UNOFFICIAL TRANSLATION

In the event of any doubt or misunderstanding arising from this translation, the standard in Thai will be held to be authoritative

TIS 420-2540(1997)
Thai Industrial Standard
for
Steel Wires Strands for Prestressed Concrete

1. Scope

1.1 This standard specifies category, type and class, chemical composition and making, requirements, packaging, marking and labelling, sampling and criteria for conformity and testing for steel wires strands for prestressed concrete.

1.2 This standard covers 2, 3, 7 and 19 wire-strand, normal and low stressed relieved wire.

2. Definitions

For the purpose of this standard, the following definitions apply:

2.1 Steel wires strands: hereinafter referred to as “wire strands” : A linear product consisting of two or more carbon steel wires spun together. The pitch and direction of spinning are the same for all the helical wires in the same layer. The strand is given a final stress-relieving treatment and is delivered in coil form.

2.2 Compacted strand: Wires strand which has been compressed, stranding and given a stress-relieving treatment before winding into coil form.

2.3 Lay: The direction of strand is twisted in right or left.

2.4 Right hand lay: The direction of the strand is twisted out from the viewer in the same direction as the hands of a clock around the axis.

2.5 Left hand lay: The direction of the strand is twisted out from the viewer in the turn back direction of the hands of a clock around the axis.

2.6 2-wire strand: Two wires spun together over a theoretical common axis.

2.7 3-wire strand: Three wires spun together over a theoretical common axis.

2.8 7-wire strand: A straight core wire around which are spun 6 helical wires in one layer.

2.9 19-wire strand: A straight core wire around which are spun two layer of wires.

2.10 Cast analysis: Chemical analysis of a sample of the molten steel during casting.

2.11 Characteristic value: Value having a prescribed probability of not being attained in a hypothetical unlimited test series.

2.12 Nominal cross-sectional area: The cross-sectional area equivalent to the area of a circular plain bar of nominal diameter.

2.13 Relaxation: Time-dependent stress loss for a constant length. Relaxation is stated as a percentage of the initial stress applied to the steel.

3. Category, type and class

3.1 Wires strands are classified into 4 categories i.e.
- 3.1.1 2-wire strand;
- 3.1.2 3-wire strand;
- 3.1.3 7-wire strand;
- 3.1.4 19-wire strand.

3.2 Wires strand are divided into 2 types i.e.
- 3.2.1 ordinary;
- 3.2.2 Compacted.

3.3 Wires strand are separated into 2 classes i.e.
- 3.3.1 Normal relaxation;
- 3.3.2 Low relaxation.

4. Sizes

4.1 Size

The nominal diameter, nominal cross-sectional area, mass per metre and tolerance on mass per metre of non-stress relieved wires are as given in Table 1.

The determination of the mass per metre shall comply with clause 10.1.

Table 1 Nominal diameter, nominal cross-sectional area, mass per metre and characteristic values for non-stress relieved wires.

(clauses 4.1, 6.3.1 and 10.4.3)

Type[1] of strand	Nominal strand diameter[1]	Nominal tensile srength[1]	Nominal cross-sectional area[2]	Mass per length		Charactersitics value[2], min		
				Nominal	Permissible deviation	maximum force[2)3)4)]	0.1% proof force[3)4)5)]	0.2% proof force[4)5)]
mm	(mm)	N/mm?	mm?	(g)	(%)	kN	kN	kN
2-wire 2 x 2.90	5.8	1910	13.2	104		25.2	21.4	22.3
3-wire	5.2	1770	13.6	107		24.0	20.4	21.1
2 x 2.40		1960				26.7	22.7	23.5
3 x 2.90	6.2	1910	19.8	155		37.8	32.1	33.2
3 x 3.50	7.5	1770	29.0	228		51.2	43.5	45.0
		1860				54.0	45.9	47.0
7-wire	9.3	1720	51.8	405		88.8	72.8	75.4
	9.5	1860	54.8	432	+ 4	102	83.6	86.6
	10.8	1720	69.7	546	- 2	120	98.4	102
	11.1	1860	74.2	580		138	113	117
	12.4	1720	92.9	729		160	131	136
	12.7	1860	98.7	774		184	151	156
	15.2	1720	139	1101		239	196	203
	15.2	1860	139	1101		259	212	220
7-wire	12.7	1860	112	890		209	178	184
compacted	15.2	1820	165	1295		300	255	264
	18.0	1700	223	1750		380	323	334
19-wire	17.8	1860	208	1652		387	317	329
	19.3	1860	244	1931		454	372	386
	20.3	1810	271	2149		491	403	417
	21.8	1810	313	2482		567	465	482

