1.3.8 Percentage total elongation at maximum force (A_{gt})

The specified minimum value of the percentage total elongation at maximum force when tested in accordance with AS 1391.

1.3.9 Proof force ($R_{e0.1}$ or $R_{e0.2}$)

The 0.1% and 0.2% proof force are determined from the non-proportional elongation calculated using the nominal cross-section area and the specified characteristic minimum breaking force.

1.3.10 Quenched and tempered wire

A product manufactured from a hot-rolled rod or cold-drawn wire, which has been subsequently heated to a high temperature, rapidly cooled to produce a martensitic structure and then tempered at a suitable temperature. The heat treatment is carried out using a continuous in-line process. The surface of the wire may be covered with a thin film of scale. The wire may be plain, ribbed, grooved or indented (see Clause 1.3.12). The product is delivered in coils.

1.3.11 Relaxation

Relaxation is a time dependent decrease in stress when the strand, wire or bar is maintained at a constant strain. Relaxation is stated as a percentage of the initial force applied to the steel.

NOTE: Relaxation should not be confused with creep, which is the change in strain at constant load.

1.3.12 Strand

A product consisting of two or more wires spun together in helical form. The pitch and direction of spinning are the same for all the helical wires in the same layer. The pitch is appropriate to the size and type of strand. The strand is given a final stress-relieving treatment, in the same way as stress-relieved cold-drawn wire (see Clause 1.3.4(b)), and is delivered in coil form. Strand is classified as follows:

- (a) *2 wire and 3 wire strand*—two or three wires, respectively, spun together over a notional common axis.
- (b) *7 wire strand*—a straight core-wire around which are spun six helical wires on one layer.
- (c) *19 wire strand*—a straight core-wire around which are spun two layers of wires.
- (d) *Compacted strand*—a strand that has been compressed (e.g., by cold working after stranding) prior to the stress-relieving treatment.
- (e) *Indented strand*—a strand that has the outer wires indented prior to stress-relieving.

1.3.13 Stress-relieving treatment

A continuous short-term isothermal heat-treatment, designed to improve certain mechanical properties and relaxation characteristics. The heat-treatment may take either one of the following forms (procedure (b) giving lower relaxation):

- (a) *Relax 1*—the straightened tendon is heat-treated while being maintained under minimal tension.
- (b) *Relax 2*—the tendon is heat-treated while being maintained under conditions of high longitudinal strain.

NOTE: Relax 1 and Relax 2 were formerly identified (in AS 1310 and AS 1311) as Normal Relaxation and Low Relaxation, respectively.

1.3.14 Surface configuration

A regular pattern impressed on the tendon at final hot-rolling or after final cold-drawing, as appropriate, to improve bond properties between tendon and concrete. A plain surface is one, which is devoid of periodical irregularities, such as indentations or grooves.

NOTE: Examples of typical configurations are described in Appendix C.

1.3.15 Tensile strength (R_m)

The quotient of characteristic minimum breaking force and the nominal cross-section area of the product expressed in megapascals (MPa).

1.4 MANUFACTURING PROCESS

Steel in accordance with this Standard may be made by any process except the air or mixed air/oxygen bottom-blown processes.

1.5 REQUIREMENTS

1.5.1 Chemical composition

The chemical composition shall be related to the type of product and its size and tensile strength. In cast analyses, the content of both sulfur and phosphorus shall not exceed 0.04%.

If requested by the purchaser, the cast analysis of the steel shall be provided.

1.5.2 Geometrical properties

The geometrical properties are based upon nominal diameters.

Where the definition of geometrical properties by nominal diameters is insufficient or not appropriate, the geometrical properties may be defined by nominal cross-sectional area with specified tolerances and appropriate details of the surface configuration of the wire, strand or bar (see Sections 2 to 6).

1.5.3 Mechanical properties

1.5.3.1 General

This Standard contains requirements for the following mechanical properties of the products covered:

- (a) Tensile strength (or characteristic minimum breaking force).
- (b) Proof force (or proof stress).
- (c) Percentage total elongation at maximum force (A_{gt}).

