Prestressing steels

Strands

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DOCUMENTS TO BE CONSULTED

In principle, the latest edition of the standards and PTV applies. If necessary, an addendum to this PTV will be issued in case of incompatibility following the revision of one of the documents listed below.

Standards

- NBN I 10-001, Prestressing steels – Wires, strands and bars – Generalities and common requirements
- NBN I 10-002, Prestressing steels – Cold drawn wires
- NBN I 10-003, Prestressing steels – Strands
- NBN I 10-201, Prestressing steel products – Determination of the bond behaviour of prestressing steel to concrete
- NBN EN ISO 15630-3, Steel for the reinforcement and prestressing of concrete – Test methods – Part 3: Prestressing steel

Technical Prescriptions

- PTV 311 – Prestressing steels – Strands
- PTV 312 – Galvanized prestressing steels
- PTV 314 – Prestressing steels – Cold drawn wires

FOREWORD

These Technical Prescriptions (PTV) have been drawn up by the Sectoral Commission Steel for reinforced concrete and for prestressing (SC ST1) on the basis of a consensus within the sector. SC ST1 is the consultative body within PROCERTUS where the various stakeholders in this sector are represented:

- public sector users;
- private sector users;
- manufacturers;
- experts;
- suppliers.

The purpose of these PTV is to standardise and, where necessary, supplement the technical requirements for strands in construction practice in Belgium. They serve as reference technical prescriptions for defining the characteristics of products with a view to their suitability for use in structures or parts of structures.

These PTV support both the private and public construction sectors in drawing up tender documents, awarding contracts and carrying out technical assessments of products. In the context of risk management, these requirements may be regarded as rules of good professional practice. Their content is tailored to the specific needs of the various stakeholders in the sector.

These PTV take account of the current European framework for construction products and, where applicable, comply with harmonised technical specifications and the terminology used therein. The provisions of these PTV are fully compatible with CE marking.

Furthermore, these PTV contain the provisions necessary to manage the risks associated with the use of the products, including the interaction between the various construction elements and the durability of the structure.

These PTV are not regulatory in nature, but may be made applicable, in whole or in part, by contractual means, in particular through specifications or other contractual documents.

Purchasers or users may require evidence of compliance with these PTV. This may be provided through batch approval or product certification in accordance with standard NBN EN ISO/IEC 17067 (such as the BENOR mark).

Such certification confirms that the product complies with the requirements of these PTV. Where applicable, this is independent of the CE marking, which relates exclusively to the placing of products on the market and the performance declared by the manufacturer in accordance with the applicable harmonised technical specifications.

1 SUBJECT AND SCOPE

These Technical Prescriptions specify the requirements with which the strands shall comply. Compliance relates to the requirements of the NBN I 10-001 and I 10-003 standards series, supplemented by the clarifications, modifications and additions described in these Technical Prescriptions.

2 CLARIFICATIONS, MODIFICATIONS AND ADDITIONS RELATING TO NBN I 10-001

2.1 Clause 1 – Scope

The properties specific to each type of prestressing steel product are specified in the following standards or technical prescriptions: NBN I 10-002, NBN I 10-003, PTV 311, PTV 312, PTV 314.

2.2 Clause 2.1.1 – Definitions

- Strand: set of cold drawn wires laid out in a helical way (NBN I 10-003). The strand shall consist of 3 or 7 wires.
- Indented strand: set of indented cold drawn wires laid out in a helical way (NBN I 10-003). The indented strand shall consist either of 3 indented wires or of 1 central smooth or indented wire and 6 peripheral indented wires.
- Smooth galvanised strand: the definition of a smooth galvanised strand is given in PTV 312.

2.3 Clause 2.4 – Nominal cross-sectional area

The nominal cross-sectional area is that used for the calculation of the mechanical characteristics.

2.4 Clause 4.2 – Conventional designation

For indented strands, the following shall be used:

- the term “indented strand”
- the symbol ⊗

For 7-wire strands with a nominal diameter ≥ 12,5 mm, the conventional designation shall be completed by the guaranteed value of the behaviour under multiaxial loads, determined by the deviated tensile test (D ≤ 28 or D ≤ 20).