Note
1) The type of strand, nominal diameter and nominal tensile strength are for designation purposes only.
2) The nominal tensile strength is calculated from the nominal cross-sectional area and the specified characteristic maximum force (see footnote 5).
3) No single test result shall be less than 95% of the specified characteristic value.
4) Considering the small tolerance on mass per length, characteristic forces have been specified rather than stresses.
5) The 0.1% proof force is mandatory and the 0.2% proof force is for information only, except when otherwise agreed.

5. Chemical composition and manufacture

5.1 Chemical composition of materials should be related to the category of product, size and tensile strength. If required by the purchaser the cast analysis of the steel shall be given. The content of both sulfur and phosphorus shall not exceed 0.04%.

5.2 Construction

5.2.1 Strand

5.2.1.1 In 2-wire and 3-wire strand, the individual wires shall be of the same nominal size and the pitch shall be 12 to 22 times the nominal strand diameter.

5.2.1.2 In 7-wire ordinary strand, the diameter of the straight centre-wire shall be at least 2% greater than the diameter of the outer helical wires, with a pitch between 12 and 18 times the nominal strand diameter.

5.2.1.3 In 7-wire compacted strand, consisting of the same wires as 7-wire ordinary strand. After drawing and stress-relieving treatment, the strand shall have a pitch of 14 to 18 times the nominal strand diameter.

5.2.1.4 In 19-wire strand, the construction shall be 9+9+1 Seals or 12+6+1 Spiral strand, and the pitch shall be 12 to 22 times the nominal strand diameter.

6. Requirements

6.1 General requirements

Wire strand shall be free from fracture, pits and longitudinal cracks with a depth less than 4% of the diameter of the component wires shall not be considered as defects for 2 and 3-wire strand. In 7-wire and 19-wire strand, these shall be no strand joints, butt-welded joints may be made in the individual wires during fabrication of the strand, provided there is not more than one such joint in any 45 m section of the completed strand.

Compliance is checked by visual inspection.

6.2 Curvature

Wire strand shall be straight. When tested in accordance with clause 10.2, the curve shall be not greater than 25 mm.

6.3 Mechanical properties of wire strand

6.3.1 Maximum force and proof force shall conform to Table 1.

Testing shall be in accordance with clause 10.2 or other equivalent test method.

6.3.2 Elongation and ductility

When tested as directed in clause 10.3, the characteristic percentage total elongation shall be not less than 3.5%.

6.3.3 Relaxation

When tested as directed in clause 10.4, the relaxation at an initial force of 70% of the characteristic maximum force specified in Table 2 shall be determined. If requested, the relaxation shall also be determined at initial forces of 60% and 80% of the characteristic maximum force specified in Table 2.

Testing shall be in accordance with clause 10.3.

Note: In case the relaxation at 1000 h is completed, testing for follow-up is not required.

Table 2 Maximum relaxation values

Initial force in percentage of the characteristic maximum force	Class Normal relaxation, %	Low relaxation, %
60	4.5	1.0
70	8.0	2.5
80	12.0	4.5

6.3.4 Fatique

If agreed between purchaser and manufacturer, fatique behaviour shall be demonstrated according to the clause 10.5, without damage.