NOTE: The measured elongation is the total elastic and plastic elongation at maximum force with a reduction in load not exceeding 5% when measured in accordance with ISO 15630-3.

- (d) Modulus of elasticity and, if requested, the stress-strain (or load-extension) relationship.
- (e) Ductility.
- (f) Isothermal relaxation.

The specified tests and required values for each product are given in the relevant Sections of this Standard.

1.5.3.2 Tensile properties

The following applies:

- (a) *General* The values for tensile strength, characteristic minimum breaking force and percentage total elongation at maximum force (A_{gt}) shall be specified as characteristic values. At least 95% of all of the test values under consideration shall have tensile properties equal to or greater than the specified characteristic value, and no single test result shall be less than 95% of the specified characteristic value.

By agreement between manufacturer and purchaser, the characteristic values specified in the relevant sections of this Standard may be used as guaranteed minimum values.

The values given for all other properties shall be considered either as a maximum or a minimum value, as designated.

- (b) *Proof force* The specified proof force value is the proof force at 0.1% non-proportional elongation and it shall be the mandatory requirement. In the relevant Sections of this Standard, the 0.2% proof force is also given, and this may also be specified in the order.
- (c) *Elastic modulus* The modulus of elasticity shall be established by plotting a curve of load against strain (or against elongation, as appropriate) during tensile testing.

1.5.3.3 Ductility

Prestressing steel shall be proved to have suitable ductility by the means specified in the relevant Sections of this Standard.

1.5.3.4 Long-term behaviour

The following applies:

- (a) *Isothermal relaxation* For products other than hot-rolled bars and as-drawn (mill coil) wire, isothermal relaxation testing shall be carried out at the mandatory stress level of 80% of the characteristic minimum breaking force. The 60% and 70% stress level values are not mandatory but may be provided if so agreed between the supplier and the customer.

Relaxation testing of bars and as-drawn (mill coil) wire shall be at 70% of the characteristic minimum breaking force.

- (b) *Fatigue* If agreed between purchaser and manufacturer, satisfactory fatigue behaviour shall be demonstrated by testing in accordance with Clause 1.6.5.

1.5.4 Surface condition

The finished product shall be free from deleterious defects that may impair the performance of the product.

Unless otherwise specified, longitudinal seams or discontinuities shall not be considered as defects if their (radial) depth is less than 4% of the nominal diameter of the bar or wire, or component wires in strand.

Slight rusting shall not be a reason for rejection, provided that no pitting is visible with normal corrected vision.

Prestressing steel shall not carry on its surface (or between the wires in strand) any lubricant, oil or other matter likely to impair its adhesion to concrete or cement grout.

NOTES:

- 1 As-drawn (mill coil) wire normally carries a residual film of wiredrawing lubricant.
- 2 Additional coating for specific purposes shall only be applied to the surface of the steel if previously agreed between purchaser and manufacturer.
- 3 Hot-dip galvanizing may seriously impair relaxation properties, especially in the case of Relax 2 tendons.

1.6 TESTING

1.6.1 Scope of testing

Where the following tests have been nominated in this Standard, they are mandatory:

- (a) Breaking force or tensile strength.
- (b) Proof stress or force at 0.1% non-proportional elongation.
- (c) Percentage total elongation at maximum force.
- (d) Modulus of elasticity.
- (e) Reverse bend test or simple bend test, as and where appropriate.
- (f) Relaxation at 80%, or 70% for hot-rolled bars and as-drawn (mill coil) wire, of the characteristic minimum breaking force.
- (g) Fatigue (see Clause 1.6.5).

Inspection and testing of tendons, to demonstrate compliance with this Standard, shall be performed in accordance with Clauses 1.6.2 to 1.6.5 and with the particular requirements of the relevant sections of this Standard.

The test pieces and gauge lengths for testing shall be in accordance with Table 1.1.