The simplified mention of the guaranteed value alone shall be permitted, in the form “D20” or “D28”.

The conventional designation of galvanised products is given in PTV 312.

2.5 Clause 5 – Geometrical properties

The nominal diameters, their tolerances and the straightness of the different products are specified in standards NBN I 10-002 and NBN I 10-003, unless modified by PTV 311 and PTV 314. For galvanised products according to PTV 312, the geometrical properties shall apply to the product including the zinc coating.

2.6 Clause 6 – Mechanical properties

The mechanical properties of the different products are specified in standards NBN I 10-002 and NBN I 10-003, unless modified by PTV 311 and PTV 314. For galvanised products according to PTV 312, the mechanical properties shall apply to the product including the zinc coating.

2.7 Clause 6.2 – Tensile strength

The tensile strength is expressed in N/mm² and shall be calculated from the breaking force and the actual cross-sectional area. The actual cross-sectional area shall be determined by measurement of the length and the mass of the product, including the zinc coating where applicable, in accordance with NBN EN ISO 15630-3.

The actual cross-sectional area shall be calculated with an accuracy of ± 1 %.

2.8 Clause 6.3 – Yield force

The yield force shall be determined graphically on the force–elongation diagram in accordance with NBN EN ISO 15630-3.

2.9 Clause 6.5 – Modulus of elasticity

The modulus of elasticity (E) shall be determined from the force–elongation diagram in accordance with NBN EN ISO 15630-3.

2.10 Clause 6.7 – Behaviour under multiaxial loads

The behaviour under multiaxial loads of 7-wire strands with a nominal diameter ≥ 12,5 mm shall be characterised by the behaviour under deviated tensile test according to NBN EN ISO 15630-3. Depending on the case, the test shall be carried out on the bare product or on the galvanised product.

2.11 Clause 7.4 – Stress corrosion

Resistance to stress corrosion shall be determined by the test described in NBN EN ISO 15630-3 using solution A. The test shall be carried out under a load equal to 80 % of F'm. The test shall be carried out on the bare product.

3 CLARIFICATIONS, MODIFICATIONS AND ADDITIONS RELATING TO NBN I 10-003

3.1 Clause 1 – Scope

This document shall apply to high tensile strength steel strands intended for the prestressing of concrete.

3.2 Clause 2.1 – Stranding

For galvanised products, the stranding shall be carried out starting from galvanised wires. For this purpose, reference shall be made to PTV 312.

3.3 Clause 4 – Control

Control shall be carried out in accordance with:

- NBN I 10-003, amended by PTV 311, for bare products
- PTV 312 for galvanised products

3.4 Clause 4.1 – Verifiable properties

- n° 1 Geometrical properties:

- Strands: diameter, nominal cross-sectional area and lay length
- Indented strands: diameter, nominal cross-sectional area, lay length and indentations (see §3.8).

3.5 Clause 4.2.7 – Time depending behaviour

The frequency of the relaxation tests (No. 10), fatigue tests (No. 11) and stress corrosion tests (No. 12) shall be specified at the time of ordering. The frequency of the tests shall at least reach the minimum frequency stated in TRA 282. By special agreement at the time of ordering, the producer shall communicate test results obtained on steels of the same type, for property No. 13.

3.6 Clause 4.2.8 – Behaviour under multiaxial loads

The frequency of the deviated tensile tests according to NBN EN ISO 15630-3, to assess the behaviour under multiaxial loads, shall be specified at the time of ordering. The frequency of the tests shall at least reach the minimum frequency stated in TRA 282.