7. Packaging

Unless otherwise agreed between purchaser and manufacturer, the adhesive or any other suitable packaging material shall be used for tightly spun the wire strand in each size.

8. Marking and labelling

8.1 Each coil of wire strands shall have attached to it a tag, which shall bear at least number, letter or mark indicating legibly and clearly the following information:

(1) Name of product "PC STRAND";
(2) Category and types of wire strand
(3) Nominal diameter;
(4) Nominal tensile strength;
(5) Relaxation class:
- relax 1 for normal relaxation;
- relax 2 for low relaxation

(6) Lay
(7) Net weight of coil expressed in kg;
(8) Number of coil
(9) Name of a manufacturer, factory or a registered trade-mark ;

Example PC strand 7-wire ordinary-12.7-1860-Relax 2-right : 7-wire ordinary strand of nominal diameter 12.7 mm and nominal strength 1860 N/mm□ with class 2-relaxation and right-hand lay

8.2 Each coil packaging material of wire strand shall bear at least number, letter or mark indicating legibly and clearly in accordance with clause 8.1.

8.3 In case foreign language is used, the meaning shall correspond to that in Thai specified above.

9. Sampling and criteria for conformity

9.1 Lot in this standard refers to wire strand of the same category, type, class and size designation which are manufactured, delivered or purchased at one time.

9.2 Sampling and acceptance shall comply with the sampling plan below or with any other technically equivalent plan.

9.2.1 Type test and approval

9.2.1.1 Sampling and acceptance for testing on mass per metre, general characteristic and curvature of strand, samples shall be taken at random from the same lot as specified in Table 3.

Table 3 Sampling plan for testing on mass per metre, general characteristic and curvature of strand
(clauses 9.2.1.1 and 9.2.1.2)

Lot size (coil)	Sample size (piece)	Acceptance number
Not exceeding 50	5	0
Over 50	8	1

9.2.1.2 Provided that all samples failing to comply with the requirements of clauses 4, 6.1 and 6.2 does not exceed the acceptance number specified in Table 3, that lot shall be deemed as conforming to the requirements.

9.2.1.3 Sampling and acceptance for testing on mechanical properties

(1) Sampling

Samples are being complied with clause 9.2.1.2 shall be taken at random at the following number:

(1.1) Three samples for testing on the characteristic percentage total elongation and ductility;

(1.2) One sample for testing on the relaxation.

(2) Acceptance

Provided that all samples meet the requirements of clauses 6.3.1, 6.3.2 and 6.3.3, that lot of wire strand shall be deemed to comply with the requirements. Should any test piece fail to fulfil the requirements of clauses 6.3.1, 6.3.2 and 6.3.3, retest shall be carried out on new test pieces, twice the number of those failing the test, cut from the same test samples.

Provided that the result of retest meet the requirements of clauses 6.3.1, 6.3.2 and 6.3.3, that lot of wire strand shall be deemed as conforming to the requirements.

9.2.1.4 If failing to comply with the requirements results because fracture occurs outside the gauge mark, a duplicate test shall be made on new test pieces, the same number of those failing the discarded test, cut from the same test sample.

9.2.2 Criteria for conformity

Provided the samples meet all the requirements of clauses 9.2.1.2 and 9.2.1.3 (2), that lot of wire strand shall be deemed as conforming to this standard.

9.2.3 Routine test for factory

9.2.3.1 Whenever, the properties of materials for use in manufacturing are changed, the manufacturer shall test the characteristic value, elongation, elasticity of each coil and test relaxation on one test specimen at least once time per year.

9.2.3.2 Provided the wire strand meet the requirements of clauses 6.3.1, 6.3.2 and 6.3.3, that lot of wire strand shall be deemed as conforming to the requirements.

10. Testing

10.1 Mass per metre

10.1.1 Apparatus

10.1.1.1 A weighing device accurate to 0.1 g.

10.1.1.2 A metal measuring tape accurate to 1 mm.

10.1.2 Procedure

The length and weight of each test piece shall be determined to the nearest 1 mm and 1 g respectively, then the mass per metre of each test piece shall be calculated to 3 decimal points.