TABLE 1.1
TEST PIECES AND GAUGE LENGTHS

Product	Test piece mm	Gauge length mm
As-drawn wire	500	200
Stress-relieved wire	500	200
Indented wire	500	200
Crimped wire	500	200
Plain strand	>10 lay lengths	500
Indented strand		500
Plain bars	2000	500
	2000	500
Ribbed bars	2000	500
	2000	500

NOTE: For fatigue tests the minimum free length shall be as follows:

- (a) Wire—150 mm or 15 diameters.
- (b) Strand or bar—the greater of 500 mm or 2 lay lengths.

1.6.2 Tensile properties

The tensile properties, except for percentage total elongation at maximum force (A_{gt}), shall be determined in accordance with AS 1391. The percentage total elongation at maximum force shall be determined in accordance with ISO 15630-3.

The modulus of elasticity shall be the slope of the chord between 20% and 70% of the characteristic minimum breaking force (see Clause 1.3.5) corresponding to the specified characteristic maximum force, and its calculation shall be based on the nominal cross-sectional area of the test piece.

Extensometers used for elongation measurements and determination of modulus of elasticity shall comply with AS 1545 and shall not be inferior to Grade D.

NOTES:

- 1 Load-elongation testing should be treated with caution, even where the laboratory is well equipped and personnel are skilled. Results of tests are very sensitive to factors such as evenness of tensile tester gripping, axially of loading, and strain rate (see AS 1391). This test does not apply to crimped wire.
- 2 Elongation up to maximum load is uniform over the length of the test piece and hence gauge length is relatively unimportant. However, longer gauge lengths provide greater accuracy of results.
- 3 The extensometer may be removed from the specimen prior to rupture after values for determination of the specified property have been recorded.

1.6.3 Bend test

Sections 2 to 4 of this Standard specify that the prestressing steel shall be assessed by means of the bend test, which shall be conducted in accordance with AS 2505.2 or AS 2505.4.

1.6.4 Relaxation

Relaxation testing shall be carried out in accordance with the procedure given in Appendix B and with the requirements specified for each product.

1.6.5 Fatigue

Where agreed between purchaser and manufacturer, the material shall withstand, without failure, 2×10^6 cycles under conditions of stable upper force and frequency where the upper force shall be 70% of the actual breaking force determined in a tensile test on an adjacent test piece. The fluctuating force range (i.e., twice the force amplitude) is defined for each product in the relevant Sections of this Standard and in Table 1.2. The fatigue test shall be carried out for each type of steel and an appropriate number of diameters. Testing shall be in accordance with ISO 15630-3.

TABLE 1.2
FLUCTUATING FORCE RANGE
FOR PRESTRESSING STEELS
IN AXIAL FORCE FATIGUE TESTS

Product		Fluctuating force range N
As-drawn wire		$200 \times A_n$
Stress-relieved wire		$200 \times A_n$
Ribbed, grooved or indented wire		$180 \times A_n$
Crimped wire		$150 \times A_n$
Plain strand		$195 \times A_n$
Indented strand		$170 \times A_n$
Plain bars	$D \geq 40$	$245 \times A_n$
	$40 < d$	$200 \times A_n$
Ribbed bars	$D \geq 40$	$195 \times A_n$
	$40 < d$	$160 \times A_n$

1.6.6 Straightness

When an approximately 1.2 m length of bar, wire or strand is placed without constraint on a flat, smooth, horizontal surface, the maximum bow height (or deviation) from a base line of length 1 m, measured to the inside of the curved tendon, shall not exceed the value specified in the relevant section. This is not a requirement for as-drawn wire.

1.7 ROUNDING OF NUMBERS

For the purpose of deciding whether a particular requirement of this Standard is satisfied, the determined value, observed or calculated, shall be rounded off in accordance with AS 2706. The number of significant places retained in the rounded-off value shall be the same as that of the specified value in the appropriate Section of this Standard.