3.7 Clause 5.1 – Properties

Tables 3 to 5 of standard NBN I 10-003 are supplemented by the properties of the following indented strand:

- indented strand - ⊗ 7,5 - 3 wires - 1860 - R2
- indented strand - ⊗ 6,9 - 3 wires - 1860 - R2
- indented strand - ⊗ 6,5 - 3 wires - 1860 - R2
- indented strand - ⊗ 5,2 - 3 wires - 1960 - R2
- indented strand - ⊗ 9,3 - 7 wires - 1860 - R2
- indented strand - ⊗ 12,5 - 7 wires - 1860 - R2
- indented strand - ⊗ 12,9 - 7 wires - 1860 - R2
- indented strand - ⊗ 15,2 - 7 wires - 1860 - R2
- indented strand - ⊗ 15,2 - 7 wires - 1770 - R2
- indented strand - ⊗ 15,7 - 7 wires - 1860 - R2
- indented strand - ⊗ 15,7 - 7 wires - 1770 - R2

Except for the geometrical properties of the indentations, they shall meet the same specifications as strands made of smooth wires.

In addition, the following strands are defined:

- strand - ∅ 5,2 - 3 wires - 2160 -R2
- strand - ∅ 5,2 - 3 wires - 2060 -R2
- indented strand - ⊗ 5,2 - 3 wires - 2060 - R2
- strand - ∅ 6,5 - 3 wires - 1960 - R2
- indented strand - ⊗ 6,5 - 3 wires - 1960 - R2
- strand - ∅ 9,2 - 3 wires - 1670 - R2
- strand - ∅ 6,4 - 7 wires - 2060 - R2
- indented strand - ⊗ 6,4 - 7 wires - 2060 - R2
- strand - ∅ 6,85 - 7 wires - 2060 - R2
- indented strand - ⊗ 6,85 - 7 wires - 2060 - R2

- strand - ∅ 6,85 - 7 wires - 2160 - R2
- indented strand - ⊗ 6,85 - 7 wires - 2160 - R2
- strand - ∅ 6,9 - 7 wires - 1860 - R2
- strand - ∅ 7,0 - 7 wires - 2060 - R2
- indented strand - ⊗ 7,0 - 7 wires - 2060 - R2
- strand - ∅ 8,6 - 7 wires - 2060 - R2
- indented strand - ⊗ 8,6 - 7 wires - 2060 - R2
- strand - ∅ 9,0 - 7 wires - 1960 - R2
- indented strand - ⊗ 9,0 - 7 wires - 1960 - R2
- strand - ∅ 11,0 - 7 wires - 1860 - R2
- indented strand - ⊗ 11,0 - 7 wires - 1860 - R2
- strand - ∅ 11,3 - 7 wires - 2060 - R2
- indented strand - ⊗ 11,3 - 7 wires - 2060 - R2
- strand - ∅ 18,0 - 7 wires - 1770 - R2
- indented strand - ⊗ 18,0 - 7 wires - 1770 - R2

The properties of smooth strands specified in Tables 3bis to 5bis below shall apply both to bare strands and to galvanised strands (see also PTV 312).

In the case of galvanised strands, the properties specified for the steels shall apply to the strand including the zinc coating.

Tables 3 to 5 supplemented accordingly are reproduced below.

Table 3bis – Properties of 3-wire strands

Strand type	Nominal diameter (mm)	Characteristic tensile strength (N/mm²) min	Nominal cross-sectional area Sn (mm²)	Nominal mass per metre (g/m)	Characteristic value of tensile strength (kN) min	Characteristic value of 0,2 % yield strength (kN) min	Characteristic value of 0,1 % yield strength (kN) min	F'm / F'p0,2 min	Characteristic value of F'm / F'p0,1 min	Stress corrosion at 80 % of Fm – minimum duration (h)
(1)		(2, 12)	(6)		(2, 12)	(3, 12)	(3, 12)	(4)	(4, 13)	(7, 8)
3 x 4.25	9.2	1670	42.6	336	71.1	62.6	60.5	1.025	1.08	if dcw < 3,2 mm: individual: 1 h 30 min median: 3 h 00 min if dcw ≥ 3,2 mm: individual: 2 h 00 min median: 5 h 00 min
3 x 4.25	9.2	1860	42.6	336	79.2	69.9	69.9			
3 x 3.55	7.7	1860	29.7	233	55.2	48.7	48.7			
3 x 3.50	7.5 (*)	1860	29.0	228	54.0	47.6	47.6			
3 x 3.15	6.9 (*)	1860	23.4	183	43.5	38.4	38.4			
3 x 3.00	6.5 (*)	1860	21.3	167	39.7	34.9	34.9			
3 x 3.00	6.5 (*)	1960	21.1	165	41.4	36.7	36.7			
3 x 2.90	6.3	1920	19.8	157	38.0	33.5	32.5			
3 x 2.60	5.6	1960	15.9	125	31.2	27.7	27.7			
3 x 2.40	5.2 (*)	1960	13.6	107	26.7	23.7	23.7			
3 x 2.40	5.2 (*)	2060	13.6	106	28.0	24.9	24.9			
3 x 2.40	5.2	2160	13.6	106	29.4	26.2	25.8			
3 x 2.25	4.8	1960	12.0	94.2	23.5	20.9	20.9			