10.1.3 Report

The mass per metre of each test piece shall be reported.

10.2 Curvature of strand

Test piece is lying free on a plain surface, the curvature of the test piece shall be measured the maximum bow height from a base-line 1 m in length, as shown in Figure 1.

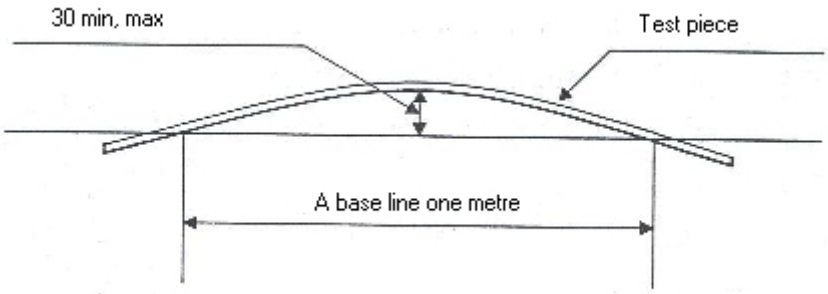

Figure 1 Measurement of curvature
(clause 10.2)

10.3 Maximum force, proof force and elongation

10.3.1 Apparatus

10.3.1.1 A tensile testing machine

10.3.1.2 An extensometre accurate to 0.001 mm and the grips.

10.3.2 Preparation of test piece

The guage length (G) are marked on the middle of test piece depending on testing, the distance between the grips of the machine shall be equal to at least 50 mm (see Figure 2).

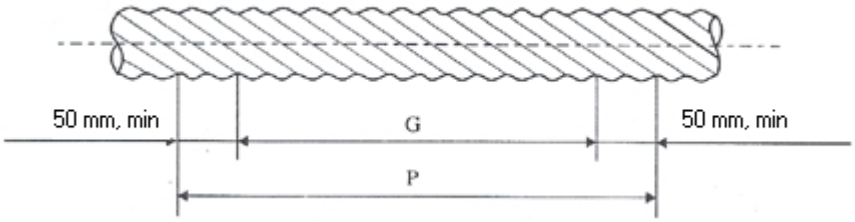

Figure 2 Test piece
(clause 10.3.2)

10.3.3 Procedure

10.3.3.1 Temperature of test piece prior to test should be equal to room temperature.

10.3.3.2 Test pieces shall be hold in such a way that the load is applied as axially as possible.

10.3.3.3 Loading rate not exceeding 30 MPa/s is recommended. After proof strength determination, increasing loads during a tensile test may be used, at the maximum permitted without exceeding the loading rate of 100 MPa/s, and should be made with uniformly and consistently load.

10.3.3.4 Determination of proof strength

(1) An extensometer shall be hold at 2 gauge marks on test pieces. The gauge length shall be equal to 100 mm.

(2) The scale of extensometer shall be adjusted at zero point, then the load shall be increased as consistent as defined in clause 10.3.3.3. The strength values shall be recorded every 0.05 mm of the extension of test pieces.

(3) The proof strength is determined from the force extension diagram by drawing a line at 0.1% percentage elongation (or 0.2% percentage elongation) parallel to the straight portion of the curve. The point at which this line intersects the curve gives the force corresponding to the desired proof strength 0.1 percentage elongation (or 0.2 percentage) as the case may be.