1.8 DELIVERY DETAILS

1.8.1 Identification

Unless otherwise agreed, each coil of wire or strand or quantity of bars shall carry a legible and durable label. The label shall include the following information:

- (a) Designation of surface configuration:
 - P = plain
 - I = indented
 - C = crimped
 - S = spiral
 - R = ribbed
- (b) The number of this Standard (i.e., AS/NZS 4672.1).
- (c) Nominal diameter.
- (d) Mass and/or length.
- (e) Characteristic minimum breaking force, or nominal tensile strength.

- (f) Relaxation class.
- (g) Coil number.

1.8.2 Coil size

Unless otherwise agreed, the coil size shall meet the requirements given in the relevant Section of this Standard.

The diameter of the coil of wire or strand shall be sufficiently large to ensure that the material can be uncoiled without difficulty, and without affecting the mechanical properties and the straightness of the product. Where appropriate, a maximum curvature of the prestressing steel is given in the relevant section of this Standard.

1.8.3 Transport and storage

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

NOTE: Particular care is required in protecting product that will be transported by sea or stored in a marine environment.

1.8.4 Report

The manufacturer shall provide a report showing the results of tests performed for the purpose of establishing compliance with this Standard. This report shall include, but not be limited to, the following items:

- (a) Information from the identification label (see Clause 1.8.1).
- (b) All the information necessary to identify the batch from which the tested specimens were drawn.
- (c) A summary or detailed report of the relevant test results [including proof force, breaking force, the percentage total elongation at maximum force, value for modulus of elasticity (see Clause 1.6.2)].
- (d) A unique coil number or bar batch number that corresponds with the specific results on the test report, and any other information necessary to identify the batch or consignment.
- (e) Manufacturer's name and plant.

NOTE: Typical relaxation and/or fatigue results should be included if requested by the purchaser.

SECTION 2 AS - DRAWN (MILL COIL) WIRE

2.1 SCOPE OF SECTION

This Section specifies requirements for round, as-drawn wire, plain, indented, ribbed or crimped. The product is supplied as mill coil wire in coils or cut lengths, in accordance with the general requirements specified in Section 1.

The distinguishing feature of as-drawn (mill coil) wire is that it has not been subjected to a stress-relieving heat treatment.

2.2 CONDITIONS OF MANUFACTURE

2.2.1 Steel

The wire shall be manufactured from high carbon steel in accordance with Section 1.

2.2.2 Welds

The wire shall be supplied without welds or other joints.

2.3 SURFACE CONFIGURATION

There are several types of patterned surface configuration (ribs, indentations, crimps), the purpose of which is to improve bond properties between wire and concrete. The type of surface configuration shall be agreed between purchaser and manufacturer.

NOTE: Examples of indentations and crimps are given in Appendix C.

2.4 PROPERTIES AND REQUIREMENTS

2.4.1 General

Due to the physical nature of crimped wire it shall not be required to be tested for elongation, reverse bend or relaxation. However, a ductile fracture shall be manifest on tensile testing.

2.4.2 Mill coil wire—Dimensions and properties

2.4.2.1 Dimensions, masses and strength

The nominal dimensions, masses and strength values of as-drawn (mill coil) wire shall be as stated in Table 2.1. Any straightening prior to testing shall be done cold. Straightening shall be the least possible to enable testing to be carried out satisfactorily.

NOTE: Excessive cold-working to effect more-than-adequate straightening may result in incorrect results.

2.4.2.2 Elongation and ductility

The percentage total elongation at maximum load (A_{gt}), measured on a gauge length of not less than 200 mm, shall be not less than 1.5%. All wires shall show a ductile fracture with a constriction visible to normal corrected vision.

2.4.2.3 Bend test

All wires shall withstand a reverse bend test around the bend radius given in Table 2.1, without removal from the test frame. The minimum number of bends is four for plain wires and three for indented and ribbed wires.

2.4.2.4 Relaxation

The relaxation at 1000 h at an initial force of 70% of the characteristic minimum breaking force specified in Table 2.1, shall be not more than 10%.