(1) Diameters not listed are not standardised.

(2) The specified characteristic tensile strength is calculated from the nominal cross-sectional area of the prestressing steel and the specified characteristic breaking force (see note No. 3).

(3) Due to the tight tolerances on mass per metre and on cross-sectional area, specified characteristic forces are often considered rather than stresses.

(4) F'm, F'p0,1, F'p0,2 = breaking force, 0,1 % and 0,2 % proof force, measured by tensile test.

(6) The cross-sectional area is calculated assuming a density of 7,85 kg/dm³.

(7) dcw = diameter of the constituent wire

(8) The measurement is carried out in hours and minutes and shall be rounded to the nearest multiple of 10 minutes, for example: 4h52min = 4h50min < 5h00min and 4h56min = 5h00min.

(12) The characteristic value is determined as the 5 % fractile with a confidence level of 95 %.

(13) The characteristic value is determined as the 10 % fractile with a confidence level of 95 %.

(*) Smooth or indented constituent wires

NOTE: The value of the modulus of elasticity may be taken as E = 200 kN/mm² ± 10 kN/mm², unless otherwise specified by the producer.

Table 4bis – Properties of 7-wire strands

Nominal diameter (mm)	Characteristic tensile strength (N/mm²) min	Nominal cross-sectional area Sn (mm²)	Nominal mass per metre (g/m)	Permissible deviation on diameter (mm)	Characteristic value of tensile strength (kN) min	Characteristic value of 0,2 % yield strength (kN) min	Characteristic value of 0,1 % yield strength (kN) min	F'm / F'p0,2 min	Characteristic value of F'm / F'p0,1 min	Deviated tensile test Dmax (%)	Stress corrosion at 80 % of Fm – minimum duration (h)
(1)	(2, 12)	(6)			(3, 12)	(3, 12)	(3, 12)	(4)	(4, 13)	(9)	(7, 8)
6.4 (*)	2060	25.0	196.3	+0.3 -0.15	51.5	45.8	45.8	1.025	1.08		if dcw < 3,2 mm: individual: 1 h 30 min median: 3 h 00 min
6.85 (*)	2160	28.2	221.4		60.9	53.6	53.6				
6.85 (*)	2060	28.2	221.4		58.1	51.6	51.6				
6.9	1860	29.0	227.7		54.0	47.6	47.6				
7 (*)	2060	30	235.5		62.0	54.9	54.9				
8.6 (*)	2060	45	353.3		92.7	82.4	82.4				
9 (*)	1960	50	393		98.0	87.0	87.0				
9.3 (*)	1860	52	408		97.0	85.3	85.3				
11 (*)	1860	70	549	+0.4 -0.2	130	115	115				if dcw ≥ 3,2 mm: individual: 2 h 00 min median: 5 h 00 min
11.3 (*)	2060	75	589		155	137	137				
12.5 (*)	1860	93	730		173	153	153			28 (20)	
12.9 (*)	1860	100	785		186	164	164			28 (20)	
15.2 (*)	1860	139	1090		260	228	228			28 (20)	
15.2 (*)	1770	139	1090		248	217	217			28 (20)	
15.7 (*)	1860	150	1180		279	246	246			28 (20)	
15.7 (*)	1770	150	1180		265	234	234			28 (20)	
18 (*)	1770	200	1570		354	312	312			28 (20)	