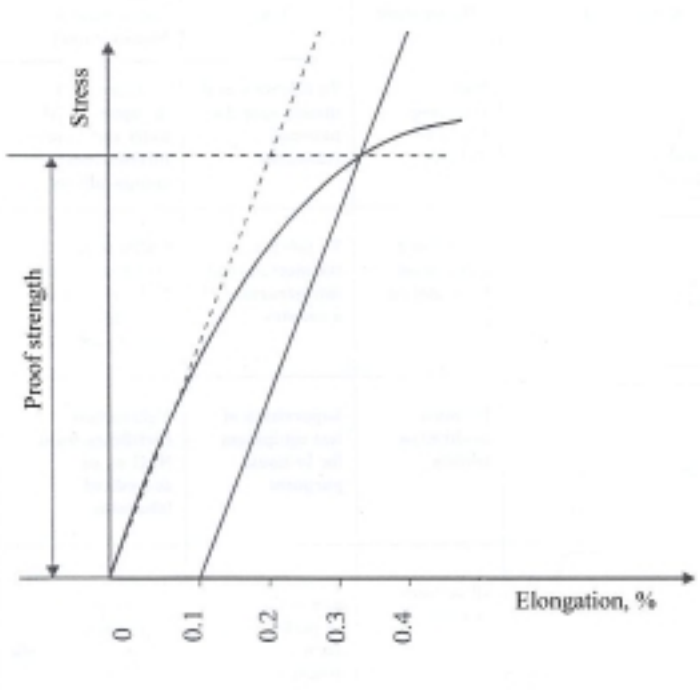

Figure 3 Proof force, non-proportion extension
(clause 10.3.3.4(3))

10.3.3.5 Elongation

(1) Test piece of gauge length 600 mm shall be hold by testing machine.

(2) Loading rate shall be increased with consistent, until the value of percentage elongation shall be rounded to the 0.1%. The distance between the grips with the original gauge length (X_1) shall be measured.

(3) Extensometer shall be removed, then the stress is increased to the test piece until the fracture of the test piece has occurred at a section situated between the gauge marks.

(4) Measure the distance between the upper grip level, when the test piece is stressed until any wire fracture with the upper grip level, when the test piece is stressed to 1 percentage elongation as shown in Figure 4.

(5) The percentage elongation at maximum force is calculated from the formula:

$$\text{Elongation at maximum force,\%} = \left[\frac{X_2 - X_1}{\text{The original gauge length}} \times 100 \right] + 1$$

When the original gauge length: Gauge length before application of force of wire strand between the grips, when the scale of extensometer read to zero point, expressed in mm.

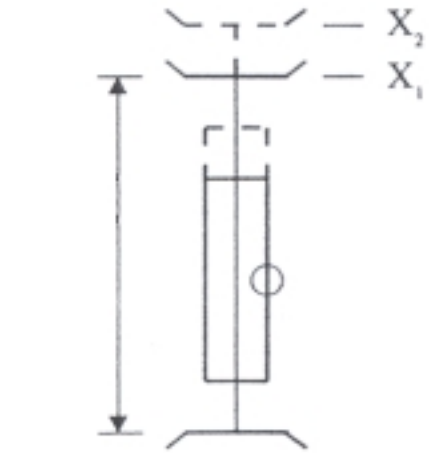

Figure 4 Determination of elongation
(clause 10.3.3.5(4))

10.4 Relaxation

10.4.1 Tests carried out controlled conditions shall be made at a temperature of $20 \pm 2°C$.

10.4.2 The distance between the ends of the grips shall exceeding 60 times of the diameter of wire strand (in case of the tensile testing machine or extensometer have a short distance, the distance between the grips 40d of the diameter of wire strand shall be applied).

10.4.3 Test piece shall be strained equal to 60, 70 or 80% of characteristic maximum force as given in Table 1. Load is increased until to the strength test within 5 min maintain this position. When strength value in 1 min is completed, the initial forces shall be read and again force a period of 1000 h.

10.4.4 Values for relaxation

$$\text{Relaxation,\%} = \frac{(\text{Initial forces} - \text{desired forces of 1000 h})}{\text{Initial forces}} \times 100$$

10.5 Fatique

The strands shall withstand, without fatique, 2 x 10^6 cycles of a stress fluctuating down from a maximum stress of 70% of the nominal tensile strength.
The stress range shall be 195 N/mm² for all strands.