(1) Diameters not listed are not standardised.
(2) The specified characteristic tensile strength is calculated from the nominal cross-sectional area of the prestressing steel and the specified characteristic breaking force (see note No. 3).
(3) Due to the tight tolerances on mass per metre and on cross-sectional area, specified characteristic forces are often considered rather than stresses.
(4) F'm, F'p0,1, F'p0,2 = breaking force, 0,1 % and 0,2 % proof force, measured by tensile test.
(6) The cross-sectional area is calculated assuming a density of 7,85 kg/dm³.
(7) dcw = diameter of the constituent wire
(8) The measurement is carried out in hours and minutes and shall be rounded to the nearest multiple of 10 minutes, for example: 4h52min = 4h50min < 5h00min and 4h56min = 5h00min.
(9) The figures in parentheses relate to strands used in post-tensioning systems and as deviated prestressing steel in the prefabrication industry.
(12) The characteristic value is determined as the 5 % fractile with a confidence level of 95 %.
(13) The characteristic value is determined as the 10 % fractile with a confidence level of 95 %.
(*) Smooth or indented constituent wires
NOTE: The value of the modulus of elasticity may be taken as E = 200 kN/mm² ± 10 kN/mm², unless otherwise specified by the producer.

Table 5bis – Common characteristics for all strands

				Maximum relaxation at 1000 h			
Nominal cross-sectional area Sn (mm²)	Nominal mass per metre (g/m)	Characteristic elongation at maximum force Lo > 500 mm (%) min	Minimum reduction of area at fracture (%)	Initial load (% of actual breaking force)	R1 (%) max	R2 (%) max	Fatigue test, stress range (Fmax – Fmin) for Fmax = 0,8 F'm (N)
(6)		(10, 13)					(11)
+2% -2%	+2% -2%	3.5	Ductile wire fracture, visible to the naked eye	60 70 80	4.5 8 12	1 2.5 4.5	200 × So for smooth strands 180 × So for indented strands

(6) The cross-sectional area is calculated assuming a density of 7,85 kg/dm³.
(10) Lo = initial gauge length (according to NBN EN ISO 15630-3).
(11) So = actual cross-sectional area of a straight section before application of the load, determined by a weighing method with a maximum error of 0,4 %.
(13) The characteristic value is determined as the 10 % fractile with a confidence level of 95 %.

3.8 Clause 5.4 – Indentations (new)

3.8.1 Clause 5.4.1 – Constituent wires

The indentations of the constituent wires of indented strands shall comply with the specifications of Clause 5.2.2 of standard NBN I 10-002 (wires), except for the dimensions of the indentations, which shall comply with the requirements of the table below relating to measurements carried out on each test piece.

Table 6 – Geometrical characteristics of indentations

Nominal strand diameter (D) (mm)	Nominal depth (a) (mm)	Permissible deviation on depth (mm)	Length (L) (mm)	Lay length / spacing (P) (mm)
D ≤ 12	0,06	± 0,03	3,5 ± 0,5	5,5 ± 0,5
D > 12	0,07	± 0,04	3,5 ± 0,5	5,5 ± 0,5

The frequencies and methods of control during manufacture shall be those provided for in standard NBN I 10-002; for the central wire, the indentations need not be measured.

3.8.2 Clause 5.4.2 – Measurement after stranding

It shall be permitted to check the indentations on the constituent wires of the strand before stranding. The additional condition in this case is that the producer shall guarantee and demonstrate the traceability of the wires incorporated in the strand.

4 HISTORY OF REVISIONS

Revisions 0 à 5, creation, adaptations

Revision 6 :

- reference to BENOR asbl
- density equal to 7,85 kg/dm³

Revision 7 : update of Table 4bis

Revision 8 : update of Table 4bis

Revision 9 : transfer from OCAB to PROCERTUS

Revision 10 : modification of the tables in Clause 3.7 (alignment with EN 1992-1-1, including the addition of the requirement relating to F'm / F'p0,1 and the adaptation of the characteristic values of 0,1 % yield strength)